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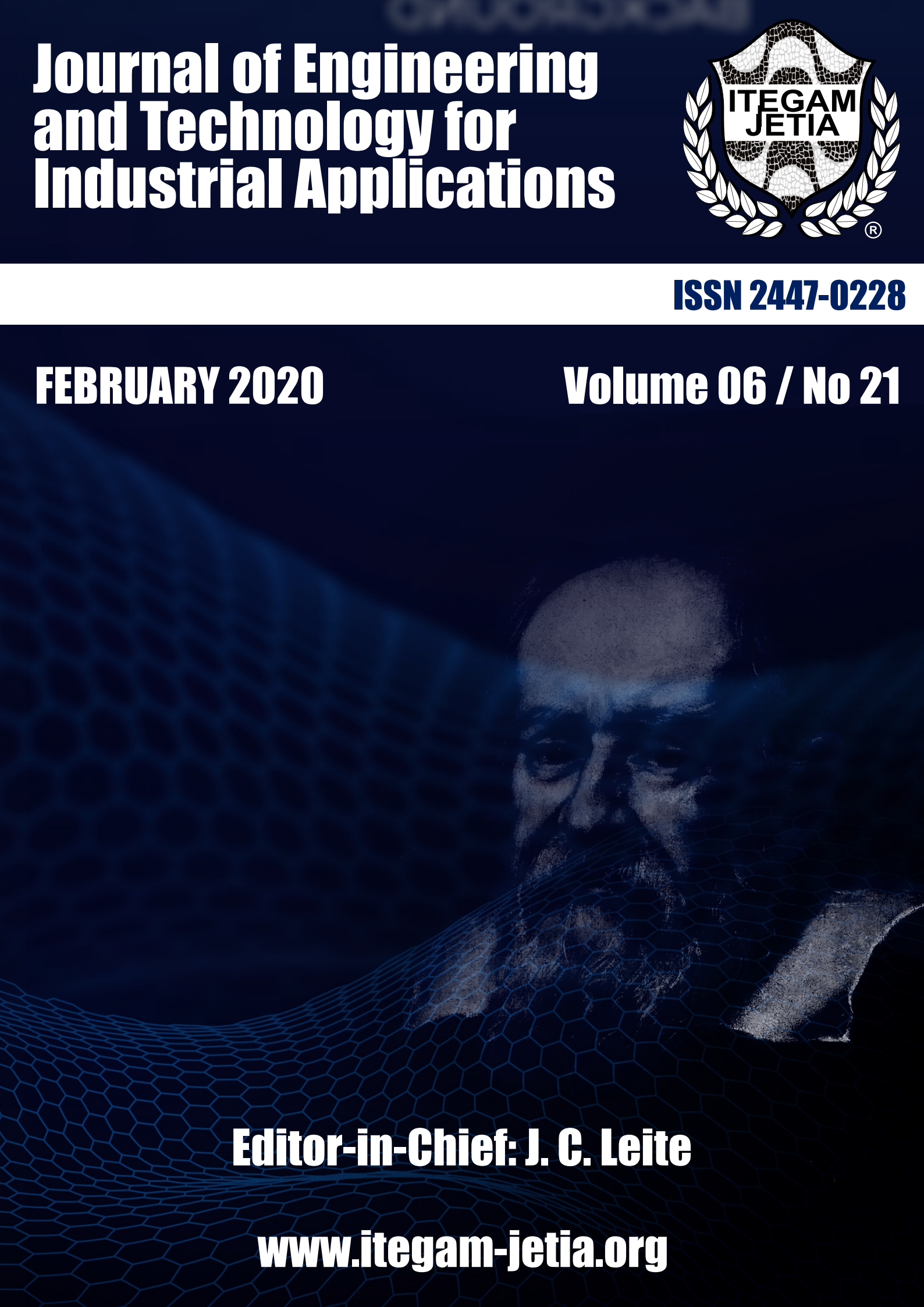

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RESEARCH ARTICLE OPEN ACCESS

COMPARISON BETWEEN DECISION TREE AND OPTIMAL POWER FLOW TECHNIQUES APLIED TO VOLTAGE CORRECTIVE CONTROL IN ELECTRIC SYSTEMS

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ABSTRACT

This article presents a comparison of using techniques of optimal load flow and decision tree in making corrective voltage control actions for electrical power systems under insecure operation condition, that is, with voltage constraints violated. The decision tree technique is used in conjunction with a technique of sensitivity analysis in such a way that control actions are taken to be more effective to eliminate the voltage constraints violation in each case of contingency analyzed. A comparison is made between the control actions suggested by the optimal load flow strategy and those suggested by the decision tree for the same operating condition, discussing the achievement of implementing these actions in a real power system. The analysis methodology proposed here is tested in a real power system of a Brazilian utility, which operates in the State of Amapá - Brazil. The results showed how both methodologies can be used as operational tools in power system supervision and control centers.

Keywords: Decision tree, data mining, optimal power flow, voltage sensitivity analysis, power systems.

I INTRODUCTION

Electric Power Systems (EPS) are highly complex systems to operate mainly due to some aspects as the increasing power demand to be supplied with high power quality indicators; incorporation of massive distributed generation in the electric networks; and an increasingly participation of automation and data communication links to make the system more observable, controllable, secure, economic and efficient.

Static Security Assessment (SSA) is a main function that continuously tracks the EPS steady-state operation points aiming at detecting insecure operation conditions in order to support the adoption of preventive and corrective management actions to maintain the EPS integrity and operating in a secure region. In steady-state condition, a power system can be disturbed in several ways that can make it insecure, such as changes in grid topology, load variation, switching maneuvers of grid equipment, changes in generating machines operational points, and other severe disturbances that may cause serious damage to equipment, accidents, and disruption of power to large areas [1, 2].

In situations of insecure operation, the system operator must identify which control measures needs to be taken to bring the system back to a secure operation region. At this moment, the experience in system operation is considered fundamental, because only with previous knowledge of the system under analysis, the operator can know which control variables will most influence the system in the return to secure operating points [3].

The present work proposes to use a methodology based on Decision Trees (DTs) as presented in [4], as an auxiliary tool for the application of corrective control measures in the operation of a real electrical power system in situation of contingency and insecure operational state. A comparative analysis of the corrective control actions suggested by the decision tree methodology and those obtained by the application of an Optimal Power Flow (OPF) procedure with objective function of voltage

control, is made in order to verify the effectiveness and feasibility of the control actions proposed by both methodologies. The software FLUPOT [5] and ANAREDE [6] were used to form the database of electric power system operation points for training the DT structure as well as to calculate optimal power solutions for the EPS under analysis.

II.1 ELECTRIC POWER SYSTEMS SECURITY ASSESSMENT

Electric Power Systems can be disturbed by various causes, and when the system withstands these disturbances without violating operational limits, it is said the EPS operates in a secure state [7]. It is very important to predict the disturbance consequences and the ability to prevent deterioration in quality of service [8].

The analysis of EPS security covers static and dynamic analysis. Static Security Assessment (SSA) considers operating conditions such as overloads, under and over voltages, active and reactive power generation limits, among others using load flow calculation [9, 10]. Dynamic Security Assessment (DSA) evaluates the system transient behavior after the occurrence of large disturbances, such as short circuit for example, so that it is of interest to determine if the system can operate maintaining a dynamically acceptable performance (transient stability) [11], and it is simulated considering dynamic time-varying models to represent the EPS, whose solution involves numerical integration algorithms that require great computational effort [12].

Implementing real-time security measures becomes dependent on observing the runtime of power flows and optimal power flow (OPF), but the larger the system, the greater the complexity and amount of data to be processed and interpreted. Considering these factors, data mining techniques applied to power systems stand out as a complementary action in the analysis of EPS due to their ability to extract useful information for the EPS operation from data sets, serving as an auxiliary tool for making decision on corrective controls [13].

An EPS may be subject to loading, operating and security restrictions. Load constraints are the active and reactive power injections specified on the load and generation buses using the load flow equations. Operating restrictions are specified for the bus voltage magnitude limits during operation, the power flow limits on the transmission lines and transformers, and the reactive power injections at generation buses. Under security restrictions, the system is subjected to a set of possible contingencies to characterize the EPS security margins in the case these contingencies happen [3, 4, 14].

The SSA performed in this work subjects the system to contingencies such as loss of generation, load variation, disconnection of transmission lines and transformers, switching of capacitor banks and reactors, among others. In these situations, it is up to the operator to analyze which control measures to be employed in real time, depending on which operating state the system is in. The EPS operating states can be classified as: secure, alert, emergency and restorative [15].

In the secure state, also called normal-secure, three type of restrictions must be met, that is, loading, operation and security restrictions, this means that the system provides active and reactive power to the load demand and there is no violation of operating limits and none of the contingency conditions listed as possible will bring the system to an emergency state. In the normal-insecure state, load and operating restrictions are met, but not all security restrictions are met. The system supplies the demand, but one of the possible contingencies can move the system to an emergency-state.

The emergency-state is characterized by violation of operation restrictions, as voltage magnitude limits, loading conditions of transmission lines and transformers among others. In the restorative state, the emergency is eliminated by manual or automatic shutdown of system parts with command coming directly from the control and supervision center or by local devices. When the system is shifted from the emergency state to the restorative state, system integrity is sacrificed for the benefit of compliance with operating restrictions.

Real-time operating statuses data and operating restrictions from an EPS are passed on to operators through the Supervisory, Control, and Data Acquisition System (SCADA) to the operating centers. With this real data and power flow simulation data, the system can be viewed and better operated, increasing its reliability [14].

II.2 POWER FLOW FORMULATION

A real-time supervision and control system consists of partial systems, grouped into data acquisition, generation control, analysis and network control (security). Tools available at the supervision and control center include: power flow studies, security assessment, state estimation, and sensibility analysis among others [16].

The power flow calculation essentially consists of determining the electric network operating state using a static model to represent the electric network. The modeling for power flow calculation is done by a set of algebraic equations, representing the active and reactive power balances at each electric node, as presented in equations (1) and (2) respectively [3].

$$P_{Gi}-P_{Ci}-P_{Ti}=0 \quad (1)$$

$$Q_{Gi}-Q_{Ci}-Q_{Ti}=0 \quad (2)$$

Where,
"P" _"Gi" e "Q" _"Gi" are the active and reactive power generation at bus i.
"P" _"Ci" e "Q" _"Ci" are the active and reactive consumed power by loads connected at bus i.
"P" _"Ti" e "Q" _"Ti" are the active and reactive power injections at bus i, that is, the power flowing from bus i to all buses connected to bus i.

Considering the electric network is modeled by its admittance matrix Ybus , than the active and reactive power injections at bus i can be represented as in (3) and (4) respectively [4].

$$P_{Ti}=V_i\sum_{k=1}^{n}V_k[G_{ik}\cos(\delta_{ik})+B_{ik}\sin(\delta_{ik})] \quad (3)$$

$$Q_{Ti}=V_i\sum_{k=1}^{n}V_k[G_{ik}\sin(\delta_{ik})-B_{ik}\cos(\delta_{ik})] \quad (4)$$

Where,
V_i and V_k : voltage magnitudes at buses i and k respectively;
δ_ik: phase angles difference between voltages at buses i and k, being δ_i and δ_k phase angles of voltages V_i and V_k respectively.

The algorithm for simultaneous solution of equations (1) and (2), via Newton-Raphson method can be found in [18]. The use of conventional load flow algorithms can produce many viable and secure solutions to the problem in question. Adopting one or other solution is a decision that depends on the merit analysis of each solution, by the technical team responsible for the EPS planning/ operation.

However, in many situations, it is desired to obtain an optimal solution to the problem. In this case, equations (5) and (6) are solved in such a way that the solution obtained minimizes an objective function, also known as cost function. This scenario is solved by optimal load flow (OPF) algorithms [20], whose generic formulation is:

Minimize F(x)

Subjected to:

$$G(x) = 0 \quad (5)$$
$$H(x) \leq 0 \quad (6)$$

Where,
F(x) – is the cost function to be minimized;
G(x) – corresponds to the set of equations (3) and (4) of the conventional load flow;
H(x) – are inequality constraints imposed on the problem.

III PROPOSED METHODOLOGY

As stated in the introduction section, two distinct procedures will be used to generate corrective control actions to return the EPS to a secure operational condition, when it is subjected to different types of contingencies. The first technique used is based on decision trees (DTs) which is a computational intelligence technique, and the second is optimal power flow (OPF), which is an analytical technique widely used for solving this type of problem.

The same contingency situations are simulated by the two proposed techniques and secure operation points are taken from both solutions and the results found in the corrective control applications are compared.

III.1 DECISION TREE

The decision tree classification is an extremely simple technique that requires no configuration parameters and generally has a good degree of assertiveness [17]. The purpose of this paper is to use this technique [4] by analyzing the corrective control actions suggested by the DT solution, observing operation factors such as decision time, number of control actions necessary to implement the suggested solution, visualization of operating limits, system response to corrective action, among other aspects.

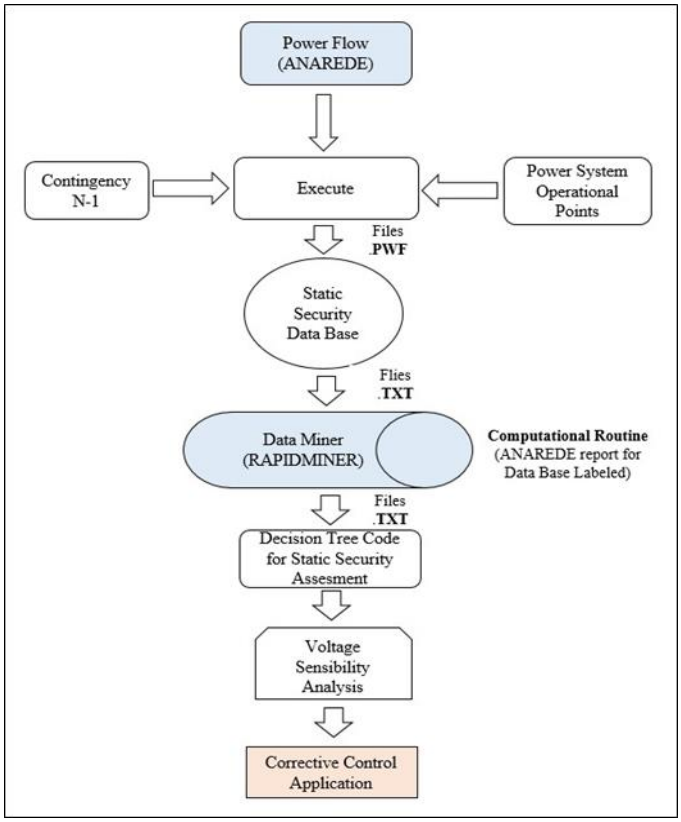

Figure 1: Flowchart of the proposed Decision Tree Methodology for EPS security assessment analysis.
Source: Adapted from [4].

According to figure 1, the steps for decision tree application on EPS corrective control are described as follows:

a) Using the ANAREDE software, a set of secure operating points are generated, following the EPS typical load curve profile, for the daily operating period;

b) Again, using the ANAREDE software the secure operating points obtained in a) are subjected to a (N-1) contingency list, typical of the EPS operation such as, switching of transmission lines, transformers, capacitor banks, among others. The results of these simulations are files with PWF extension, and are labeled as secure or insecure, for the database formation to characterize the EPS static security under these operating conditions.

c) Then this labeled database is subjected to a data mining step, via the RAPIDMINER software, in order to create the DT structure for the security classification of EPS operating points.

The generated DT will indicate, for each operational condition under contingency, which branches lead to a secure operation state. Following these branches, the operator may take the respective corrective control actions suggested by the DT in order to take the EPS back to a secure operating condition. At this point, a voltage sensitivity analysis is carried out.

III.2 SENSITIVITY ANALYSIS

Sensitivity analysis calculates the first order sensitivity factors, showing the behavior of certain electric grid quantities, called dependent variables, related to the variation of a control quantity, called the control variable.

Equations (3-4) could be rewritten in compact form as:

$$\bar{g}(\bar{x}, \bar{u}, \bar{p}) = 0 \tag{7}$$

Where, $\bar{u}$ is the control variable vector, $\bar{x}$ is the controlled variable vector and $\bar{p}$ is the fixed parameters vector.

A perturbation in the vector of dependent variables $\bar{x}$ produced by changes introduced in the control variables $\bar{u}$ and the parameters $\bar{p}$ is given by the relation:

$$\frac{\partial g}{\partial \bar{x}} \Delta\bar{x} + \frac{\partial g}{\partial \bar{u}} \Delta\bar{u} + \frac{\partial g}{\partial \bar{p}} \Delta\bar{p} = 0 \tag{8}$$

Otherwise:

$$\Delta\bar{x} = S_u \Delta\bar{u} + S_p \Delta\bar{p} \tag{9}$$

With:

$$S_u = -\left[\frac{\partial g}{\partial \bar{x}}\right]^{-1} \cdot \frac{\partial g}{\partial \bar{u}} \tag{10}$$

and

$$S_p == -\left[\frac{\partial g}{\partial \bar{x}}\right]^{-1} \cdot \frac{\partial g}{\partial \bar{p}} \tag{11}$$

Matrices S_p and S_u are called sensitivity matrices and determine a relation between control and controlled variables.

This allows to estimate, although approximately, the behavior of electrical quantities as a function of changes made in some other system´s variables and parameters.

In other words, the sensitivity analysis function can provide the operator with information on which control actions have the greatest effect on the voltage magnitude of a particular bus.

III.3 OPTIMAL POWER FLOW

Optimal Power Flow is considered an important tool that may improve the system reliability and quality, and aims to determine, among others, the best power distribution across the generating units in operation, the best voltage profile for the EPS, or even the best reactive power distribution, all based on optimizing a cost function (objective function) while meeting a constraint set, as presented in equations (5-6), [19, 20].

In the case studies to be presented in this article, the Flupot-CEPEL software was used as a tool for choosing corrective control actions to be adopted to guarantee a secure operation condition.

The objective function chosen in the optimization process is the voltage control, which is available as an option for users of FLUPOT, having as control variables active and reactive power generation, and reactive power injection in controlled voltage buses. According to the optimization method in [5], the algorithm determines a setting for the reactive controls in such a way as to keep voltage magnitudes at user´s specified limits close to 1 pu.

The OPF procedure shown in figure 2 is based on the same operating point and the same (N-1) contingency list used to form the database in the decision tree procedure.

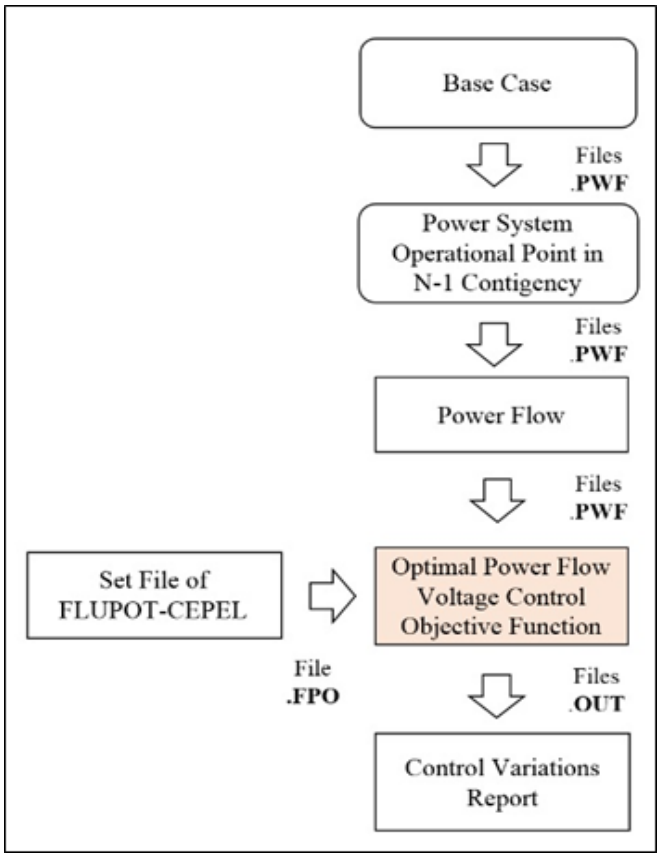

Figure 2: Flowchart of the methodology for obtaining corrective control actions via optimal power flow.
Source: Authors, (2019).

IV. RESULTS

For a better understanding of the proposed methodology, it will be presented case studies on a real electric system, the Amapá Power System, located in the north region of Brazil, in the State of Amapá. In the simulations studies, the power flow by Newton-Raphson algorithm is used to obtain operating voltage values of the system under normal conditions and under contingencies.

Acceptable limits of bus voltage magnitudes for secure operation are between 0.95 pu and 1.05 pu. The control strategies used have been performed to ensure that the system is operating within this secure voltage range.

The Amapá Electric System [4] is a hydrothermal EPS, having 51 buses, 12 equivalent generators, 32 power transformers and 17 transmission lines, operated by Eletrobrás-Eletronorte electric utility. This system is presented as a single-line diagram in figure 3.

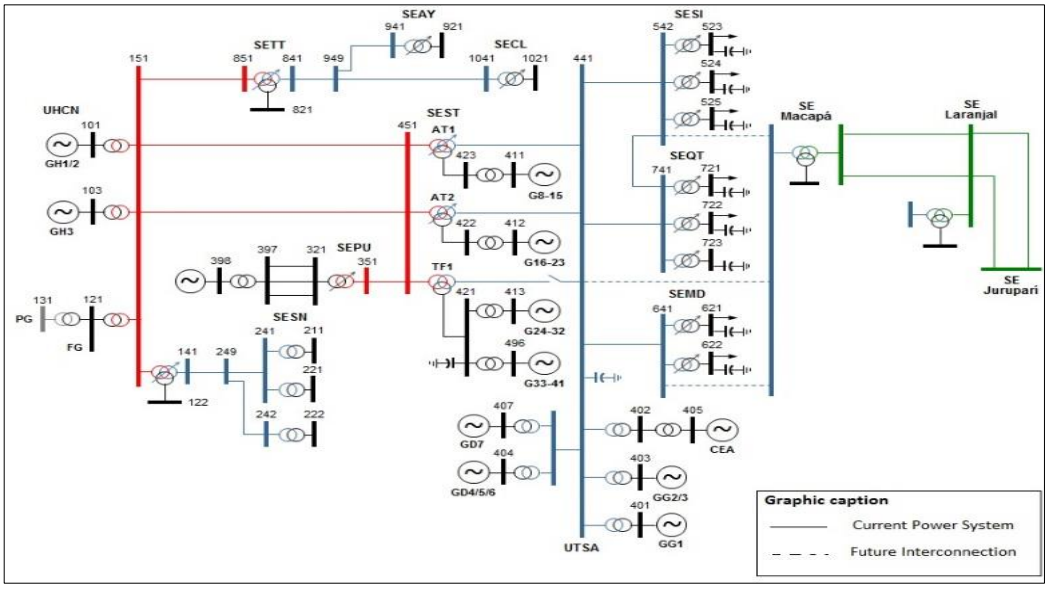

Figure 3: Amapá Power System single-line diagram.
Source: Adapted from [4].

The Amapá Electric System has predominant hydroelectric generation and is highly influenced by the availability of the Coaracy Nunes hydroelectric power plant (UHCN), whose power capacity is 78 MW. The Araguari River water flow indicates the full operation of this plant from January to September. Outside this period, the Santana thermoelectric plant (UTSA) starts operating to compose the generation base.

The Coaracy Nunes Hydroelectric Power Plant (UHCN) is connected to the Santana Thermoelectric Power Plant (UTSA) through two 138 kV transmission lines (between buses 151 and 451).

IV.1 CONTINGENCY 1: SHUTDOWN OF TRANSFORMER 722-741

Considering a loading point taken from the database, the contingency was simulated which generated a decision tree as is shown in figure 3, demonstrating two decision paths to bring the EPS to a safe operating condition (secure).

To establish corrective system control actions for this contingency, these two possible paths will be considered.

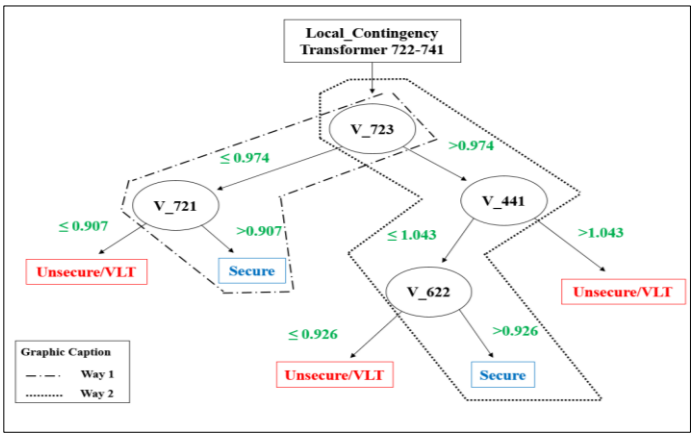

Figure 4: Decision tree generated for Contingency TR 722-741.
Source: Authors, (2019).

The critical attributes of this decision tree are voltage magnitudes at buses 723, 441, 622 and 721. All of these specified buses have capacitor banks connected to them for local voltage control.

With the application of this contingency, the load flow solution indicated 10 buses with the upper limit of voltage magnitude violated. Sensitivity factors were calculated for the buses discriminated in the decision tree paths, namely buses 723, 441, 622 and 721 which are the dependent variables, being the reactive generation and transformers´ taps considered as control variables.

Usually, in a power system with over voltages, the priority of corrective control actions follows the order: capacitor banks switching, change in transformer Taps, and voltage set point changes in generation buses. Following this principle, a sensitivity analysis was conducted to buses 723, 441, 622 and 721 in order to determine for which sources of reactive power these voltages magnitudes are more sensitive

Table 1 presents the results of this sensitivity analysis in relation to buses that have reactive power control, namely buses 404-101 and the transformers´ taps. It is indicated a possible reactive control by bus 404 that can change the voltages of all buses specified in AD and influence the system as a whole.

Table 1: Voltage Sensibility Factors for Contingency TR 722-741.

Dependent Variable	**Control Variable**			
Bus Voltage Specified by Decision Tree	**Bus Number**	**Sensitivity Factor**	**Taps**	**Sensitivity Factor**
			From/To	
V_723	404	0,587	723/741	1,256
	101	0,199	441/497	0,345
V_441	404	0,529	441/497	0,311
	101	0,179	441/498	0,308
V_622	404	0,615	622/641	1,092
	101	0,208	441/497	0,961
V_721	404	0,634	721/741	1,201
	101	0,214	441/497	0,373

Source: Authors, (2019).

According to the DT indication and sensitivity analysis results, the voltage at bus 404 was set equal to 0.98 pu and the capacitor bank at bus 723 was shutdown By applying this control action, the bus voltages are V723 = 1.027, V441 = 1.042, V622 = 0.990, and are within the limits of the decision tree way 2, shown in figure 4.

Running an OPF for the same contingency 37 control actions are activated to bring the system to an optimal operating point, as shown in Table 2. It is observed that bus voltages are as close as possible to 1 pu. Thereby, from an operating point of view, it is difficult to execute all these controls real time in a short time period and reach this operational state.

Table 2: List of Control actions suggested by the OPF solution for Contingency TR 722-741.

Control Type	Bus Number	Bus Name	Initial Value	Deviation	Final Value	Unit
GE_P	101	CNUGH-1/2	47.0	-7.9	39.1	MW
GE_P	103	CNUGH-03	29.4	-7.1	22.2	MW
GE_P	398	GER EM CEA2	2.2	-1.1	1.1	MW
GE_P	496	SYUGD 33-41	8.8	-1.6	7.2	MW
GE_P	412	SYUGD 16-23	8.8	-1.6	7.2	MW
GE_P	404	UGD-4/5/6	11.7	21.0	32.7	MW
GE_P	411	SYUGD 8-15	8.8	-1.6	7.2	MW
GE_V	101	CNUGH-1/2	0.962	0.003	0.965	p.u.
GE_V	103	CNUGH-03	1.042	-0.066	0.976	p.u.
GE_V	398	GER EM CEA2	1.037	-0.055	0.982	p.u.
GE_V	496	SYUGD 33-41	1.034	-.0.040	0.994	p.u.
GE_V	412	SYUGD16-23	1.046	-0.064	0.982	p.u.
GE_V	404	UGD-4/5/6	1.030	-0.054	0.976	p.u.
GE_V	411	SYUGD 8-15	1.045	-0.063	0.982	p.u.
AL_Q	421	SANT TF 13,8	0	1.793	1.793	Mvar
AL_Q	441	SANTANA 69	0	2.955	2.955	Mvar
AL_Q	523	SI TF1 13,8	0	2.508	2.508	Mvar
AL_Q	524	SI TF2 13,8	0	2.290	2.290	Mvar
AL_Q	525	MD TF1 13,8	0	1.636	1.636	Mvar
AL_Q	621	EQT TF1 13,8	0	2.844	2.844	Mvar
AL_Q	622	EQT TF3 13,8	0	2.580	2.580	Mvar
AL_Q	721	EQT TF1 13,8	0	2.844	2.844	Mvar
AL_Q	723	EQT TF3 13,8	0	2.580	2.580	Mvar
TAP	141/199	-	1.0000	0.0054	1.0054	p.u.
TAP	321/351	-	1.0500	-0.0114	1.0386	p.u.
TAP	1021/1041	-	1.0000	0.0032	1.0032	p.u.
TAP	921/941	-	1.0000	0.0011	1.0011	p.u.
TAP	841/899	-	1.0000	-0.0175	0.9825	p.u.
TAP	441/497	-	1.0500	-0.0468	1.0032	p.u.
TAP	441/498	-	1.0500	-0.0468	1.0032	p.u.
TAP	723/741	-	1.0500	-0.0555	0.9445	p.u.
TAP	721/741	-	1.0000	-0.0154	0.9846	p.u.
TAP	523/542	-	1.0000	0.0232	1.0232	p.u.
TAP	524/542	-	1.0000	-0.0299	0.9701	p.u.
TAP	525/542	-	1.0000	-0.229	0.9771	p.u.
TAP	621/641	-	1.0000	0.0303	1.0303	p.u.
TAP	622/641	-	1.0000	0.0217	1.0217	p.u.

Source: Authors, (2019).

The voltages at all buses can be visualized graphically in figure 5. It is observed that the proposed control actions suggested by both control strategies have changed the voltage magnitudes at all buses to within the interval between 1.05 pu and 0.95 pu, which is recommended for a secure operation.

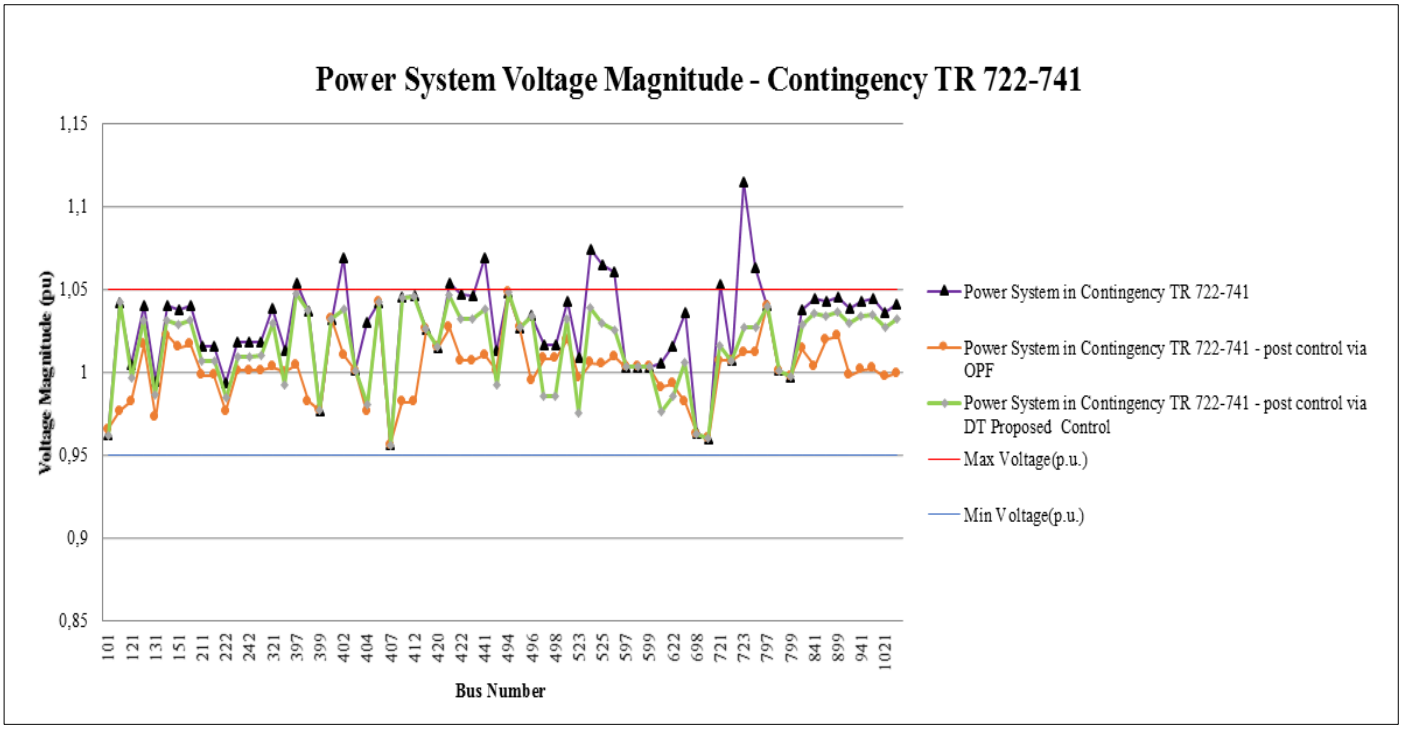

Figure 5: Bus Voltage Magnitude Profile for Contingency TR 722-741.
Source: Authors, (2019).

IV.2 CONTINGENCY 2: SHUTDOWN OF TRANSMISSION LINE 397-321

In this contingency one of the three parallel transmission lines between buses 397-321 was disconnected. The decision tree generated for this case is shown in figure 6, indicating actions to be taken with respect to voltages at buses 621 and 721, which are load buses. These buses also have capacitor banks for local voltage control. For this contingency the DT suggested only one path which will lead the system to a security operational condition.

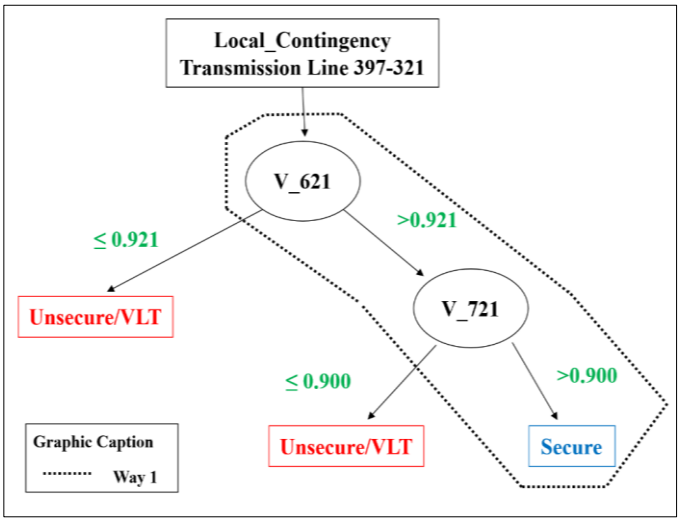

Figure 6: Decision Tree generated for Contingency TL 397-321.
Source: Authors, (2019).

Following the decision tree and sensitivity analysis of the buses indicated by the decision tree solution, according to Table 3, a control action at bus 404 may be very effective in modifying voltage magnitudes at buses 621 and 721. This control action is named control action 1 and corresponds to setting voltage at bus 404 to 1 pu.

Table 3: Sensibility Factors for Contingency TL 397-321.

Dependent Variable	Control Variable			
Bus Voltage Specified by Decision Tree	Bus Number	Sensitivity Factor	Taps From-To	Sensitivity Factor
V_621	404	0,636	622/641	1,075
	101	0,216	441/497	0,367
V_721	404	0,652	721/741	1,185
	101	0,221	441/497	0,376

Source: Authors, (2019).

With this control action, six of the seven buses that were outside the voltage limits, had their voltages returned within the limits, and only bus 723 voltage was violated, its magnitude being 1.073 pu.

The control action implemented at bus 404 was very effective, but did not eliminate all voltage violations. According to the sensitivity analysis shown in Table 3, other control actions can be tested to eliminate the voltage violation at bus 723, as for example, tap changes at transformers 622-641 and 721-741.

However, it is also known by the operation staff that bus 723 with over voltage of 1.084 pu has two capacitor banks in operation, and an evident solution is total or partial shutdown of theses banks. So the complementary control action, called control action 2, was:

Capacitor banks shutdown at bus 723.

With this complementary control action all bus voltages have returned to within the recommended operation limits. So, the proposed control actions are the performed control action 1 and control action 2.

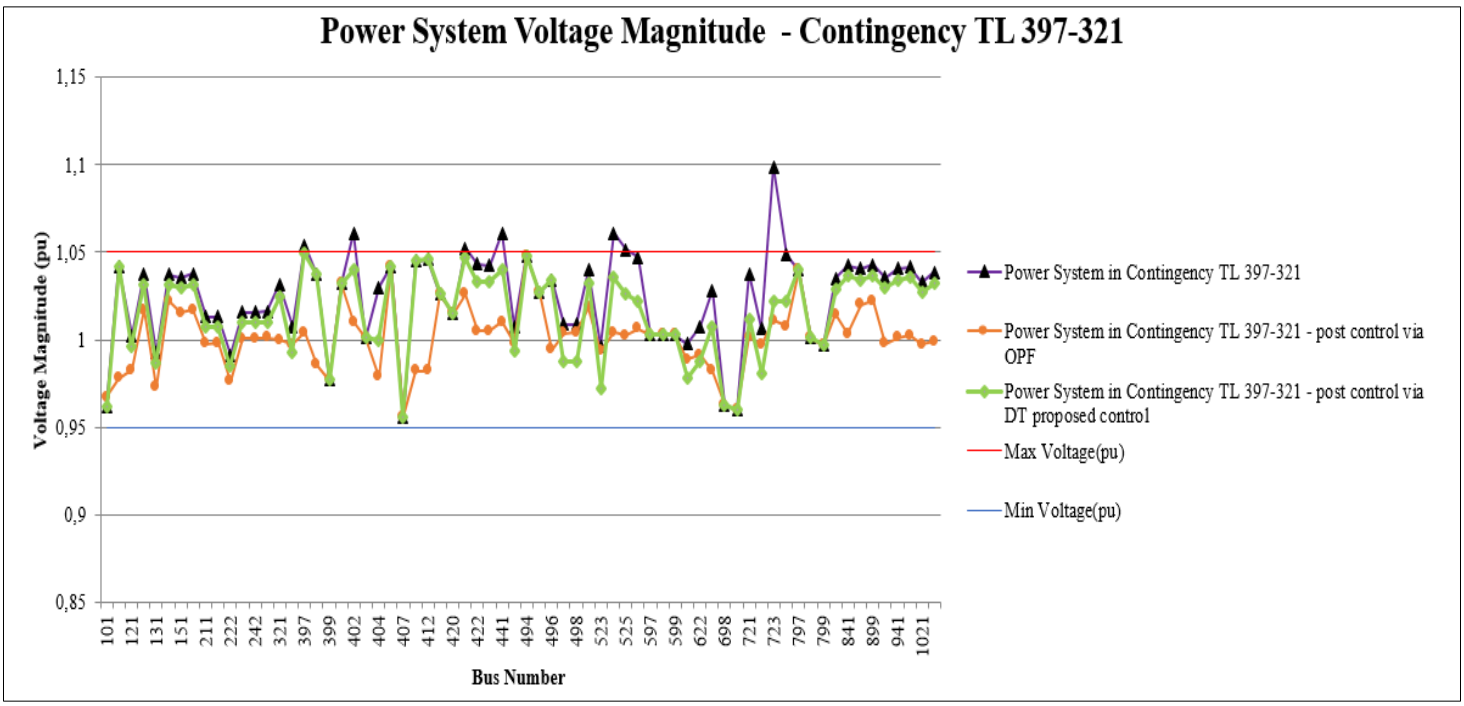

Figure 7: Bus Voltage Magnitude Profile for Contingency TL 397-321.
Source: Authors, (2019).

Table 4 shows the controls performed through the OPF procedure, showing all 39 control actions performed in the optimization process.

Table 4: List of Control actions sed in the OPF Optimization for Contingency TL 397-321.

Control Type	Bar Number	Bar Name	Initial Value	Deviation	Final Value	Unit
GE_P	101	CNUGH-1/2	47.0	-5.6	41.4	MW
GE_P	103	CNUGH-03	29.4	-5.4	24.0	MW
GE_P	398	GER EM CEA2	2.2	-1.0	1.2	MW
GE_P	496	SYUGD 33-41	8.8	-0.9	9.7	MW
GE_P	412	SYUGD 16-23	8.8	-0.6	8.3	MW
GE_P	404	UGD-4/5/6	24.2	14.6	38.7	MW
GE_P	411	SYUGD 8-15	8.8	-0.6	8.3	MW
GE_V	101	CNUGH-1/2	0.962	0.005	0.967	p.u.
GE_V	103	CNUGH-03	1.042	-0.064	0.978	p.u.
GE_V	398	GER EM CEA2	1.037	-0.051	0.986	p.u.
GE_V	496	SYUGD 33-41	1.034	-0.040	0.994	p.u.
GE_V	412	SYUGD16-23	1.046	-0.064	0.982	p.u.
GE_V	404	UGD-4/5/6	1.030	-0.051	0.979	p.u.
GE_V	411	SYUGD 8-15	1.045	-0.063	0.982	p.u.
AL_Q	421	SANT TF 13,8	0	1.962	1.962	Mvar
AL_Q	441	SANTANA 69	0	3.346	3.346	Mvar
AL_Q	523	SI TF1 13,8	0	2.728	2.728	Mvar
AL_Q	524	SI TF2 13,8	0	2.515	2.515	Mvar
AL_Q	525	SI TF3 13,8	0	2.544	2.544	Mvar
AL_Q	621	MD TF1 13,8	0	1.725	1.725	Mvar
AL_Q	622	MD TF2 13,8	0	1.702	1.702	Mvar
AL_Q	721	EQT TF1 13,8	0	3.248	3.248	Mvar
AL_Q	722	EQT TF2 13,8	0	3.477	3.477	Mvar
AL_Q	723	EQT TF3 13,8	0	2.915	2.915	Mvar
TAP	141/199	-	1.0000	0.0049	1.0049	p.u.
TAP	321/351	-	1.0500	-0.0196	1.0304	p.u.
TAP	1021/1041	-	1.0000	0.0031	1.0031	p.u.
TAP	921/941	-	1.0000	0.0010	1.0010	p.u.
TAP	841/899	-	1.0000	-0.0181	0.9819	p.u.
TAP	441/497	-	1.0500	-0.0429	1.0071	p.u.
TAP	441/498	-	1.0500	-0.0430	1.0070	p.u.
TAP	723/741	-	1.0500	-0.0544	0.9456	p.u.
TAP	722/741	-	1.0000	0.0082	1.0082	p.u.
TAP	523/542	-	1.0000	0.0211	1.0211	p.u.
TAP	524/542	-	1.0000	-0.0301	0.9699	p.u.
TAP	525/542	-	1.0000	-0.0235	0.9765	p.u.
TAP	621/641	-	1.0000	0.0274	1.0274	p.u.
TAP	622/641	-	1.0000	0.0191	1.0191	p.u.
TAP	721/741	-	1.0000	-0.0168	0.9832	p.u.

Source: Authors, (2019).

Figure 7 presents graphically the obtained solutions for solving contingency 2 voltage limits violations calculated by both solution techniques, that is, Decision Tree approach and OPF approach. Both solutions guarantee the power system is maintained operating in a secure state, but in terms of practical implementation the DT solution is more viable because only a few control actions are needed to be taken.

V. CONCLUSIONS

The results obtained by both corrective control techniques showed that these techniques are efficient in ensuring the power system secure operation. However, the big difference between both lies in the practical aspects of implementing control actions in real-time operation. Regarding this aspect, the DT technique is more attractive because, in general, the number of required control actions to maintain the power system security is much lower than the number of control actions required by the OPF approach. Besides that, DT also presents an intuitive interface for the operator, precisely identifying the electrical variables on which control actions should be exercised to return the system operation to a secure condition. In general, both methodologies are complementary tools in supporting the power system security, for both real-time operation or as operation planning tools.

VI. AKNOWLEDGMENTS

Thanks to PPGEE - UFPA and CAPES for their academic, structural, and financial support.

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RESEARCH ARTICLE OPEN ACCESS

INSTABILITY, FREQUENCY AND VOLTAGE IN MANAUS

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ABSTRACT

The article describes the system instability, frequency and voltage in Manaus. Electrical systems are relevant to the functioning of cities and are constantly evolving to meet growing demands. The deregulation of the sector and the continuous incorporation of new equipment technologies make the system's operation complex. Therefore, it is necessary to improve the methods and instruments for monitoring and controlling the operation of the system in real time. Several technologies appear every year, but in Brazil there is the Automatic Generation Control (GAG) and supervisory control of the system, which aims to control the generation in plants in order to meet the goals determined by the System Operator. Ensuring that the frequency remains constant and in a range close to its nominal value. It also has the power flow control function in the interconnection lines. Increasing demand for electricity today means that electric power systems operate near the limit. The lack of policies appropriate to the reality of the sector and the economic order of the country aggravate the problem of power generation with regard to frequency and voltage stability. The objective of this paper is to evaluate the performance and identify the most appropriate strategy of Load-Frequency and Voltage Control for the case of the Manaus system, when the Network Operation topology changes.

Keywords: Electrical Systems, Instability, Voltage.

I. INTRODUCTION

From the installation of the first generators and transmission lines to the present day, electrical systems have become more interconnected and extensive, spanning large areas, and meeting increasing demands. The intensification of this process, together with factors such as the deregulation of the sector and the continuous incorporation of new equipment technologies, have greatly increased the operational complexity of electric power systems. Then comes the need for constant improvement of methods and instruments dedicated to monitoring and controlling their operation in real time [1].

Among the new technologies that have been proposed, have added the functions of Automatic Generation Control (CAG) and Supervisory System Control (CSS) [2]. The purpose of the CAG is to control the generation of the main plants, according to the targets set by the operator, in order to keep the frequency approximately constant and within a range close to its nominal value, as well as to control the power flow in the power lines. interconnection [3].

These characteristics meet current technological needs and enhance the development of new paradigms for system supervision and control in real time. Voltage stability can be defined as the ability of the power system to maintain voltages at acceptable levels using the Automatic Voltage Regulator (AVR) both under normal operating conditions and after a disturbance. The main factor causing voltage instability is the inability of the electrical power system to meet reactive demand after a disturbance [4].

Electric power systems are operating ever closer to their limits. This is because the increase in the demand for electricity and the complexity of such systems has not been accompanied by investments, whether for economic, environmental or political reasons. Such factors have contributed to the occurrence of several problems related to frequency and voltage stability [5].

This paper aims to evaluate the performance and identify the most appropriate strategy of Load-Frequency and Voltage

Control for the case of the Manaus System, when the Network Operation topology changes.

II. MATERIALS AND METHODS

The present work presents a study about the model used for the charge-frequency and voltage control system in electric power systems specifically for the case of the Manaus-Amazonas system.

First the characterization of the generator-load system was made through the use of the DIgSILENT PowerFactor tool used in the engineering field for power system analysis and the fundamental components that are involved in the generation and control of the system.

A transient and steady state analysis was performed so that it was possible to show how the system components behave individually and also how they act together.

To prove the analysis and better understand it, simulations were performed in response to a step load variation.

The methodology for conducting the load-frequency rejection and reactive power tests consisted of field records and the supervisory system of electrical quantities such as voltage, frequency, power, in the generating units, during electrical disturbances and after impact or slow variation of active power. or reactive in the Manaus Electric System.

In each test were recorded simultaneously, in two generating units of the Plant, the following quantities: Frequency & Time; Terminal Voltage & Time; Active Power & Time; Reactive Power & Time; Field Voltage & Time & Actuator Position & Time.

Regarding the steady state voltage values, the Basic Network performance standard at the connection points must meet the requirements of ANEEL Resolution 505/2001. According to Article 4 of the referred resolution, the service voltage will be classified according to the ranges of reading voltage variation, according to the range below, and from January 2005 the voltage to be contracted by the concessionaires from The National System Operator (ONS) was the nominal voltage of the connection point [6].

In addition to the tests performed, some references from similar research works were also considered, such as: Power System Frequency Implementation and Control - Federal University of Rio de Janeiro by Rodrigo Ribeiro Ferreira. "(2009), Basic Aspects of Load-Frequency Control in Power Systems - Faculty of Technology of Brasília by Frederico Alves Matos de Lima." (2008), Santa Rosa, Arthur da Silva. Influence of Non-Representation of Slow Control Devices on Voltage Safety Analyzes. Dissertation by M. Sc., Federal University of Itajubá, Itajubá, MG, 2007. Ehrensperger, Juliana Gubert. "Synchronized phasor measurement systems: state-of-the-art analysis and applications in power system monitoring." (2004). In the English and Portuguese languages, in order to provide greater reliability in the data to be used, as well as internal studies of Eletrobrás in the Manaus unit which data were collected from a supervisory software called Wartsila-WOIS Online Monitoring System over a period of 90 days, imported and grouped in applications such as Word and Excel, for analysis and data processing, through a system analyzer, compared to the goals set by ONS, in order to keep the frequency and voltage approximately constant and within a range close to its nominal value.

III. FREQUENCY AND VOLTAGE INSTABILITY IN THE MANAUS SYSTEM

III. 1 FREQUENCY INSTABILITY

To understand why the frequency can go out of 60HZ, just look at the mathematical formula of the dynamic equation for a disturbing system [7].

Dynamic Equation Frequency 1

a) $$\frac{dw}{dt} = \frac{w}{2H} * (Pm - Pe) \quad (1)$$

At where:

dw = Angular velocity derivative in radian per second
dt = Derived as a function of time in seconds.
dw/dt = Angular velocity derivative as a function of time in seconds.
2H = Inertia constant in seconds.
w = Angular Speed
Pm = Mechanical power imposed by the Primary Machine.
Pe = Electrical power requested by the system.

It is found that dw / dt is the angular velocity derivative as a function of time, ie, in steady state where Pm = Pe the derivative is zero, ie the frequency is constant, where (w = 2.Pi.f), ie the frequency is directly proportional to Machine speed and inversely proportional to Inertia.

"Big" machines with heavy axles have a higher Inertia, which consequently has a smaller speed variation (dw / dt). Therefore, in order to have an imbalance, a variation of Pm or Pe is necessary. In the increase of load (Pe) the derivative is negative, and there is a decrease in speed and frequency as well [8].

In load relief (Pe) the derivative is positive, and there is an increase in velocity and therefore the frequency tends to rise.

ANEEL, through the National Electric System Operator [9], determines in accordance with Module 3.6 (Grid Procedures) that the frequency does not vary above + - 0.1 Hz. The main control systems acting on the synchronous generator are three:

1. primary speed control;
2. Supplemental load-frequency control, or Automatic Generation Control;
3. Control of Excitation.

The primary speed control, which is local, basically monitors the turbine-generator set shaft speed and controls the mechanical torque of the turbine to make the electrical power generated by the unit adapt to load variations. The time constants of the primary control are of the order of a few seconds [9].

Since actuation of the primary control usually results in frequency deviations, another control system must be relied upon to reset the frequency to its nominal value. This system is called supplementary control (or Automatic Generation Control) which, in the case of interconnected systems, also has the task of keeping the power exchange between neighboring utilities as close as possible to the previously programmed values. It is a centralized control system, executed in the operations center of companies, and whose time constants are of the order of minutes.

Manaus operates with a Window of + - 0.5 Hz, due to the fluctuation of the system due to instability in the External System, which causes [10]:

• Increased fuel consumption;

• Increased wear on Governor fuel injection racks and actuator;

• Increased wear on injection pumps; and

• Instability at Machine Operating Speed.

Each time the frequency varies by + - 0.5 Hz (60 + - 0.5 Hz), the Woodward-723 Speed Hydraulic Actuator changes from KW control to Speed Droop Mode in 100 milliseconds and returns to Operation mode. MW control within 15 seconds, as shown in the graph of figures 1 and 2 below, shows the graph of the frequency range threshold window.

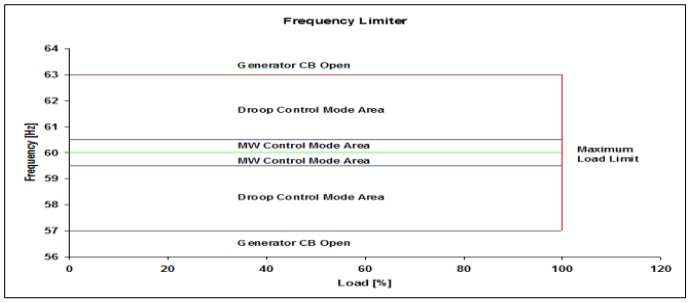

Figure 1: Graph of indication of frequency variation limits (Droop window).
Source: [11].

The parameters configured in the electronic regulator are:

a) Maximum Load Limit: 16.15MW;

b) MW Control Override: 60.5 / 59.5Hz; and

c) Override Reset Time: 15 seconds (if inside 60 + - 0.5Hz window).

As mentioned above, Figure 2 shows the graph shows the load / frequency response:

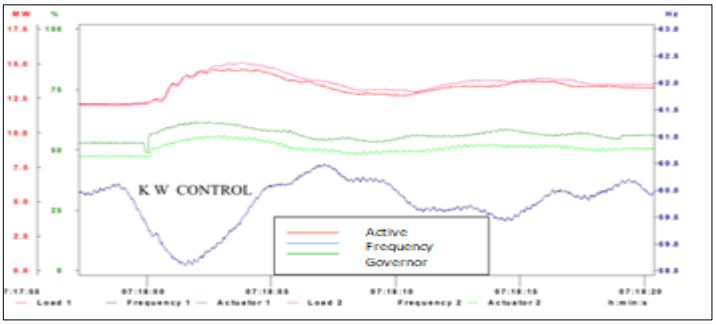

Figure 2: Load / Frequency Response Graph of droop window machine.
Source: [11].

Figure 3 shows the chart of the Control chart of the current system frequency situation behavior, with a collection every half hour, with a total of 48 daily samples, graphed by the average of each day. It is found that the variable is not under statistical control, ie the frequency tends to go out of control at the upper limit.

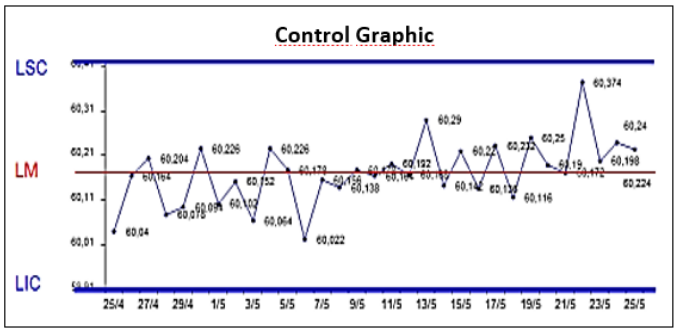

Figure 3: Amplitude graph of frequency behavior in Manaus.
Source: [11].

The figure 4 shows that the frequency amplitude did not exceed the upper limits (0.93 HZ) and had a slight tendency to exceed the lower limits, but did not get out of control. In addition to measuring the wave size, the equidistant oscillation between the points is verified, as it is not possible to verify this abnormality in the control mean.

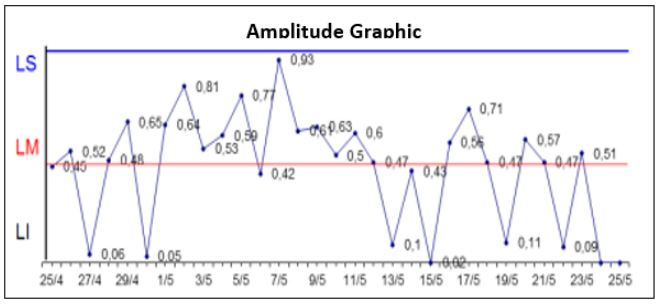

Figure 4: Amplitude graph of frequency behavior in Manaus.
Source: [11].

III. 2 TENSION INSTABILITY IN THE MANAUS SYSTEM

III. 2. 1 POWER FACTOR EFFECTS AND LEGISLATION

Reactive power overloads generation equipment and the distribution network, limiting the ability to meet the active power demand. For this reason, the DNAEE, through Ordinance 1569 of 12/23/93, establishes that the consumers of electric energy keep the power factor of not less than 0.92 inductive from 6h30min to 24h30min, and not less than 0.92 capacitive. from 12:30 am to 6:30 am Failure to observe this condition leads to the application of costly fines, presented on monthly energy bills. From the consumer's point of view, a low power factor means overload of transformers and cables, limiting their full utilization. Most loads in industrial and commercial installations produce inductive reactive power, such as motors, transformers and induction furnaces [2].

The flow of energy through the power grid consists of two distinct components:

• Active power is power that is effectively transformed into heat, light, mechanical work, or other uses. Its traffic in the system is unidirectional: from generation to consumer cargo. Represented by P, its unit is W (or kW).

• Reactive power that is temporarily stored in the electrical and magnetic fields of system equipment circulates pulsating between them. Its flow is bidirectional, coming and going with each cycle. Reactive power does not produce work or any other usable manifestation, and its presence is imposed by the characteristics of the charges, and may be inductive or capacitive. Its symbol is Q and its unit is var (or kvar) [12].

III. 2. 2 REACTIVE ENERGY FLOW

Reactive electric energy is usually expressed in kVArh. By convention, when it is given in positive values it is inductive, and when negative it is capacitive. The opposite of inductive reactive energy is capacitive reactive energy, which is why it is expressed in the same unit, but with a negative value. Capacitive reactive energy is normally supplied to the electrical system by capacitors, [12].

Reactive energy is required for the operation of: induction electric motors, transformers, discharge lamps, induction furnaces, among others, are formed by charges that require an electromagnetic field for their operation. For the creation of this magnetic flux is the presence of reactive energy, which does not

perform work. It circulates between the source and the load, taking up a "space" in the electrical system that could be used to provide more active energy. The active power loads that effectively performs work generating heat, light, motion, etc. It is measured in KW as illustrated in figure 5.

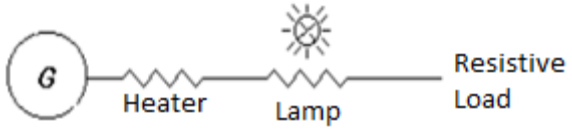

Figure 5: Active Power.
Source: [13].

Reactive power loads, power used only to create and maintain the electromagnetic fields of inductive loads. It is measured in KVAR as shown in figure 6.

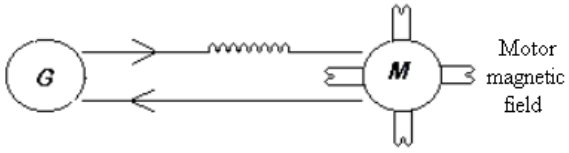

Figure 6: Reactive Power.
Source: [13].

Figures 7 and 8 below show the situation of the Manaus system before the implementation of the new voltage control system through manual control of the power factor.

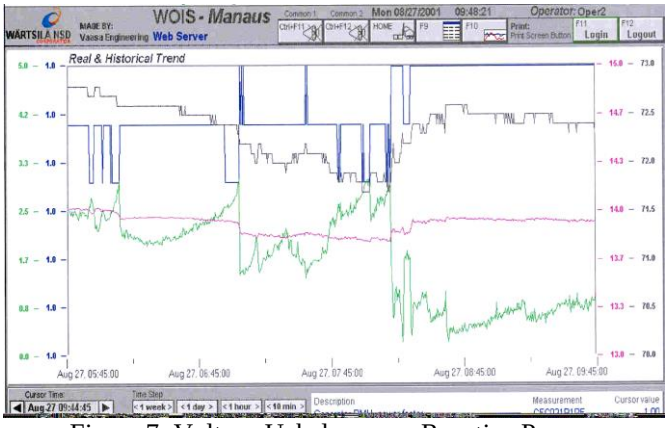

Figure 7: Voltage Unbalance vs. Reactive Power.
Source: [11].

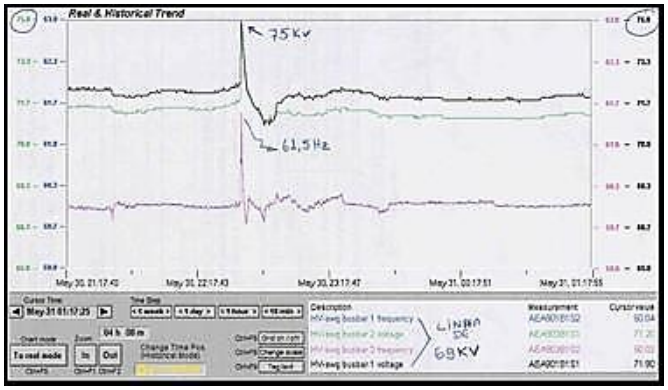

Figure 8: Effects of voltage instability (voltage oscillation).
Source: [11].

III. 3 REAL TIME AUTOMATIC FREQUENCY CONTROL TECHNOLOGY

The frequency is controlled through the electronic speed regulator - Woodward 723, which works in two modes: KW control and Speed Droop Control. KW Control is the mode of operation in which the machine is running with a constant load and the variations of load in the external system do not affect the value of the power in which the machine is working, it is as if the electric power had no variation. That is, in this mode of operation the Speed Regulator will not control or contribute to the frequency variations of the external System. Speed Droop Control, in this case the external system determines the System frequency, the machine being in parallel with other machines, and increasing or decreasing the reference speed will change the frequency. In Wartsila W46 technology the speed control is performed by Woodward Electronic 723 regulator (figure 08), the module has two inputs for magnetic speed sensors, which are installed to detect the passage of the flywheel teeth, the same provide voltage pulses of frequency corresponding to the machine's RPM, inputs are programmed so that readings are redundant, preventing possible sensor failures.

The WW-723 features a 20 to 200mA analog output that acts directly on the hydraulic speed actuator to control fuel injection, increasing or decreasing machine speed to maintain its load-frequency ratio. The module also has a 4 to 20mA analog input to read the active power being delivered by the generator to the system.

The speed regulator is programmed to maintain the machine's RPM so that the frequency stabilizes at 60Hz, under any load conditions imposed by the external system. This regulator has an analogue input of 4 to 20mA so that the operator can supervise the operator. can increase or decrease the load on the system, and digital inputs to perform the same procedure manually, performed in emergencies or in manual synchronization of the machine with the bus, where the operator will need to adjust the electrical speed of the generator to to equalize the phase angle of the voltage with the phase angle of the bus voltage, for this maneuver the operator counts on the aid of the synchronoscope, which is the equipment in charge of comparing the phase voltage angle of the generator with that of the bus generating a visual signal at the moment the phase angles equal, giving the operator generator circuit breaker, thus completing the manual synchronization procedure of the machine.

III. 4 AUTOMATIC VOLTAGE CONTROL TECHNOLOGY

Voltage control is performed by the Automatic Voltage Regulator (AVR). AVR operating modes are Voltage Droop and Power factor, whose operating mode settings are:

Voltage Droop: The external system determines the voltage, which once the voltage value is set the MVC (master voltage control), tracks the voltage on the high voltage side bar to minimize any fluctuations by sending the setpoint. and the signal (mA) for each generator's PLC, which is converted to a voltage at the terminals of each AVR (Unitrol 1000) so that generators connected to the same bus share the reactive load, ensuring voltage control [14].

Power Factor: This is the mode of operation in which the machine is operating with a constant reactive load and variations in the external system load do not affect the value of the reactive power in which the machine is working. That is, in this mode of operation the Voltage Regulator will not control or contribute to voltage variations of the external System. The Machine Reactive Power value can be controlled by injecting more or less excitation

current through the value of the power factor set on the PLC in the Control Room.

The automatic voltage regulator (AVR) is responsible for maintaining constant voltage at the generator output terminals, it acts directly on the field excitation current, increasing or decreasing the magnetic field intensity, depending on the load characteristics at which Thus, we can say that loads with inductive characteristics tend to decrease the voltage, increasing or decreasing the intensity of the magnetic field, as a function of the characteristics of the load to which the system is subjected. Inductive loads tend to decrease the voltage at the generator terminals and capacitive loads tend to increase this voltage. Because these variations are inherent to the system, it is necessary to constantly change the generator excitation current by adjusting the power factor.

The UNITROL 1000 has an RS 232 serial port to communicate with other AVRs of machines working in parallel (figure 9):

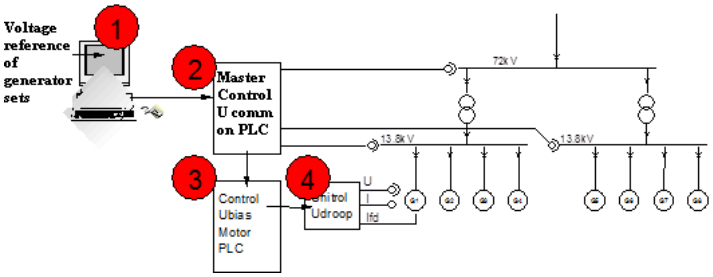

Figure 9: Circuit block diagram for voltage control.
Source: [15].

Studying the diagram above it was observed that the Operator sets the voltage reference on the high voltage side, which in practice will be adjusted by Unitrol 1000. The new voltage control system makes it possible to run droop mode motors with an Automatic control (Voltage Control Master-CVM) voltage grid has been added.

Running in CVM mode means that the Reactive Energy will automatically be readjusted to keep the voltage grid at an adjusted level. Meaning that the Generated Energy Factor will fluctuate according to demand it may even be negative during some situations.

When stopping an engine in MVC mode, giving a stop command will start to unload the engine normally. The voltage mode will be changed to Power Factor mode and set to 1.0. This is done to minimize disturbance when an engine is to be shut down.

IV. RESULTS AND DISCUSSIONS

IV. 1 MANAUS PLANT TEST WITH NEW MODE OF OPERATION

Considering the history of identifying difficulties in controlling the voltage and frequency of the electrical system in Manaus, even on a permanent basis and mainly after the startup of the Independent Energy Producers, a meeting was held in Brasilia involving the national company, the state company and independent producers, define an action plan involving the Areas of interest and affected by these difficulties in controlling that system.

Test tests were performed that generated the results described below according to the assumptions considered in the methodology:

• The Manaus Electric System generating units operate in automatic voltage and constant frequency control mode.

• The Manaus Electric System generating units allow operation with 0.9 inductive or capacitive power factor.

• The underfrequency protection setting on each generating unit is not more than 57 Hz and its time delay is not less than 600 milliseconds.

• The overfrequency protection setting on each generating unit is not less than 62 Hz and its timing is not less than 2 seconds.

• Criteria to consider are described below:

• The permanent regime statism of the generating units must be less than or equal to 6%.

• Overshoot resulting from stepping on the RT of each generating unit must not exceed 5%.

• RT time / response from generating units should not exceed 500 milliseconds.

Frequency variation in the Manaus Electric System should refer to ANSI / IEEE Guide C37.106 / 1987, in conjunction with C37.106-2003, as shown in Table 1, for underfrequency operation [16]:

Table 1: Event and Alarm Supervision Screen.

FREQUENCY RANGE	LENGHT OF STAY
59,5 Hz a 60,00 Hz	CONTINUOUS
58,8 Hz a 59,50 Hz	50 minutes
58,0 Hz a 58,80 Hz	09 minutes
57,5 Hz a 58,00 Hz	1,7 minutes
57,0 Hz a 57,50 Hz	14 seconds
56,5 Hz a 57,00 Hz	2,4 seconds
Less than or equal to 56,5 Hz	1,0 seconds

Source: [12].

IV. 2 IMPLEMENTATION AND TESTS PERFORMED IN VOLTAGE CONTROL MODE

The tests to validate the voltage control mode of a generating unit consisted of applying 2 to 5% steps in the voltage regulator reference of the unit under test and rejection of reactive power in unit in the electrical neighborhood of the unit under test, recording - voltage, reactive power, frequency, active power and field current in the unit under test. An observation test to validate the voltage control mode of a generating unit may be carried out by preselecting a reference voltage in the field and, in the electrical vicinity of the unit under test, to voluntarily reduce or increase the voltage by one unit. not exceeding 5% variation, sufficient to significantly vary the reactive power of absorption or supply in the unit under test, obeying the power factor of 0.9 pu, inductive or capacitive, and recording voltage, reactive power, frequency and active power in the unit under test.

IV. 3 IMPLEMENTATION AND TESTING OF FREQUENCY CONTROL MODE

The test to validate the frequency control mode of a sub-frequency excursion generating unit consisted of rejecting in the field, in the electrical vicinity, another dispatching generator unit that voluntarily causes a change in the load - generation balance, sufficient to reduce (up to 1 Hertz maximum) system frequency, ensuring no load shedding by the ERAC (Regional Load Relief Scheme) or shutdown of any system generating unit by under frequency protection and recording voltage , reactive power, frequency and active power in the unit under test.

The test for validation of the frequency control mode of the generating unit with over-frequency excursion is to reject in the

field the generating unit itself under test sufficient to significantly (up to 3 Hz maximum) increase the frequency empty terminal of the unit under test, ensuring no load shedding by the ERAC (Regional Load Relief Scheme) in the remaining system or shutdown of any remaining system generating unit by under frequency protection and recording voltage, reactive power, frequency and active power in the unit under test.

An impact test to validate the frequency control mode of an over frequency excursion generating unit consists of voluntary system separation on two stable islands, where possible and without load shedding, with active power interruption between future islands. That voluntarily cause a change in the load - generation balance, sufficient to significantly increase (up to 1 Hertz maximum) the frequency of the island frequently, taking care that there is no load cut by the Regional Load Relief Scheme (ERAC). On the sub frequency island or generator unit shutdown on either island by sub-frequency or over-frequency protection and recording voltage, reactive power, frequency and active power on the unit under test.

Records to be obtained during the tests:

Voltage response test as a function of time

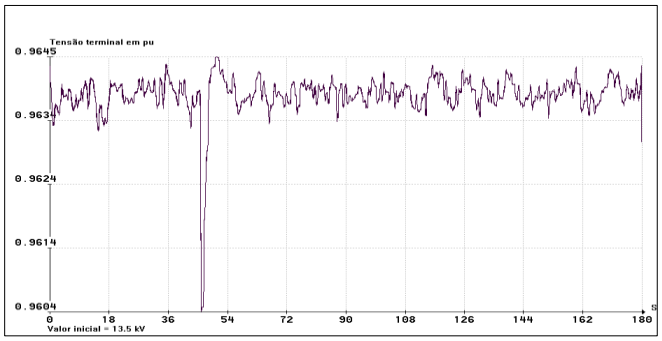

Figure 10: Graph of Voltage (pu) x Time (seconds) in Plant B unit 2.
Source: Authors, (2019).

This graph shows a maximum voltage deviation of 0.36% immediately after impact with response time less than 0.5 seconds and pre-impact voltage recovery by 2.9 seconds, with control accuracy less than 0.1%, indicating operation in response mode. Constant voltage control adequately to the Manaus Electric System Operation. It is observed that the response time (less than 0.5 seconds) and stabilization time (2.9 seconds) were shorter than the reference time of 0.5 seconds and 5 seconds, respectively.

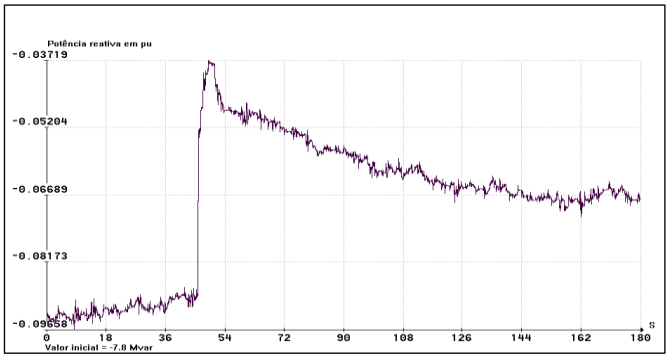

Figure 11: Reactive Power Graph (pu) x Time (seconds) in Unit 2 of Plant B.
Source: Authors, (2019).

The graph in figure 12 shows a maximum deviation of 2.34 Mvar in the reactive power of Plant B unit 2 from the initial value, reaching a deviation value with a stabilization trend of 1.0 Mvar, after 117 seconds of impact. Graph 12 shows the voltage droop operating mode validation test test on Wartsila motor technology at the Rio Negro plant.

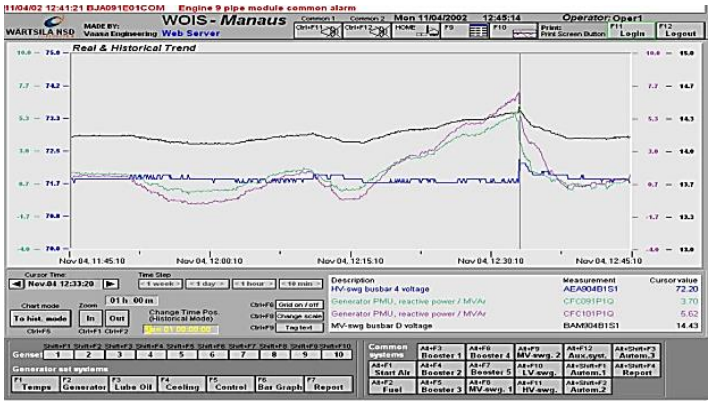

Figure 12: Reactive Response Assay.
Source: Authors, (2019).

In this example we observe a disturbance in the system such as the output of a machine that was generating reactive, and that machines 09 and 10 reacted and maintained the set voltage under control.

Frequency response test through load rejection.

Active Power Impact Test on a Plant W unit. This Test was performed by disconnecting Unit 2 Plant B with 40 MW, shown in Figure 13.

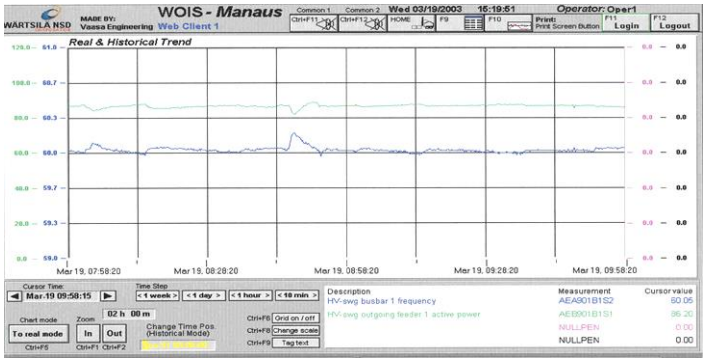

Figure 13: Frequency x Time graph (seconds) in W unit.
Source: Authors, (2019).

This graph shows maximum frequency deviation in Plant W unit 2 from 0.80 Hz downward at 2.86 seconds after impact and frequency recovery trend from this moment on, with deviation stabilization at 0.48 Hz, featuring automatic control mode operation. Constant frequency (load absorption). Speed droop test mode test with 16MW reject for validation as shown in figure 14.

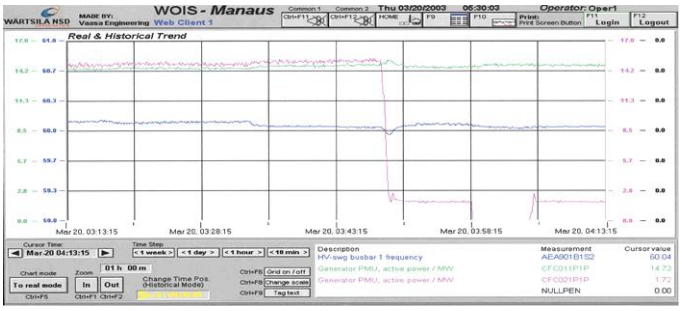

Figure 14: Active Power vs. Time Graph (seconds) in Plant W unit 2.
Source: Authors, (2019).

This graph shows the maximum active power deviation in Plant B unit 2 of 16.4 MW, stabilizing the average deviation of 10.16 MW, characterizing operation mode in constant frequency automatic control with steady state statism of 5.3% considering power. rated at 67.5 MW.

V. CONCLUSION

It is concluded, therefore, that the methodology used in this process corresponded to the analyzes for performance evaluation and identification of the best Load, Frequency and Voltage Control strategies, when the Network Operation topology changes. It was found that the most appropriate strategy of Control Load, Frequency and Voltage for the case of the Manaus System was the replacement of discontinued technology equipment that worked with only one mode of operation. The Voltage Control and Woodward Load-Frequency Control Unitrol has been replaced by new modern Unitrol 1000 and Woodward 723 control equipment, which operate in two modes of operation: Unitrol 1000 which enabled the generators to operate beyond voltage control via the power factor, the automatic voltage control mode "Voltage droop" has now been implemented and a Master-CVM Voltage Control has been added to the high and medium voltage output bus. With MVC control, Generators connected to the same bus will share Reactive load quickly and efficiently, keeping the voltage level stable at the value determined by the operator. In the event of a sensor failure on the 69kV or 13.8kV output bus, the MVC is set to automatically change the operating mode and the system will be switched to Power Factor (PF) control mode. Woodward 723 electronic machine speed governor that operates with two modes of operation Speed Droop Control and KW control. For the case of the Manaus system the solution was to enable both control systems automatically with limited variation window, initially operates in KW Control mode and the external system determines the frequency of the System, and the Machine is in parallel with other Machines, and increasing or decreasing the reference speed will change the frequency and the system will change the operating mode to Speed Droop Control to make load-frequency correction shared between the generators. Speed control is performed by Woodward Electronic 723 regulator, the module has two inputs for magnetic speed sensors, which are installed to detect the passage of the flywheel teeth, and they provide voltage pulses of corresponding frequencies. At machine RPM, inputs are programmed so that readings are redundant, preventing possible sensor failures. At the end of the research, it was observed that the operation that meets all steady state load conditions and supports contingencies and disturbances, with minimum voltage and frequency deviation, fulfills the quality requirements of electric power supply, reducing frequency indices and duration of interruptions and providing higher revenues, thus representing the best strategy for load-frequency and voltage control when topology changes of the Manaus Operation Network occur.

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RESEARCH ARTICLE OPEN ACCESS

RESIDENTIAL SMART PLUG WITH BLUETOOTH COMMUNICATION

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ABSTRACT

Electricity forms the backbone of the modern world but increasing energy demand with the growth of urban areas in recent decades has overwhelmed the current power grid ecosystem. So, there is a need to move towards a more efficient and interconnected smart grid infrastructure. The growing popularity of the Internet of Things(IoT) has increased the demand for smart and connected devices. In this work we developed a hardware device based on the ATmega2560 microcontroller that can estimate the power consumption and control the state of electro-electronic devices interconnected to it through Bluetooth wireless technology. The developed hardware is a smart plug focusing on smart home applications. As a result, by using a smartphone device with Bluetooth communication, one can control and measure electrical parameters of the interconnected electro-electronic hardware such as the RMS (Root Mean Square) current and RMS power been consumed. The obtained results showed the technical viability in the construction of energy consumption measuring device using modules and components available in the Brazilian market.

Keywords: Smart Plug, Internet of Things, Home Automation, Bluetooth.

I. INTRODUCTION

Users of the electricity supply networks are largely unaware of the electricity consumption of their household electrical appliances, and the lack of technical knowledge about their home's electrical installations and appliances is frustrating.

This paper seeks to use the concept of IoT to help solve this problem by implementing a device capable of estimating the energy consumption of a home appliance to which it is connected and transmitting this information via Bluetooth wireless communication to a smartphone device. Bluetooth has been used as it is currently one of the most widely used technologies in solutions that integrate wireless sensors and mobile devices.

IoT is a paradigm that has the idea of integrating objects into people's daily lives, using wired and wireless sensors, tracking technologies and actuator networks, bringing practicality to users' lives [1-5]. Within this view, the concept of IoT can allow access to a huge amount of data generated daily by such objects and, therefore, enables the creation of differentiated services by public agencies and private companies [6].

In this work we intend to use the concept of IoT integration in the construction of energy consumption meter device that using Bluetooth wireless communication is able to monitor the consumption of an electro-electronic device to which it is connected. In the work was used shelf hardware, available in the national market, to build a prototype of such device, showing technical feasibility.

II. THEORETICAL FOUNDATION

This section presents the basic concepts related to Bluetooth technology and the current sensor employed in the development of this research.

II.1 BLUETOOTH

The first steps in the development of Bluetooth technology were taken by Ericsson in 1994 in search of a low cost and low power solution between mobile communication devices and their accessories. The potentiality of the project caught the attention of companies in the industry that in 1998 joined together forming the Bluetooth Special Interest Group (Bluetooth SIG), a group of 5 companies responsible for developing Bluetooth standards, licensing technology and trademark to other companies. device manufacturers using the technology. The following year, the first version of the Bluetooth specification was released, demarcating connection patterns, devices, procedures and security [7].

Bluetooth technology works on an ad hoc wireless network, meaning you don't need a pre-existing infrastructure made up of routers or access points. This Bluetooth network without infrastructure is called piconet. A piconet must have a device identified as master, responsible for controlling, synchronizing transmissions and registering new Bluetooth network devices. A maximum of 7 devices called slaves can also actively participate in the network, which communicate directly with the master device [7].

The master device can also register other devices to be added to the network in the future as needed, paired with them. Devices that are not associated with any piconet are identified as standby.

Figure 1 shows an HC-05 hardware module used in this article. The HC-05 provides Bluetooth wireless communication and also has a serial interface that integrates with external devices such as computers or microcontrollers intuitively, cheaply and affordably.

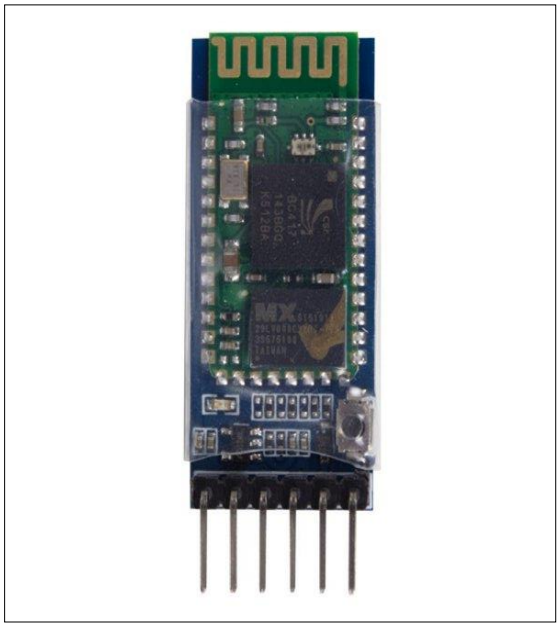

Figure 1: HC-05 Module.
Source: Authors, (2019).

The HC-05 has two operating modes, corresponding to Bluetooth operating modes, namely master mode and slave mode. An HC-05 module configured in master mode is capable of creating a piconet. To configure the module and change its parameters, it is necessary to use AT mode, provided that the module is open to receive, via serial communication, control commands.

II.2 ACS712 SENSOR

The ACS712 sensor is a device capable of reading AC (Alternative Current) or DC (Discrete Current) current, enabling integration with other industrial, commercial or communication electronic devices. The ACS712 is composed of a hall effect sensor connected to a copper track, which once a current travels, excites the sensor, generating an analog signal of voltage proportional to the read current [8].

This device is available in the market in 3 versions that differ in both the current supported by each model and the accuracy of each, with models of 5, 20 and 30 A (amps). The current supported by the ACS712 is inversely proportional to the sensitivity of its reading.

The ACS712 comes in an 8-pin Small Outline Integrated Circuit (SOIC) package, with pinouts implemented as shown in Figure 2 [8]:

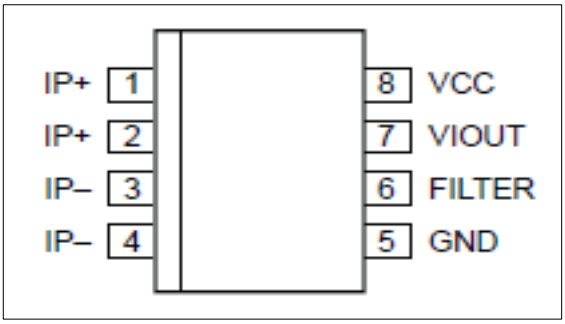

Figure 2: IC ACS712 Pinout Diagram.
Source: [8].

An important feature of this device is described in its technical specification, the IC (Circuit Integrated) operates with output that depends on the applied supply voltage. Causing reading to be severely impaired if any variation in input voltage occurs.

The ACS712 (Figure 3) is sold in IC form and can be integrated with hardware prototype microcontrollers such as the one proposed in this article.

Figure 3: ACS712 in module.
Source: Authors, (2019).

The ACS712 operates so that if supplied with a 5V voltage source and if a current flowing from pins 3 and 4 to pins 1 and 2 of the IC (Figure 4) of an intensity equal to the rated current is applied at Its input is expected to read 0.5 V at the output. If the current has the reverse direction (which flows from pins 1 and 2 to pins 3 and 4 of the IC). A 4.5V reading is expected as shown in the Figure 4:

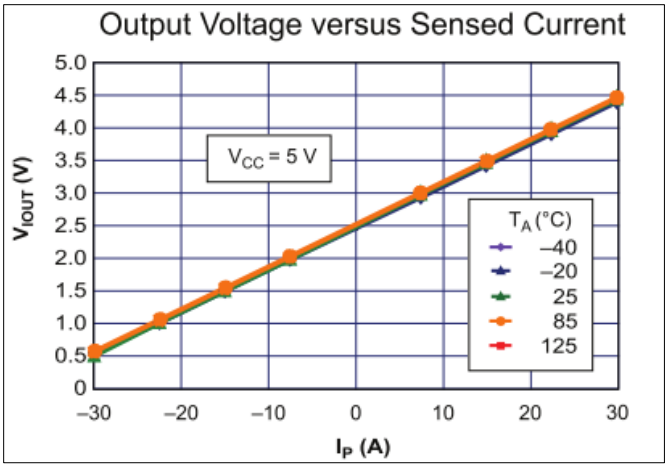

Figure 4: Description of output voltage as a function of current applied to ACS712 sensor.
Source: [8].

In the image above it is observed that it is possible to obtain a satisfactory level of stability for the system at the output of the ACS712 despite temperature variations, which is desirable because it allows the proposed prototype to be robust in various climates and installation conditions.

III. LITERATURE REVISION

Researchers have been using wireless technologies such as Zigbee, Wi-Fi, and Bluetooth for smart socket design. Some techniques have also been suggested for reducing power consumption by employing smart outlets.

The paper [9] introduces the technique of identifying devices in real time using smart sockets. The proposed system uses an Arduino microcontroller and an ESP8266 module, respectively for Wi-Fi processing and communication. The authors use a classification technique to identify the device using the consumed power data.

The proposal of [10] identifies the electrical events using the noise or the pulse transition during the equipment's electrical state switching. Noise during switching (on / off) of an application is detected, classified and associated with an electrical event or equipment using supervised learning techniques.

In the work implemented by [11] a new architecture is proposed to reduce energy use in domestic environments. The paper proposes the use of multiple Energy Management Devices (EMDs) to form the basic building block of the architecture. The blocks are connected by an EMD hub outside the network.

For [12] proposed a smart socket solution where a Power Line Monitor (PLM) is employed on each wall socket. PLMN data is reported every 10 seconds.

The nPlug developed by [13] uses analytical intelligence to determine peak demand periods, load unbalance, and it is possible to schedule high power electrical operation for off-peak hours without manual user intervention.

A power management system developed by [14] uses Bluetooth to detect user presence and control devices in user space using smart outlets. A smartphone app and a web service show the energy consumed. The article also proposed an energy saving algorithm to control the power consumed by the device plugged into the smart outlet. The system was developed and tested for a period of three months and the average energy savings were 31.3% and 15.3% for computer and lighting respectively.

In [15] an intelligent plug was proposed where an algorithm controls the voltage applied to the load instead of turning it off. This reduces the instantaneous power consumed on passive loads resulting in a low peak demand. The system uses the Zigbee communication protocol and a voltage control circuit registering an 18% reduction in peak demand. The system, however, has some limitations such as the considerable increase in THD (Total Harmonic Distortion) during voltage control.

In [16] the authors designed and developed a smart plug using Bluetooth for power consumption monitoring using a mobile app. The paper also compared some of the current smart sockets with the proposed device.

For [17] presented a smart plug solution that can monitor as well as control devices using a web application. This system uses Wi-Fi as a wireless communication protocol and a relay to control the state of devices. Measurement accuracy was computed and an error of less than 0.5% was reported by the authors.

For [18] Developed control hardware that analyzes through a sensor network the levels of illuminance in a given environment, later controlling the power applied to the lighting circuit, helping to reduce the consumption of electricity.

IV. METHODOLOGY

In this project we want to implement a system capable of reading the current, voltage and power consumed by a load connected to it. This system should be able to estimate these variables for any type of load (resistive, reactive or switched) with the least possible interference with the read values. In order to achieve these goals, the block diagram illustrated in Figure 5 describing the main components of the system was developed:

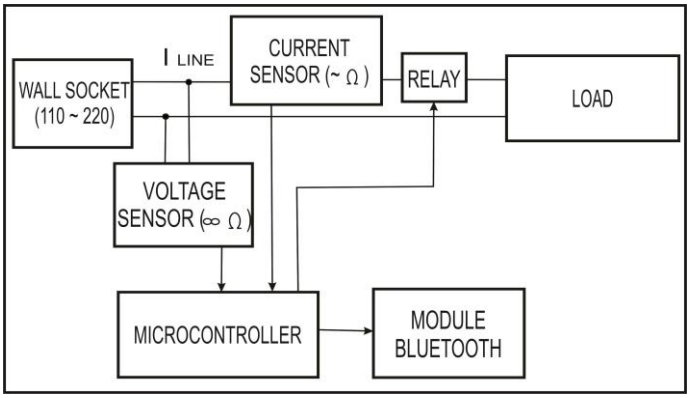

Figure 5: Block diagram of the hardware solution.
Source: Authors, (2017).

The block diagram shows the following components:

• Wall Socket - Represents the power input to which the system will be connected and which will power both the load and the active electronic monitoring and control device components. Since the proposed device is intended for use in a home environment, voltage in the range 110 to 220V RMS is assumed for calculation and circuit design purposes;

• Current Sensor - Represents a device capable of converting the value of the AC current that feeds the load into a voltage signal compatible with the chosen microcontroller. For this project the ACS712ELECTR-30A-T sensor produced by AllegroTM was chosen. For prototyping purposes, a development module provided by the company was used to encapsulate the chip.

• Voltage sensor - Sensor capable of converting a high voltage level that feeds the load linearly into a low voltage level compatible with the chosen microcontroller. This device was

designed and implemented in a module with passive components in a process that will be described later in the article.

• Microcontroller - ATMELA2560 was chosen from ATMEL Corporation which works in conjunction with Arduino Bootloader and integrated into a development board to facilitate the prototyping process.

• Relay - Represents the switching device used to cut the load supply. In the article the relay is controlled directly by the microcontroller, without the use of drivers. For this article we used the SRD-05VDC-SL-C, compatible with 5V operating voltage and 10 A maximum load current. The relay development board was used for simpler prototyping.

• Bluetooth Module - The Bluetooth module is a component capable of communicating with the microcontroller using serial communication interface, as well as transmitting information obtained from the microcontroller to other devices such as smartphones. The module used in the article was HC-05.

• Load - Due to the fact that the prototype of this article is intended for domestic use, it is expected that the loads found by the system will be mostly composed of switched sources, except for a few cases, because due to computerization, the most commonly used domestic loads are of this nature such as mobile phone chargers, computer supplies, LED lamps, etc.

IV.1 CURRENT READING WITH ACS712 MODULE

Using the code shown in Figure 6 it is possible to observe the output of the ACS712 module in real time through the serial communication present on the microcontroller development board. In addition, the IDE provided by the Arduino platform enables real-time visualization of the collected signal through its Plotter Serial tool. This allows the code and the reading module to be validated in their operation prior to the definitive implementation of the prototype.

```
1  //Rotina simples de leitura de porta analógica
2  void setup() {
3    // Inicialização serial a um baudrate de 250000
4    Serial.begin(250000);
5  }
6
7  void loop() {
8    // realiza a leitura da entrada analógica
9    int sensorValue = analogRead(A0);
10   // escrita do valor de sensor lido na
11   // interface serial
12   Serial.println(sensorValue);
13 }
```

Figure 6: Simple analog read code.
Source: Authors, (2019).

For a current reading through the ACS712 module it is necessary that the module has its reading terminals, pins 1-2 and 3-4 connected in series with the load for which the reading process of the module is to be performed. chain. In Figure 7, these pins will not be visible as the modular version of the ACS712 appears, where C.I. pins 1-2 and 3-4 are equivalent to the two (2) connection terminals located on the right side of the module.

The circuit allows a current through the ACS 712 sensor module to be converted to an analog voltage signal at output pin 2 (pin OUT) with respect to pin reference 3, GND. This voltage can be converted to a digital signal via the A/D converter (Analog / Digital) integrated in the microcontroller used. The A/D converter can be accessed via the "AIN0" pin on the Arduino Mega development board, which can be configured via C language programming code.

In order to validate the current reading method, the current module was connected in series with a fully resistive load electric device (15W soldering iron) in order to verify the current consumed by it non-invasively. The resistive element chosen was used as the load on the circuit shown in Figure 7.

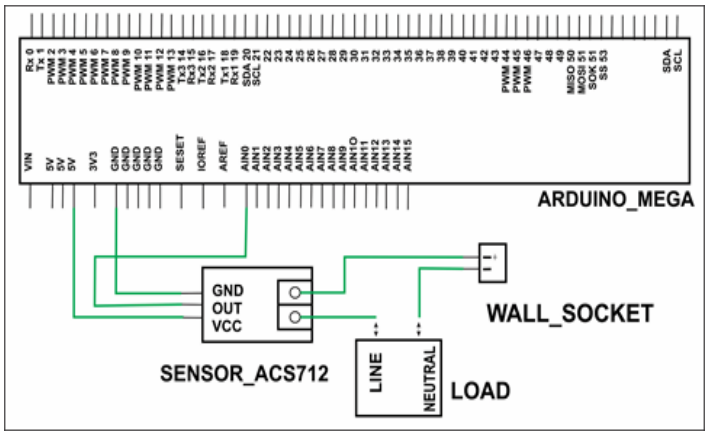

Figure 7: Current Reading Circuit.
Source: Authors, (2019).

Using the graphical construction tools present in the Arduino platform, we obtained the signal illustrated in Figure 8. This is the signal of the ACS712 module output voltage, which when interpreted by the Arduino A / D converter assumed values between 510 and 519 within an integer range from 0 to 1024 corresponding to the voltages of 0V and 5V respectively. Therefore, the above values must be converted to voltage values through the relationship shown in Equation (1):

Conversion of the measured voltage

a) $$V = \left(\frac{D}{1024}\right) * 5000mV \quad (1)$$

Where D is the integer value obtained by the A/D converter and V is the estimated voltage at the ACS712 sensor output. With this information and knowing that the relationship between V and the current that flows through the terminals of the ACS712 is directly proportional, and specified by the manufacturer, it is possible to estimate the electric current consumed by the load. Since the ACS712 module used in this article is of model ACS712ELCTR-30A-T, it is observed that the relationship between output voltage and read current is 66mV / A, according to the documentation provided by the manufacturer. Equation 2 illustrates how current can be calculated, where S is the sensitivity of the module as specified by the manufacturer.

Measured current conversion

b) $$I = \frac{\left(\frac{D}{1024}\right) * 5000mV}{S} \quad (2)$$

Figure 8 illustrates the current behavior read by the ACS712 module. It is observed that the current oscillates around the value 39A which is not the value actually consumed by the load. This is due to an offset present in the sensor.

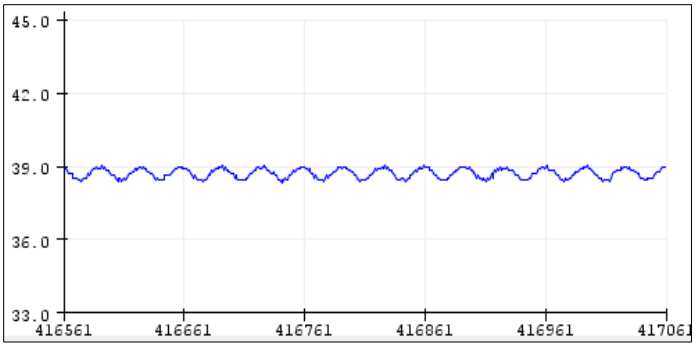

Figure 8: Offset measured current signal.
Source: Authors, (2019).

To correct the offset, a moving average algorithm using the last 70 samples was used to determine the average current value. The resulting signal is shown in Figure 9.

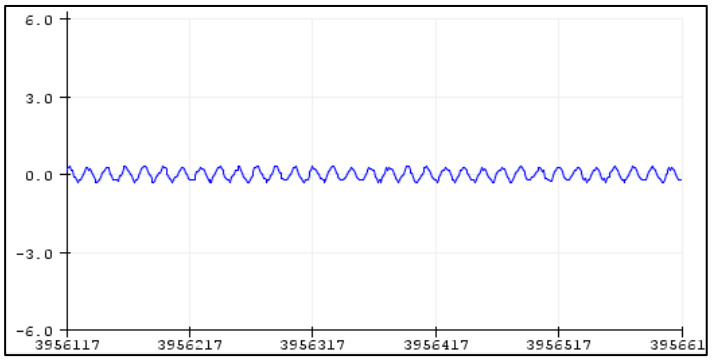

Figure 9: Current reading without offset.
Source: Authors, (2019).

IV.2 VOLTAGE READING

Unlike current reading, where a commercial module facilitates prototyping work, no module was found that met the prototype needs and was compatible with the Arduino microcontroller. Therefore, it was necessary to develop a module capable of providing isolation between the line voltage and the electronic circuits present in the system and to transfer the voltage information read on the line in a linear, instantaneous and with low current consumption.

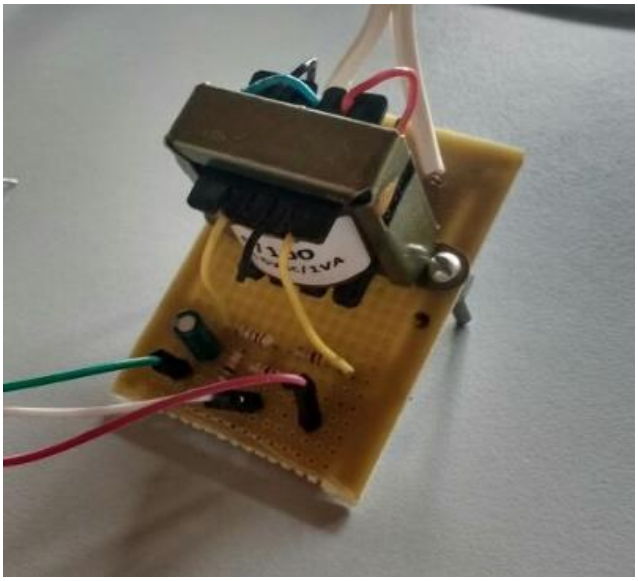

Figure 10: Voltage sensor module developed.
Source: Authors, (2019).

According to Figure 10 the designed voltage sensor module has three distinct parts:

1. The transformer that is responsible for lowering the voltage and isolating the circuit from voltage fluctuations. This has a voltage reduction factor of 100: 6.

2. In Figure 11, resistors R1 and R2 are responsible for dividing the voltage from the transformer so that it is within the operating values of the Arduino microcontroller.

3. Also in Figure 11, resistors R3 and R4 are responsible for raising the signal to a DC level equal to half of the microcontroller read voltage range, so that the generated voltage signal, including negative voltage values, visible to the ADC (Analog to Digital Converter) converter of the Arduino microcontroller. Capacitor C1 has the function of stabilizing this DC voltage level avoiding to generate sudden variations that may be available in the Arduino ADC input.

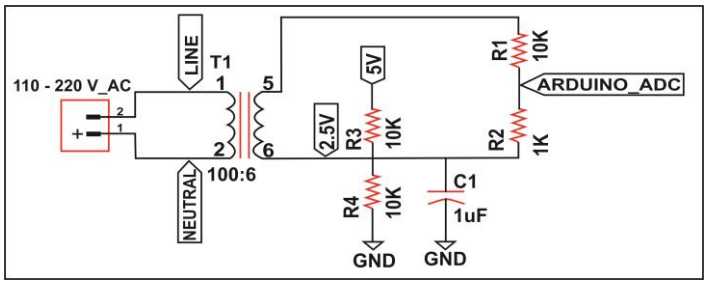

Figure 11: Voltage sensor module circuit diagram.
Source: Authors, (2019).

For the voltage sensor module to be used as a voltage reading device, a linearity constant that relates the actual voltage and the voltage read by the Arduino must be found (Equation 3). Assuming, for calculation purposes, that the peak voltage value of 220VAC (Volts Alternating Current) is present at the input of the voltage sensor module. You can calculate the read voltage value and the linearity constant that relates it to the voltage observed by the microcontroller. Assuming an ideal transformer:

Obtaining the actual voltage

c) $$V_{out} = \frac{6}{100} * V_{in} = 13{,}2V \quad (3)$$

The voltage V_out corresponds to the peak voltage VAC observed at the transformer output. Thus, assuming the resistors R1 and R2 to be ideal gives Equation 4:

Voltage divider

d) $$V_{div} = 13{,}2V * \frac{R_2}{R_1 + R_2} = 1{,}2V \quad (4)$$

The voltage V_{div} div is observed by the voltage divider at the circuit output, but it is necessary to sum the DC level in resistors R3 and R4 in order to obtain the value detected by Arduino. This is because, in the previous calculation we are taking as reference this level DC and not the level DC in relation to the ground. Therefore, the actual voltage available on Arduino is shown in Equation (5).

Real tension

e) $$V_{adc} = 1{,}2V + DC = 3{,}7V \quad (5)$$

The linearity relationship between the line voltage and the voltage observed by Arduino was obtained according to Equation (6). However, due to the nonlinear characteristics of the components used, there was a considerable difference between the value obtained and that observed in practice. Therefore, it was decided to perform empirical tests to obtain a satisfactory linearity constant for the proper functioning of the system.

Linearity constant

f) $$S = \frac{V_{arduino}}{V_{in}} = \frac{3,7V}{220V} = 16,8mV \quad (6)$$

From the value obtained in the above calculation, an iterative improvement search process was performed in order to find a value. The RMS voltage of a 127V electrical outlet was verified using a multimeter. Then, the same reading was performed through the microcontroller in order to refine the obtained proportionality constant. The obtained empirical proportionality constant is shown in Equation (7).

Proportionality constant

g) $$S = 5,2mV \quad (7)$$

Similar to the procedure performed to correct the obtained current, the voltage signal obtained was treated. Using a vector of determined size to fix the number of samples, an arithmetic average of the values is calculated and this average is used to correct the stress value.

IV.3 BLUETOOTH MODULE CONFIGURATION

To use the Bluetooth module, it was necessary to perform previous configurations of: i) slave mode operation; ii) configuration of the module name in the network; iii) access password setting. These setup operations can only be performed in AT mode.

To access AT mode the Bluetooth module is connected to the Arduino microcontroller, which during this process will operate as a serial interface between the serial terminal and the Bluetooth module. Arduino serial communication / Bluetooth module is performed through the receiver (Rx) and transmitter (Tx) pins of the HC-05 module and the microcontroller pins 10 and 11, respectively. It was also necessary to activate the KeyPin pin present in the Bluetooth module. To perform the configuration, this pin must be at logic level 1 when the module is energized.

Figure 12 illustrates the wiring diagram of the connection between the Bluetooth module and the Arduino microcontroller. Importantly, in order for the configuration to work and AT mode to be successfully accessed, the HC-05 module power supply must be connected only after the Arduino pin 9 (PWM / 9) raises the KeyPindo HC-module pin. 05 to 5 Volts, otherwise the BluetoothHC-05 module will not enter AT operation mode.

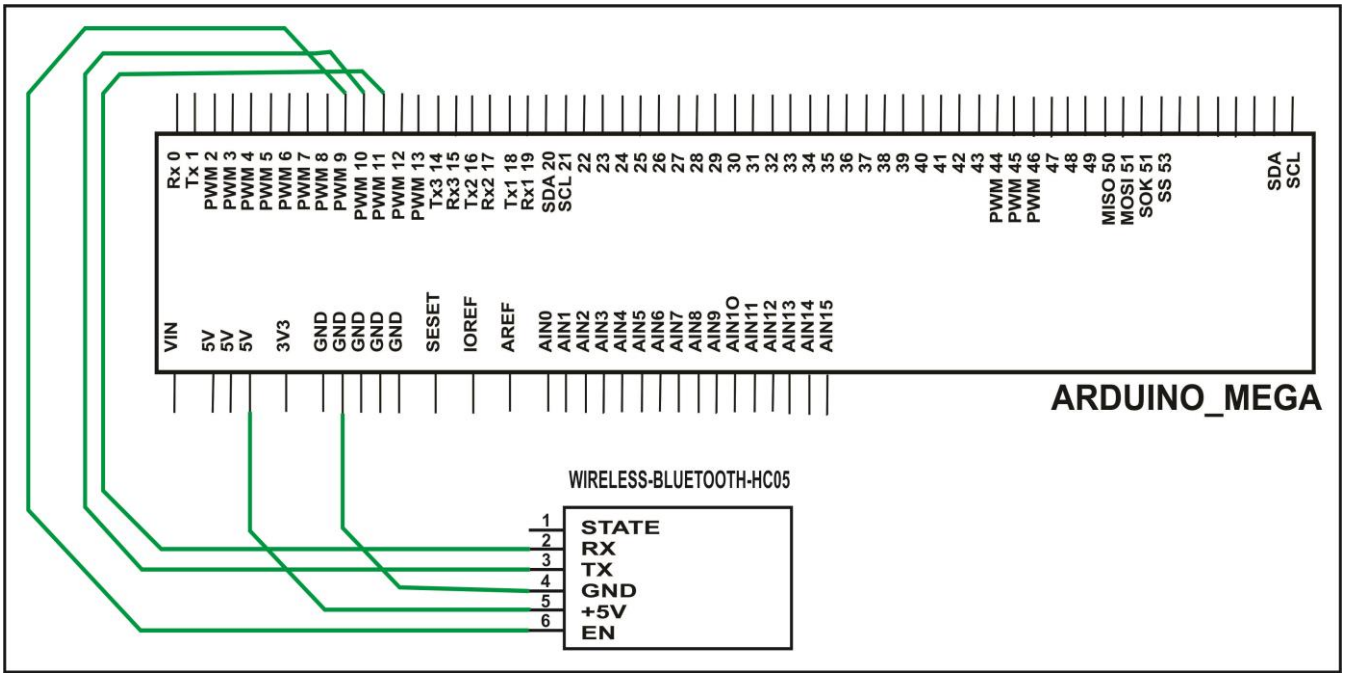

Figure 12: Electrical diagram of HC-05 module connection in AT mode.
Source: Authors, (2019).

IV. PROTOTYPE CREATION

A prototype based on the diagram in Figure 5 was developed. The prototype has a USB port that allows communication with a computer in order to perform code loading and electrical powering of the Arduino module. The prototype also has a plug used to connect the appliance to be controlled and whose voltage and current you want to read. In addition, the prototype also has a socket that allows connection to a socket, and is compatible with voltages ranging from 110 to 220VRMS.

The prototype, whose electrical scheme is shown in Figure 13, was encapsulated in a 14.5x9.5x5.5cm plastic box, in which all components were inserted and fixed with few clearances. To the voltage sensor input was connected a plug according to the Brazilian standard (NBR14136), with 4mm diameter terminals, thus supporting up to 10A. To the output of the circuit was connected a socket of 4x2,3cm also of the Brazilian standard, supporting a maximum of 10A.

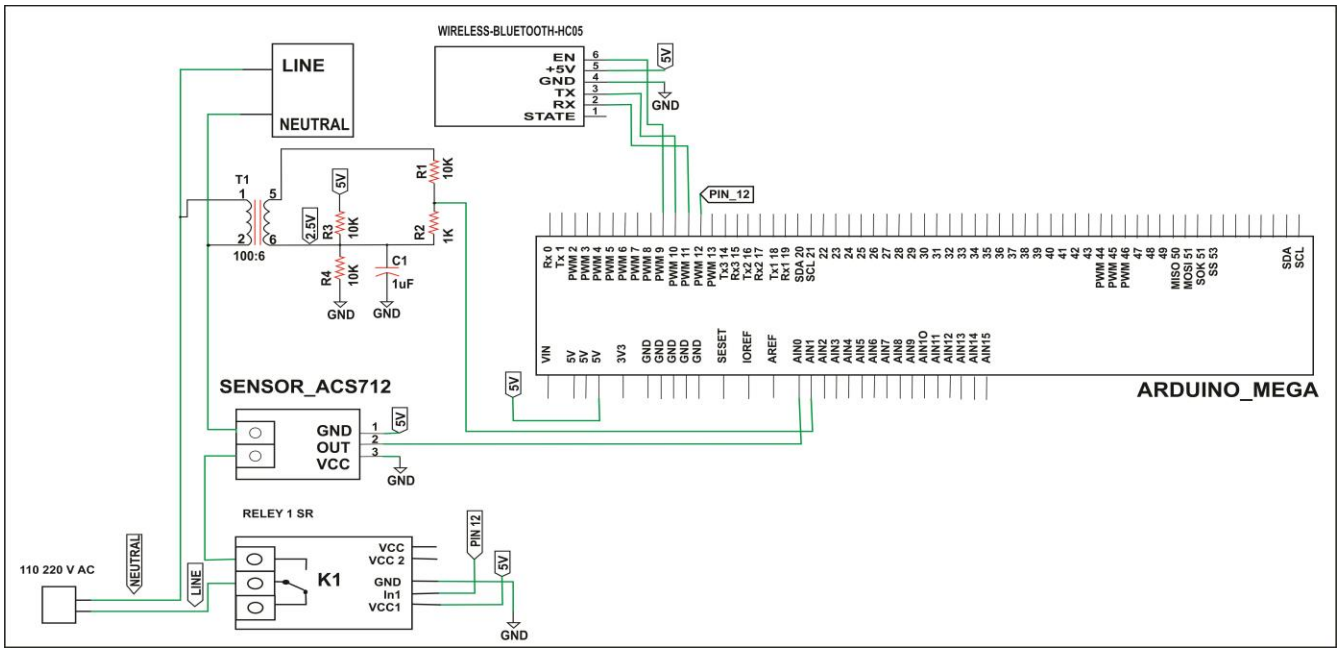

Figure 13: Electrical prototype diagram.
Source: Authors, (2019).

The components were arranged inside the box in 2 layers. In the first layer the voltage sensor, current sensor, relay and socket were arranged and in the second layer the Arduino module was positioned as shown in Figure 14:

Figure 14: Open prototype.
Source: Authors, (2019).

The Bluetooth module has been fixed to the prototype side wall to minimize interference from other components and cannot be seen in the image above due to perspective.

IV.5 INSTANT READ RELIABILITY TESTING METHODOLOGY

For a reading system as developed in this article there is a need for frequent voltage and current readings. The ideal situation is where these physical quantities are measured simultaneously, but they are measured by the Arduino microcontroller and therefore read sequentially. One possible consequence of this factor is that there is a lag between the instantaneous voltage and current reading that is not due to the circuit, but rather the small-time difference between the current/voltage measurements. To measure the influence of this effect on reading the following test protocol was performed:

1. Obtain 30 zero-pass readings of both the voltage signal and the current signal during prototype operation while feeding a resistive load and an inductive load.

2. Calculate the instant of time at which both the voltage signal and the current signal pass through zero, by determining a line representing the transition between a positive and a negative value, according to Equations 8 and 9.

Zero Crossing Voltage

$$h) \quad Zv = \frac{-(Tp*Tn*Vp)+(Vp*Tn^2)+(Vn*Tp^2)-(Vn*Tp*Tn)}{(Vp*Tn)-(Tn*Vn)-(Tp*Vp)+(Tp*Vn)} \quad (8)$$

Zero Crossing Current

$$i) \quad Zc = \frac{-(Tp*Tn*Cp)+(Cp*Tn^2)+(Cn*Tp^2)-(Cn*Tp*Tn)}{(Cp*Tn)-(Tn*Cn)-(Tp*Cp)+(Tp*Cn)} \quad (9)$$

Where:

• Positive zero crossing voltage (Vp) - last voltage value read by the microcontroller before the sine waveform presents its negative cycle;

• Negative zero traversal voltage (Vn) - first voltage value read by the microcontroller during the negative cycle of the read sine waveform;

• Positive zero-pass current (Ip) - last current value read by the microcontroller before the sine waveform presents its negative cycle;

• Negative zero-through current (In) - first value of current read by the microcontroller during the negative cycle of the read sine waveform;

• Positive zero crossing time (Tp) - time in microseconds at which the positive zero crossing voltage or current was obtained;

• Negative zero crossing time (Tn) - time in microseconds at which the negative zero crossing voltage or current was obtained.

Calculate the difference between the time points of the zero and voltage current passage, according to Equation 7.

Zero Crossing Difference

j) $$T_d = Z_c - Z_v \quad (7)$$

1. Estimate the current and voltage lag. Knowing that for a resistive load it is expected to observe a lag of 0% and for an inductive load it is desired to observe a delay of the current in relation to the voltage, according to the following formulation:

Inductive load lag

l) $$\phi = T_d * 10^{-6} * 360 * 60 \quad (8)$$

IV.6 VALIDATION OF THE RMS VALUE CALCULATION METHOD

It is necessary that the method for obtaining the RMS values implemented in this article be validated and compared with other means of obtaining, for this the following procedures were performed:

1. Obtain 30 sample readings obtained during prototype operation by feeding a resistive load. The prototype uses serial communication to communicate with a personal computer. The 30 reading samples shall have information on the peak voltage beyond the time at which the reading was taken, information provided by the microsecond scale microcontroller;

2. Use of the peak voltages obtained previously to calculate the RMS voltage through the relationship shown in Equation 9, and the calculation shall be performed for 30 available voltage values;

RMS voltage

m) $$Vrms = \frac{Vp}{\sqrt{2}} \quad (9)$$

3. Calculation of the mean and standard deviation of the 30 RMS values for comparison and further discussion;

4. Using a multimeter to check the available RMS voltage at the outlet where the system is powered, the reading should be taken a total of 30 times at least 1 minute intervals. The values must be recorded;

5. Calculation of the mean and standard deviation of the 30 RMS values collected from the multimeter;

6. Obtaining 30 RMS values calculated using the method implemented in the source code in Annex A provided by serial communication to a personal computer by the prototype, the values shall be recorded every 1 minute at least;

7. Calculation of the average of 30 RMS values and their standard deviation for comparison and subsequent discussion;

8. Discussion and comparison of the 3 methods.

IV.7 RELIABILITY TEST OF ACTIVE POWER ESTIMATE

In this paper, two methods for obtaining power were used, one for obtaining active power and one for obtaining reactive power. It is useful to check if the first one is in agreement with the second, presenting identical values for a resistive load. Since these are completely different methods, this would prove that the values provided by the system actually converge at a given reading. The following test aims to verify the reliability of the RMS (reactive) and active power estimation methods:

1. Obtain 30 samples of active and RMS power readings obtained during prototype operation by feeding a resistive load in serial communication with a personal computer. Readings should be taken within a minimum of 1 minute;

2. Calculate the mean and standard deviation of the difference between readings;

3. Analyze the results.

V. EXPERIMENTS AND RESULTS

The instant read accuracy tests followed the protocols described in Session IV.5. Values were acquired using the prototype. A total of 30 voltage and current samples together with the time the reading was obtained in microseconds from the microcontroller energization instant.

In Figure 15, besides recording the values verified in the experiment, the estimated moment in which the voltage value occurs assumes the zero value. This information is useful because when compared to the moment when the current assumes zero, one can estimate the lag between voltage and current waveforms.

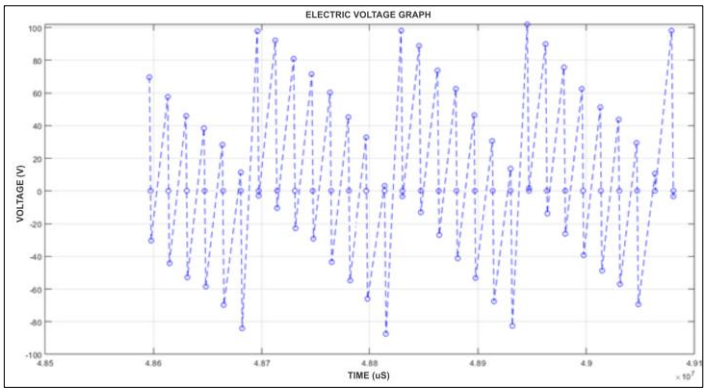

Figure 15: Voltage signal measured for resistive load.
Source: Authors, (2019).

Figure 16 represents the plot of the collected current values as well as the zero crossing time for resistive load.

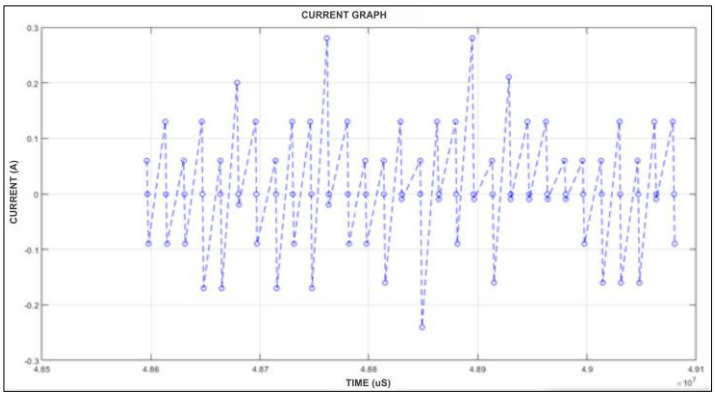

Figure 16: Current signal measured for resistive load.
Source: Authors, (2019).

Figure 17 illustrates the shifting behavior between voltage and current for the resistive load. Taking into account the mains frequency of 60 Hz, the difference between the zero crossing between the current signal and the voltage signal previously measured is calculated. Then the result is converted to microseconds to degrees.

The average of the lag values of the graph in Figure 17 is -2.59 ± 2.59 degrees, indicating a slight delay of voltage relative to current. This result does not match the behavior expected for a

purely resistive load. With this, we conclude that there is an error of 0.71% in the estimation of current and voltage lag. This average has a standard deviation of 7.55 degrees.

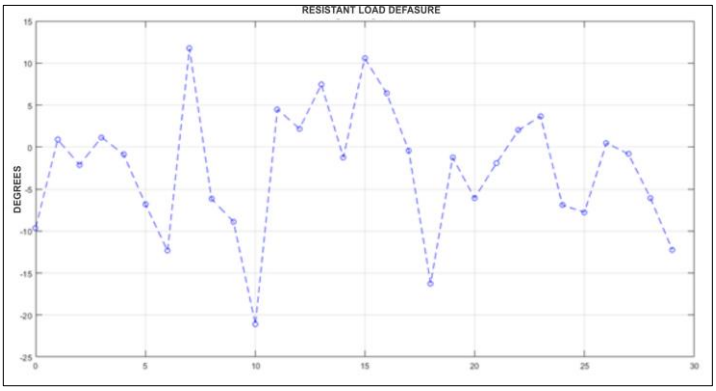

Figure 17: Resistive load lag.
Source: Authors, (2019).

Then the tests involving an inductive load were performed. For the experiment in question a 127V home fan was chosen. Due to the nature of the load, the average lag value is expected to be greater than zero, indicating a delay of current to voltage. Figure 18 shows the current signal.

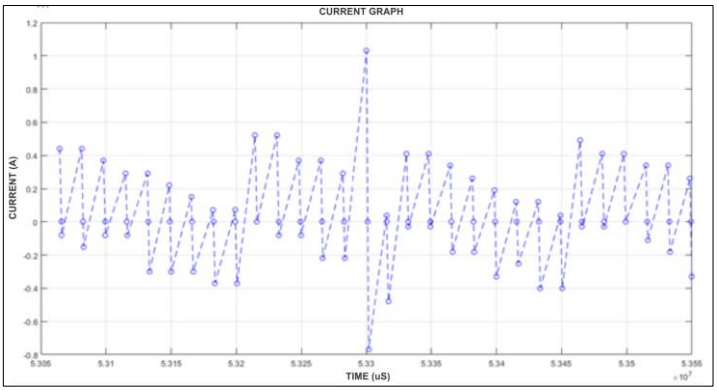

Figure 18: Current signal measured for inductive load.
Source: Authors, (2019).

Figure 19 illustrates the voltage signal behavior measured for inductive load.

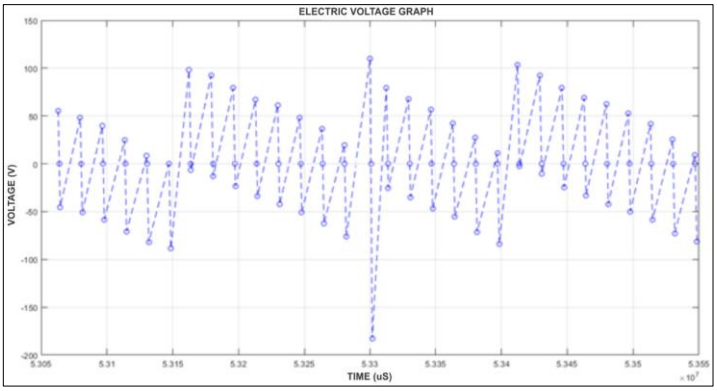

Figure 19: Voltage signal measured for inductive load.
Source: Authors, (2019).

After an analysis of the graph of Figure 20, showing the lag between voltage and current for the inductive load, it can be concluded that there was a delay of current to voltage of approximately 〖42〗^o on average, with a standard deviation of 7^o, a standard deviation very close to that obtained for resistive load.

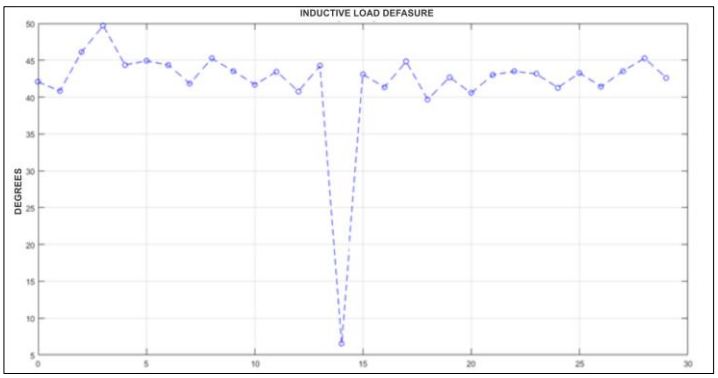

Figure 20: Inductive Load Defeasure.
Source: Authors, (2019).

From the collected data, it can be concluded that there is an error inherent in the lag detected by the system. However, this error is within a standard deviation of at most 〖7.55〗^o, meaning that for domestic applications where accuracy in offset reading is not a critical item, these results are more than sufficient to estimate residential consumption.

The next test performed, with results presented in Figure 21, was the RMS power measurement accuracy. For this purpose, 30 samples were collected from: i) peak voltage; ii) calculated RMS voltage; (iii) Bluetooth voltage: Measured by means of the voltage sensor developed and transmitted via the Bluetooth wireless network. iv) and the RMS voltage measured by a digital multimeter.

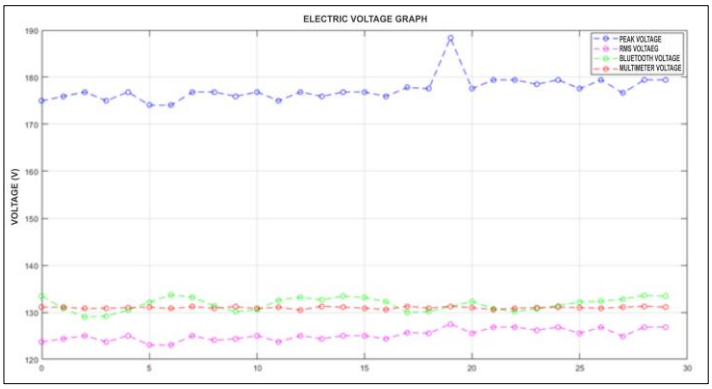

Figure 21: Stresses obtained for the calculation of RMS power.
Source: Authors, (2019).

The measured RMS voltage measured by a digital multimeter averages 131 V with a standard deviation of 0.21 V. This reading generates a base value against which the other readings are compared. The RMS voltage values calculated from peak voltages only have an average of 125.24V and a standard deviation of 1.22V. Therefore, an error of 5.76V is calculated in relation to the average obtained using the digital multimeter. The values calculated for Bluetooth voltage showed an average of 131.77V and a standard deviation of 1.41V, thus presenting an error of 0.77V in relation to the average of the values measured by the multimeter.

Thus, the technique implemented in the article for RMS value calculation actually had a higher accuracy than that obtained by the simplest method using peak voltage. This means that the prototype had an error of approximately 0.5%, which would be more than enough to effectively estimate RMS power values.

In order to verify the data obtained for active power, a resistive load connected to the system was used, since it is known that in this situation there is no delay between current and voltage and, therefore, there is no reactive component in the power making. RMS power and active power are identical. Figure 23 presents the observed data showing that RMS power values resulted in an average of 32Var and standard deviation of 0.78Var. Already the active power values showed an average of 31.56W and standard deviation of 0.77. In fact, the value of these two powers, obtained by completely different methods presented very close values. As observed in Figure 22, the difference between the two averages was only 0.56W, with a standard deviation of 0.15W. This indicates that for a resistive load the active powers and RMS are similar with an error of only 1.74%.

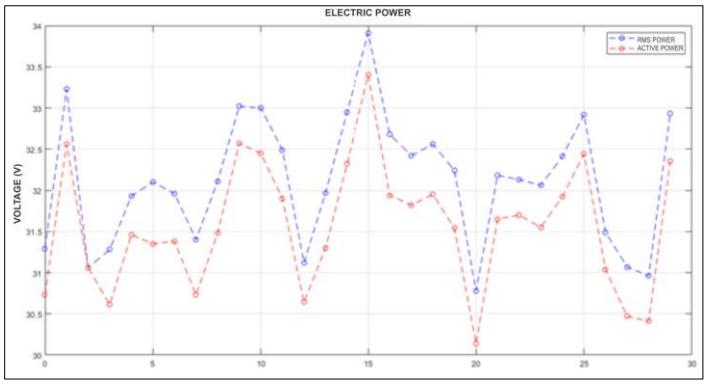

Figure 22: RMS Power and Active Power.
Source: Authors, (2019).

VI. CONCLUSIONS

In this work a prototype of a meter of electric energy consumption of electronic devices was developed. The prototype is capable of measuring quantities such as voltage, instantaneous current and RMS of the electro-electronic device to which it is connected and transmitting via Bluetooth communication the measurements made to a Smartphone. The tests and results show that the prototype developed, both in hardware and software can estimate the values of current, voltage, apparent power, active power and reactive power satisfactorily for domestic use and with the purpose of informing the consumer about your expenses. As future work we intend to design and develop a switching power supply for the microcontroller module allowing greater energy efficiency and therefore less waste. Another possibility would be the use of instrumentation amplifiers for voltage measurement.

VII. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

REUSE OF SOLID WASTE IN A STEEL COMPANY FROM MINAS GERAIS: PROCESS, BENEFITS AND RESTRICTIONS

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ABSTRACT

The objective of this research was to conduct a study on the process of formation of recyclable raw material (RRM) in a company from the steel sector, pointing out the benefits and limitations of its reuse in the manufacturing process of liquid pig iron. For this purpose, bibliographic research and field visits were carried out. Waste generated throughout the company's steelmaking process is collected daily by a service company, where it undergoes beneficiation, forming the RRM. RRM is returned to the industry in order to be reused in its production process, configuring thus an operation of reverse logistics. RRM is used in order to reduce the use of iron ore in sinter production. This reduces the direct costs of iron ore extraction, transportation and storage and environmental impacts such as water, air and noise pollution. Other externalities are also avoided, such as land use conflicts, depreciation of surrounding properties, degradation of land and disruption to urban traffic. The results show that, in addition to environmental gains, the use of RRM generates savings of R$ 767.604,00 per month to the industry. One of the limitations is that, concerning the manufacturing of special steels, there is risk of contamination and loss of quality if RRM is used in large proportions. It, however, is still an option for this sector on the pursuit of sustainability.

Keywords: Pig iron, Recyclable raw material, Iron ore, Economy.

I. INTRODUCTION

The Brazilian National Environmental Council, in Article number 2 of Resolution Number 313 from October 29, 2002, defines industrial solid waste as any waste that results from industrial activities and that is found in solid, semi-solid, gaseous - when contained - and liquid states, whose particularities make it impossible for it to be discharged into the public sewage system or bodies of water, or that require technically or economically unfeasible solutions regarding the best available technology [1].

This type of waste has been the focus of great interest and has become important in the environmental, industrial, economic and academic scenarios, since large volumes are generated annually both in Brazil and worldwide.

Treatment of industrial waste prior to disposal, as well as recycling, reduces the impacts on the environment and on human health. Therefore, Brazilian legislation requires companies to create programs aimed at sustainable management of this waste.

In Brazil there are still many obstacles in its management, such as the lack of accurate information about quantities generated in the industrial sphere and about disposal and reuse [1].

An important tool created by Law 12.305, which governs the National Policy of Solid Waste, is reverse logistics. This is a crucial instrument in economic and social development, since it is guided by a series of actions and procedures aimed at enabling the collection and the return of solid waste to its process of origin for reuse in its own or in another production cycle or to some other appropriate destination.

Several organizations have been updating their production processes in light of this new reality, bringing several advantages for society and the environment, such as the return of solid waste to its sources or processes of origin, avoiding the contamination of soil and bodies of water and the degradation of air quality.

Further important points of the National Solid Waste Policy are the creation and consolidation of a shared responsibility system, of waste sorting and the update of production processes

with the creation of cleaner processes that will facilitate reuse, creating products that are more easily inserted in reverse logistics.

With regard to the generation of industrial waste, the steel industry stands out in this aspect since it generates several types of waste in large quantities. Much of this waste, however, can be incorporated back into the productive chain.

In the sintering process the steel industry generates sintering fines and ore fines. In the blast furnace there is generation of blast furnace slag, ore fines, dust from the blast furnace's gas scrubbing system and from the dust removal system. In the steel mill, slag, dust from dust removal systems and gas scrubbing systems are generated. In the rolling stage, steel scrap and mill scale are generated, among other residues generated directly or indirectly from all these processes.

In this context, a service-providing company, whose service is the creation of industrial cleaning solutions, produces Recyclable Raw Material (RRM) through the processing of waste collected during the cleaning activities of the company, located in the state of Minas Gerais, which is object of this study. The RRM is returned to this industry to be reintegrated into the production chain of liquid pig iron, which characterizes the process as being of a Reverse Logistics nature. Aiming at achieving greater knowledge on the subject, the research questions of this work were: How is the formation process of RRM? What are its benefits? Are there any limitations on its use?

This research aimed to: conduct a study on the formation process of recyclable raw material (RRM), pointing out benefits and limitations of its reuse in the process of manufacturing liquid pig iron; describe the manufacturing process of pig iron; and conduct a survey of major Brazilian steel companies regarding waste generation and recovery rates.

In the development of this work, the main authors consulted were: [2-5].

II. THEORETICAL FRAMEWORK

II. 1 THE STEEL INDUSTRY

The 20th century was marked by the advent of a large metal-mechanical complex around the world. Along with oil and electricity, steel was one of the pillars of this complex that has profoundly transformed mankind's lifestyle [6].

The Brazilian iron and steel production sector in the early 20th century had little significance. From 1910 onwards, the sector gained notoriety in the existing debates, drawing attention to the need for investment [7].

Investments began in the state of Minas Gerais, gaining strength with the creation of Companhia Siderúrgica Nacional in 1941. Afterwards, the government created decrees in order to favor and stimulate the sector. With these investments, national production went from 3000,00 tons per year in mid-1901 to 500.000,00 tons per year from mid-1915 onwards [7].

Between 1917 and 1930, 14 new companies were created in the sector, in addition to a pre-existing one. Three companies are noteworthy: Companhia Siderúrgica Belgo-Mineira, founded in 1921, Companhia Brasileira de Mineração e Metalurgia, created by Cia. Mecânica e Importadora, in 1925, and Cia. Brasileira de Usinas Metalúrgicas, created by Hime & Cia, in 1926. These three companies not only quickly dominated the sector, but also diversified the domestic production structure, introducing themselves more sharply into the production of steel and rolled steel [7].

The steel industry's post-war growth was overwhelming, with an average annual increase rate in steel production of 5%, from 1945 to 1979. After a period of stagnation in the 1980s, the steel industry began a restructuring phase, marked by a substantial increase in production, greater pursuit of technological innovations in processes and products, greater shareholder concentration and fewer workers [5].

According to [5], this type of industry has been undergoing major changes, from its structure to the way steel is produced. Nowadays, these transformations have been happening at a faster rate, since there are forces that influence the steel companies, such as the following:

• Capital costs

Comparing manufacturing costs and value added to the raw material, there is a very high start-up capital requirement, especially for large industries that utilize coke plants, sintering and/or pelletizing, blast furnaces and steel mills. There is, therefore, a tendency to reduce their implementation costs in order to reduce the final price of the product from the very beginning of the production chain, avoiding loss of quality but also maintaining a competitive product [8].

• Limited raw material supply

The basics for producing steel are iron ore, especially hematite and mineral coal, both of which are not found pure in nature, their processing being thus necessary for their use. Lately, processes have been making use of scrap originated from waste, waste of sinter fines, ore fines, among others, in order to complete the metallic load for iron and steel production and to fulfill the low supply [9].

Although there is a large amount of iron ore available in the world, deposits are concentrated in a small portion of countries. There are still limitations regarding the maximum possible amount of reuse of the waste from scrap and fines, due to the risk of steel contamination and loss of quality in the case of special steels [5].

• Environmental Requirements

The steel companies that use charcoal in their processes and those that use mineral coal coke, the latter less expressively, are the main focus of environmental agencies, especially due to the solid waste they generate. In recent times, there has been an effort to advance and update environmental legislation to match international requirements and technological advances, especially with regard to licensing and license renewal. The COPAM Normative Deliberation Number 49/2001 was created, bringing new requirements for dedusting systems, in the stages of handling and sifting of raw materials and regularization regarding the licensing of steel mills [10].

The steel industry is a major consumer of energy and materials, as well as being responsible for considerable pollutant emissions, both in the form of liquid effluents and solid waste. During the last decades, the steel industry has improved its energetic efficiency, increased productivity and decreased pollutant emissions. An important peculiarity is the production of energetic byproducts and inputs that can be used in the plant itself or in other economic sectors [5].

The creation of COPAM Normative Deliberation Number 49/2001 was a milestone for the sector in the state of Minas Gerais, as it brought innovative requirements for the implementation of dedusting systems in the stages of reception, handling and sifting of raw materials and regularization regarding environmental licensing of companies. It also demonstrates an effort to seek measures to control coal consumption, such as the creation of

planted forests and the restriction of the exploitation of native forests, encouraging sustainable management. Coal accounts for about 70% of the final product cost and is essential to the production process of pig iron [10].

• New materials

This is one of the biggest motivators for the transformations that occur in the steel industry, and the factor that encourages them; not only does it encourage their production, but also the use of new raw materials. With advances in the reuse of sintering fines to complete the metallic load in pig iron production, the use of iron ore is reduced. Rolled steel, when it becomes scrap metal, is a type of waste that can be introduced back into the feeding process of the converting furnace, in the steel mill, in the production of liquid steel [5].

This subject is commonly not often discussed due to the companies' information protection processes and market secrets. What is generally seen is the use of steel waste in other areas, as described by [11], where the use of steel scale as an aggregate of concrete instead of sand was investigated in order to reduce the use of sand (a natural resource); but the authors also stress that it is necessary to carefully observe the resistance offered by this concrete, due to oil and grease contamination originating from the scale production process.

II. 2 ENVIRONMENTAL SUSTAINABILITY

According to [12], "sustainable" means something that is enduring, lasts for many years and can be conserved, and can thus impart the idea of continuity. Following this line of thought, companies are faced with the need to create new processes and reevaluate the relationship between economy, society and nature in order to achieve sustainability.

During Agenda 21, it was agreed that development and conservation must always go hand in hand, thus undermining the idea that, during the process of evolution, it is not possible to both preserve and economically develop, especially in underdeveloped countries [13].

Saving natural resources and reusing waste are the main tools for sustainable development and for the maintenance of life on the planet and of survival resources for the next generations [13].

Since sustainable development aims to meet the needs of current and future generations, it is up to the current generation to ensure that these needs are met, as future generations cannot yet act [14].

The term "sustainability" has two origins: one is based on ecology, in what concerns resilience due to the misuse of available natural resources by man, or due to natural events such as earthquakes, tsunamis, etc. A second origin is of economic nature, which arose through the perception of the finitude of natural resources in the purpose of production, since, with technological advance, the possibility of shortage of raw materials was recognized [15].

The concept of sustainability grew from the environmental crisis of 1950, due to the several occurrences of environmental disasters, and has been gaining traction due to its wide dissemination in the media [16].

Some of sustainability's biggest enemies are social inequality and misinformation, which still lie at the root of the lack of interest in the topic. As a result, the defense of the third dimension of sustainability grows: this is of a social nature, calling for a sustainable society which offers the minimum necessary for a dignified life to its citizens and in which no one consumes goods, or natural and energy resources that are harmful to others. Its aim and challenges being the eradication of poverty and the definition of the acceptable inequality standard, the social dimension seeks to define minimum and maximum limits of access to material goods and to implement the very desirable social justice [15].

The concept of sustainability is related to Darwin's research, which considers the trajectory of birth, development and death of species. Species follow one another, some disappear and some arise. It was like this with our hominid ancestors, and understanding what was the extinction factor of these species makes us identify ways to prevent the extinction of mankind and even to predict environmental events that could cause its disappearance [15].

II. 3 SOLID WASTE

Issues related to solid waste have been widely explored in scientific studies, as they are one of the biggest difficulties faced by a society that seeks sustainability [1].

There are several types of solid waste, among them industrial waste. It results from industrial activities and is found in solid, semi-solid, gaseous (when contained), and liquid states. Its particularities make it impossible for it to be released into the public sewage system or into bodies of water, or require technical or economically unfeasible solutions given the best available technology. Included in this definition is the sludge from water treatment systems and those generated from pollution control equipment and installations [1].

The steel industry is responsible for generating solid waste in great variety and quantity, its recycling and reuse being therefore critical. With the growing concern about environmental issues, several industries began to invest in new alternatives to solve the problems arising from the generation and disposal of waste [2].

The most important steel waste is classified into slag, dust and sludge from blast furnaces or steel mills, scale and coal and ore fines. The steel industry produced 13.5 million tonnes of waste, with an average of 435 kg/t of steel produced. Revenue generation through the recycling of these materials has made companies act in a new way on the issue of environmental management [2].

Industrial waste has attracted great interest and gained importance in the environmental scenario, in industry, economy and in the academic community, since it is generated by various types of production processes, resulting in huge quantities in Brazil and worldwide [17].

It is important to remark that every industrial enterprise generates waste and uses inputs in all its processes. Entrepreneurs often associate the taking of environmental preservation actions with additional expenses. Consequently, possibilities of cost reduction are not taken into account. Actions aimed at environment protection can bring profit, or at least neutralize the expenses related to saving energy sources and/or other natural resources [18].

In order to ensure the well-being of the population, it is necessary that companies strive to provide and maintain healthy working conditions such as safety, training and leisure for their employees and their families, as well as limiting or eliminating the levels of production and/or emission of toxic waste arising from its production process and the use or consumption of its products, ensuring the neutralization or maximum reduction of environmental damage in general and ensuring the preparation and delivery of products or services in accordance with the quality and safety conditions desired by consumers [18].

II. 4 REVERSE LOGISTICS

Reverse logistics enables saving some resources in the company's production process, since waste generated will be reused, reducing the consumption of raw materials and other resources [1].

The National Policy on Solid Waste classifies reverse logistics as an instrument of economic and social development characterized by a set of actions, procedures and means designed to enable the collection and return of solid waste to the business sector for reuse in its own or in other production cycles, or other environmentally appropriate final destination [1].

From a perspective of business logistics, considers that "the term refers to the role of logistics in product return, reduction in the source, recycling, material replacement, material reuse, waste disposal, refurbishment, repair and remanufacturing" [19].

Reverse logistics is a reality in many industrial processes nowadays; the need for further study on the subject continuously increases, following a gradual increase of the need to reintroduce waste into the production chain in order to save natural resources [20].

According to the National Policy on Solid Waste [1], reverse logistics has many advantages, such as preventing waste from polluting or contaminating the environment. It also allows savings in production processes and the use of cleaner technologies, among others. [1].

According to [20], there are examples that show that this practice has been used for years. However, due to some factors it has been noticed that, in recent years, there has been a considerable increase in this type of thought and activities related to recycling and reuse. These factors include environmental concerns, competition and cost cutting.

The environmental factor is important because there is a tendency for environmental legislation to make the company increasingly more obligated to take responsibility for the entire life cycle of its products. This means it has a responsibility after delivery to its customers as well, and also for the possible impacts that may be generated in this process [20].

Other factors are cost reduction and the company's image to customers, aiming to show that the company is active in social and environmental issues, since it would be making use of clean technologies, reducing waste, recycling and reusing products that would certainly be otherwise discarded [21].

This can lead to differentiation in relation to competitors, since retailers see an advantage because they believe that there is an appreciation of companies that have a more liberal return policy [20], as highlighted by [22], [3] and [3]. Interviewed a number of companies and demonstrated that low investment in reverse logistics generates substantial savings. He quotes a Sears executive who said, "Reverse Logistics is the ultimate frontier in cost savings" [23].

According to [3] reverse logistics is the process of planning, implementation and control of the flow of post-consumer and after-sales products and their flow of information from the point of consumption to the point of origin, in order to recover value or perform proper disposal. This concept contributes to the consolidation of the concept of sustainability in the business sphere, supported by the concepts of environmental and economic development.

From [3] propose that a proper design of reverse logistics systems (when there is post-consumer product flow back to manufacturers and suppliers) can be used not only to comply with legislations regarding product recall and sustainability, but also as a source of competitive advantage. For example, remanufactured products represent a significant addition to some companies' product lines, enabling them to serve otherwise unattainable consumer segments. Everyone benefits from this: companies, consumers and the environment.

For a reverse logistics strategy to work, action must be started at the end of the chain, that is, with the end consumer. The whole process follows a flow with basic steps, which can be represented in a cycle diagram, in which the lifespan of the given product ends and it becomes waste. Waste is collected and separated according to its classification in the recycling process so that it can be used as raw material in the production of a new product, which in turn will be destined for trade through distribution and sales lines [24] (Figure 1).

Figure 1: Simplified reverse logistics flowchart.
Source: Adapted from [24].

The biggest problem faced is the lack of systems capable of integrating Reverse Logistics with the common logistics flow, which causes these services to be outsourced or performed by their own systems [22].

Waste sorting is a major partner of reverse logistics, as waste is separated by class and recycling or reuse potential. The separation of waste and waste sorting prevents solid waste from being sent to a landfill, reducing transportation costs and extending the landfill's lifespan. Waste sorting also contributes to the creation of jobs in society through waste pickers' associations. These associations, in addition to generating jobs, offer an option to many people that otherwise only have marginalization as a choice. They discover in recycling a new life, and a new purpose for waste [25].

II. 5 RECYCLABLE RAW MATERIAL (RRM)

Recycled Raw Material is part of the fundamental concept of reverse logistics, which is the return of waste generated during the production process to the beginning of the production chain, preferably in the same process in which it was generated [1].

In the production process of pig iron in a company, the blast furnace's metallic load is composed of sinter (produced in sintering), iron ore and recyclable raw material (RRM). For the steel industry, the use of sinter is of great importance, as it can be used in place of iron ore, and because it is produced on the plant itself, it is cheaper [27].

RRM is composed of all usable waste material generated throughout the steelmaking process, such as sinter fines, which are

generated throughout the sinter-making process. They can also originate from the fall of materials during transportation on conveyor belts, from cleaning residues on equipment and residues of raw materials used in the manufacture of sinter. Dust from dedusting systems (which is collected by the system itself and deposited in collection boxes where it will be transported). Grinder swarf (generated during the thinning of the billet in the rolling process). Blast furnace cyclone powder (generated during blast furnace gas washing in the gas scrubber). Ore fines (originated from falls during transport on conveyor belts, cleaning residues on equipment) [28].

III. METHOLOLOGY

Regarding the objectives, this research was characterized as exploratory and explanatory. In exploratory research, critical points are verified, initial contacts for field entry are established and the necessary data sources for the study are located [29]. In regard to explanatory research, fact records are generated, analyzed and interpreted, their causes being then identified [30]. The research was also characterized as quali-quantitative [30].

As for the technical procedures, research was conducted through both bibliographic and field studies. The literature research consisted of data collection in databases pre-defined before the study [31]. The data were researched in scientific articles, doctoral dissertations, master's theses and journals through the Google Scholar and SciELO platforms, with the keywords: waste generation, steel industry, waste reuse in the steel industry, sustainability in the steel industry, advantages of reverse logistics, impacts caused by landfills, among others, totaling about 50 researched works. Some data were obtained from employees of the company under scrutiny, since literature on the subject is scarce.

The survey on the generation of waste and its recovery rates was obtained through research of the main Brazilian steelmakers [32]. The research on the process of pig iron formation was carried out by consulting the works of Silva [27] and UFSC [33].

Field research was also conducted in order to comprehend the process of formation of Recyclable Raw Material (RRM), as well as the benefits and limitations of its reuse [34]. To this purpose, five visits were made to the company that provides services to the steel company in study. Data were collected from the month of January 2018 to October 2018. The service provider company is responsible for collecting waste from the steel company, for its recycling, for forming the RRM and returning the RRM to the steel company from Minas Gerais.

IV. RESULTS AND DISCUSSION

Pig iron, the main raw material for steelmaking, is a 95% ferrous liquid obtained through the purification of iron ore by heating. This process is carried out in the metallurgical reactor, which is called the blast furnace [35].

However, thin materials cannot be used in this process, as they are carried by the rising gases. To prevent this, the ore undergoes an agglomeration process. The iron ore agglomeration processes most commonly used as blast furnace fillers in the steel industry are pelletizing and sintering.

Pelletizing produces the agglomerate called pellet and the process is carried out in the mining companies themselves. The agglomeration process involves physicochemical steps in order to aggregate the portion of ore fines (size inferior to 0,15 mm) into spheres with the appropriate particle size and quality. In order to produce sinter, a process of agglomeration of the basic raw materials is required, which is called sintering: that is, the heating of the basic raw materials below the melting point, from the burning of solid fuel (coke) agglomerated to iron ore and fluxes, the outcome being the sinter produced by the steel mills themselves [36].

In the pig iron production process, the blast furnace's metallic load is formed from sinter (produced in sintering), iron ore and recyclable raw material (RRM). Percentages were not disclosed by the company which is the subject of this research, due to internal information security policies. The use of sinter is of great importance because it can be used in place of iron ore, and because it is produced on the plant itself it is less expensive [27].

For the production of pig iron (Figure 2) it is necessary to transport the metallic load through conveyor belts that feed the blast furnace. In addition, fluxes and atmospheric air are inserted, and the iron ore, which composes the metallic load, is reduced by carbon until pig iron is obtained. This whole process occurs at an approximate temperature of 1000ºC [33].

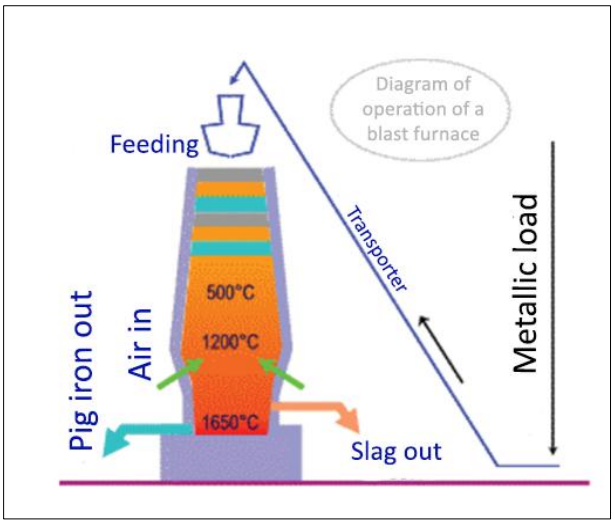

Figure 2: Pig iron production flow chart.
Source: Adapted from [33].

Steel industries are major producers of solid waste. In 2006, the main Brazilian steel mills produced about 13 million tons of waste, as shown in Table 1. Generation varies considerably across companies, depending on factors such as technological process, raw material, energy source, etc. [32].

Table 1: Generation and recovery of solid waste from the main steel companies in Brazil (2006).

Companies	Waste generation(1)	Recovery rate(2)
IBS(3)	0,42	98%
ArcelorMittal (long steel)	N/A	92%
ArcelorMittal (flat steel)	N/A	58%
CSN	0,66	99%
Gerdau	N/A	77%
Usiminas (Cubatão)	0,77	97%
Usiminas (Ipatinga)	0,73	94%
V&M	0,31	N/A
Vilares	N/A	N/A

Source: Adapted from [32].

Overall, solid waste recovery rates in most companies were above 90% (Table 1). These numbers are only reached through widespread acceptance of steel aggregates by other industrial sectors. Among these residues a variety of metals can be

reused, such as aluminum, antimony, cadmium, chromium, tin, manganese, molybdenum, selenium, thallium and vanadium, representing 78% of the waste generated [27].

The ease of commercializing waste (and even its resulting revenue) apparently diminished preventive actions, since the generation rate between 2004 and 2006 increased by 22% from 0,268 tonnes/tonne of crude steel to 0,327 tonnes/tonne of crude steel [32].

In 2013, Brazilian steelmakers produced 17.7 million tonnes of waste, of which three million were scrap with potential for reuse by the sector itself. Waste production per ton of steel reached 0,594t [37].

In Minas Gerais, from 2009 to 2018, the average amount of solid waste declared by the steel industry in the Inventário de Resíduos Sólidos (Solid Waste Inventory) was 13.154.468,00 tonnes [46], being one of the sectors that generate the largest amount of solid waste in the state of Minas Gerais.

The most important types of waste from steelmaking are blast furnace slag (mainly marketed to cement companies) and steel slag (used in road building). The other residues in the steel sector are dusts, sludge, fines and scale [32].

A steel company from the state of Minas Gerais found the possibility of inserting the waste generated into its own production processes through the creation of Recyclable Raw Material (RRM), which is composed of usable waste generated throughout the steel production process, such as sinter fines, dust from dedusting systems, grinder swarf, high cyclone dust and ore fines [28]. Inserting generated waste into the production process itself is a great option to send it to a correct final destination, to reduce the use of raw materials and, consequently, to reduce costs. In order to be introduced, waste sometimes needs beneficiation, which may be of a simpler nature, such as a process of sifting, or more complex, involving physicochemical steps. The simpler the beneficiation process is, the better, since it involves less skilled labor and less technology.

The waste generated throughout the company's production process is collected daily by the service provider. All of it is transported in trucks from the provider itself and taken to the beneficiation plant (Figure 3). Upon arrival at the plant, they are separated according to their specifications. Subsequently, they are placed in labelled stalls (Figure 4) [28].

Figure 3: Partial view of the beneficiation plant (silos, conveyor belt, and homogenized material).
Source: [28].

Figure 4: A truck unloading sintering fines onto a stall.
Source: [28].

From the stalls the materials are directed by a wheel loader (Figure 5) to sieves in order to remove coarse solids that may damage equipment or contaminate the RRM. Subsequently, they are packed in identified silos (Figure 6). The silos are regulated to adjust the dosage of materials according to the specifications of the company under study. From the silo, they are sent to conveyor belts that homogenize the materials forming the RRM (Figure 7), which is transported (through bucket trucks) to the raw material yard, located in the sintering area. Deliveries are made at the request of the company itself [28].

Figure 5: Silo sieves.
Source: [28].

Figure 6: Dosing silos.
Source: [28].

Figure 7: Homogenized material.
Source: [28].

RRM has a production revenue of 50 tonnes (Table 2), following industry standards, in order to prevent contamination of the pig iron.

Table 2: RRM revenue.

Raw materials	Weight (tonnes)	Silo identification number
Sintering fines	20	4
Dust from dedusting systems	1	4
Grinder swarf	4	1
Blast furnace cyclone dust	20	2
Iron ore fines	5	3
Total	50	

Source: Adapted from [28].

The data presented in Table 3 show the average price per tonne of iron ore in 2018, considering the months of January and June (weekly average and monthly average). Taking into account the average price per tonne of iron ore in June 2018 (the time the survey was conducted) and the price of the dollar quoted at the same time, which was R$ 3,8552 [45], the price, in Brazilian Reais, of the ton of iron ore corresponded to R$ 293,11.

Table 3: Average price of iron ore in 2018.

Market rate	30 January 2018	Weekly average (last 5 days)/June	Monthly average/June
	US$/dmt	US$/dmt	US$/dmt
Metal Bulletin	72,997	74,25	76,03

Source: Adapted from [38].

Figure 8 shows a large variation in the price of iron ore between July 2010 and January 2018. This commodity peaked at US$190 at the beginning of 2011 and descended to less than US$40 at the end of the fourth quarter of 2015. There was, therefore, a downward trend in the price of iron ore during the analyzed series, which started the period at US$130 and closed near US$70.

Iron ore suffers from year-round price fluctuations due to various factors such as fluctuations in the dollar quotation, the available amount in suppliers' stocks and buyers' stocks, ore purity and trade restriction or facilitation between certain countries or economic blocks, to the detriment of political positions. As with every commodity, the supply-demand law influences price so that an increase in consumption, without available supply, can cause a price increase. Large importers, especially in times of virtuous cycles in their economies, tend to increase their import rates to meet the necessary investments, which can cause significant price variation.

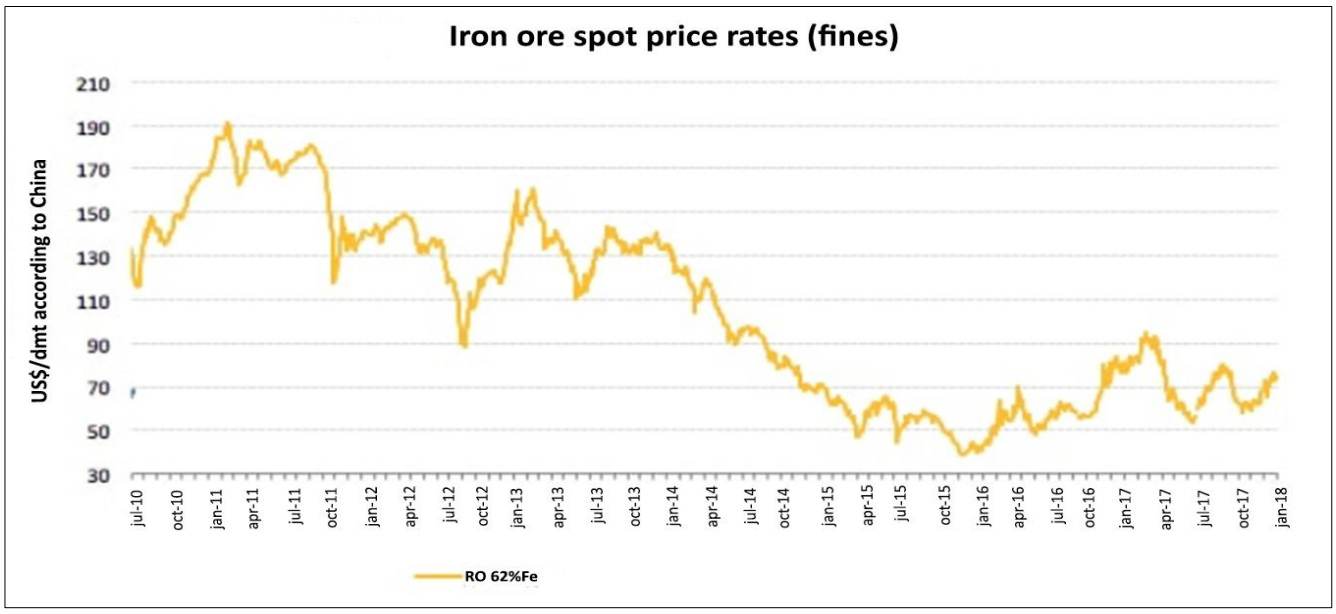

Figure 8: Variation in iron ore prices between 2010 and 2018. RO 62%Fe – Raw Ore, 62% iron.
Source: Adapted from [38].

The service provider delivers around 100 tonnes/day of RRM to the company under study, totaling 3,000 tonnes per month. The tonne of RRM cost, in 2018, R$ 38,90 [28] and the tonne of iron ore cost R$ 293,11. In light of this data it was possible to identify an economy for the company of 86,80%, comparing the costs with the acquisition of iron ore (3,000 tons) and the RRM (3,000 tons) (Table 4). These data show the great importance of using RRM, since, in addition to economic gains, the use and need for iron ore extraction, as well as the disposal of waste in the environment, are reduced, considering that they are incorporated back into the industry's production chain.

Table 4: Comparison of prices between RRM and iron ore.

	Amount in tonnes/mounth	**Cost by tonne/in Brazilian Reais**	**Total costs in Brazilian Reais/month**
Raw material			
RRM	3.000,00	38,90	116.700,00
Iron ore	3.000,00	294,77	884.310,00
	Savings		767.610,00

Source: Adapted from [38].

It is important to consider that iron ore extraction causes negative impacts on the environment. Exploited areas lose their resilience, that is, their ability to regenerate without human interference [39], since it causes loss of soil fertility and loss of seed bank. Thus, it takes a great amount of time and resources to recover these areas.

In the work of [40], an important consideration is made about the recovery of mined areas, which collaborate with the use of RRM. The author emphasizes the impossibility of returning the mined area to a situation similar to the original one (restoration in the broad sense). For these areas, rehabilitation is recommended; that is, it may have other purposes other than precisely the formation of a forest [39].

With the use of RRM 3,000 tonnes of waste are removed monthly from the environment. [40] demonstrate in their work the difficulty of finding suitable areas for construction of landfills, the distance traveled until waste reaches the landfill increasing over the years. This problem is mainly experienced in metropolitan regions due to the existence of environmentally protected areas and the impacts caused to the surroundings [41]. In addition, through the use of RRM it is possible to avoid impacts such as changes in Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), pollution of water resources, production of pollutant gases and particulate materials and degradation of large extensions of soil due to contamination with substances such as heavy metals and toxic organic materials. In what concerns social issues, the poor conditions of waste pickers are minimized and disease vectors are reduced [42].

In general, the impacts mentioned were listed on the checklist proposed by [42] (Table 5).

Table 5: Classification of impacts listed on the check-list.

Columns1	**Columns2**	**Columns3**	**Columns4**	**Columns5**
Class	Kind (P: Positive and N: Negative)	Magnitude (S: Strong, M: Medium and W: Weak)	Scope (L: Local and R: Regional)	Frequency (T: Temporary and I: Intermittent)
Impacts				
Alteration of surface water resources	N	S	R	C
Alteration of underground water resources	N	S	R	C
Alteration of soil quality	N	S	L	C
Alteration of air quality	N	M	R	C
Impacts on human health	N	S	R	C

Source: Adapted from [42].

In addition to the factors described, [43] considers that the use of RRM reduces noise pollution caused by ore mining, as well as land use conflicts, depreciation of surrounding properties and urban traffic disturbances.

In order to combine mining with sustainable development, one of the steps is the implementation of operations of recycling and reuse of the minerals themselves, as well as of inputs [44].

Thus, RRM generates savings for the industry, while simultaneously collaborating with the preservation of the environment, avoiding impacts and externalities, contributing to the sustainable development of the sector.

However, its use is limited, as its processing does not guarantee that, when used in high proportions, there will be no alteration in the final quality of pig iron and the integrity of equipment such as the blast furnace [5]. Also highlighted as limitation is the loss of quality in the case of special steels and risk of steel contamination.

There is a lack of studies on waste reuse in the steel production chain. From a total of 92 studies, carried out between 1962 and 2015, on the reuse of waste generated in the Brazilian steel industry, dusts were the only class that presented incorporation of waste in the steel production cycle itself, with only 1 work focused on this purpose [27].

V. CONCLUSION

The development of this study allowed an analysis of the use of RRM (Recyclable Raw Material) in the production of sinter in a steel company from the state of Minas Gerais, in order to reduce iron ore consumption in this process. Through analysis of RRM and iron ore costs, it was possible to understand the importance of sinter for the steelmaking process, since its use is much more economically advantageous than using purely iron ore. The use of RRM significantly reduces the iron ore load on the sinter, increasing the profit margin and meeting the basic principle of reverse logistics, which aims to return all the waste generated (or as much as possible) to the company's production process or to insert it into another process. Positive strengths related to the use of RRM include reduced mineral extraction and noise pollution, reduced water, soil and air pollution, as well as the generation of secondary problems such as land use conflicts, depreciation of properties surrounding mining areas and disturbances to urban traffic. Significant savings in sinter production were identified through the insertion of RRM. It is, however, necessary to regulate this insertion, because the process still has limitations due to the risk of contamination of the pig iron and the risk of increasing the wear rate in the equipment involved in the process. The process of formation of RRM is often not adequately discussed due to companies' protection of information and market secrets, and thus it is of importance that this topic is explored in the academic sphere, as few works have been found. Partnerships between companies and universities should be encouraged in order to create cleaner technologies that reduce the impact of this activity on the environment, as well as to share the positive experiences of the steel industry, so that other industries can make use of reverse logistics.

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RESEARCH ARTICLE OPEN ACCESS

WATER AND OIL AUTOMATIC SEPARATION SYSTEM USING FUZZY CONTROL

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ABSTRACT

This paper presents the design of a water and oil separation system as a contribution to reduce the problem of contamination of water in domestic and industrial sewage. The project consists of improvements in level detection in an automatic separation tower and in the use of the Fuzzy control. The main objective is to design a controller based on the values of the levels and increase the reliability in the process of separation of the fluids. The validation of the controller is obtained through simulation in MATLAB engineering software and the improvements applied are corroborated according to the results observed in the separation process. Satisfactory results show increased reliability in the fluid separation process, leaving the minimum fluid within the reservoir.

Keywords: Fluid separation, Water, Oil, Fuzzy control.

I. INTRODUCTION

Mechatronics is currently being applied in various sectors of society, in homes, in commerce, and is mainly in the industrial sector [1]. For technology to meet the needs of your applications more accurately, a more robust control design is required. Artificial intelligence techniques are widely used in process control, including the fuzzy controller, to assist the system with more accurate results, in addition to stability and robustness [2].

Initially presented by Lotfi Zadeh [3], fuzzy logic verifies information that is difficult to interpret at the system entrance and allows a closer and more adequate output to the desired one. Among the various applications of fuzzy control, drinking water treatment plants (DWTPs) [4], thermal comfort [5] and the diagnosis of prostate cancer [6], among others, can be cited. The separation system presented in this work is a prototype, and as a final product can be applied in various environments, such as airports, vehicle wash and maintenance facilities, railways, parking lots and areas of heavy circulation of vehicles, military installations and in oil deposits and the like.

This work aims to propose improvements in the water and oil separation tower based on the idea of the bromine funnel [7], which are the sensing of all fluids in the tank, since the oil valve is always activated after a certain time without the need for such a flow, or even if the time is not sufficient for a complete flow. It is also proposed to apply the fuzzy rules-based controller that uses level values as input parameters for valve treatment. Once the proposed improvements have been made, the fluid level monitoring algorithm performs fuzzy calculations and treats valves, and should terminate the process with minimal fluid in the tank.

This paper introduces a literature review in the second section. Next, a model is proposed in the third section. In the fourth and fifth sections are presented the operation of the system and the implemented fuzzy system, respectively. Finally, the results and conclusions are presented respectively in the sixth and seventh sections.

II LITERATURE REVIEW

II.1 FLUID SEPARATION

Separating water from oil is a very important task as it allows the oil to be given a correct destination. If one liter of oil is incorrectly discharged into soil or sewage, up to 20,000 liters of water can be contaminated. One of the biggest problems caused by the discharge of oil into rivers is the formation of a film that forms

on the surface of rivers, preventing the transfer of oxygen to water [8].

The water-oil separation system proposed in this article utilizes the oil's property of not dissolving in water. Property that is due to the fact that water is polar and oil is nonpolar and the bond between water molecules is very strong (hydrogen bond) not allowing oil molecules to separate and interact with water molecules [9]. Then the oil being together with the water in a container forms a heterogeneous mixture, where there are two phases and the water having higher density is in the lower part of the container.

It is observed that being more judicious there is a small solubility of oil in water. So the water coming out of this separator is not completely oil free, and an analysis is needed to know what concentration of oil will still be in the water, this value should be in accordance with the norm. According to [10] this allowable value can range from 40mg L-1 to 100mg L-1 according to local law. If this amount of oil is above the recommended by the norm, a further treatment should be performed to return the water to the environment.

In [7] the project of a system that contributes to the solution of the growth of the pollution of the water is approached. Where an automatic separation system of water and oil mixed in the same reservoir was developed. It was built based on the idea of the bromine funnel also known as the settling flask that observes the concepts of fluid density.

II.2 INTRODUCTION TO FUZZY LOGIC

In [3] a new set theory was proposed in which there are no discontinuities, ie there is no definition of elements belonging and not belonging to a set, but there is a degree of pertinence that indicates how much the element is part of the set. Unlike digital logic combinations, their values can be between 0 and 1, instead of just contemplating the extremes [10]. Fuzzy logic is part of the concept of intelligent systems, which makes systems more autonomous for solving various problems. A fuzzy based system must have the following basic items:

- Fuzzifier;
- Rule base for inference;
- Defuzzifier.

Fuzzy logic is applied in projects such as thermal comfort that has sensors to measure temperature, humidity, solar radiation and others, the sensing values cannot be fixed, because the sensitivity differs for each individual [5]. In the medical field, a fuzzy-based system for laboratory data analysis can help a medical expert determine appropriate treatment for a patient who has been diagnosed with a certain degree of cancer risk [6].

III. METHODOLOGY

The sketch presented in Figure 1 illustrates the proposed system for study in this work.

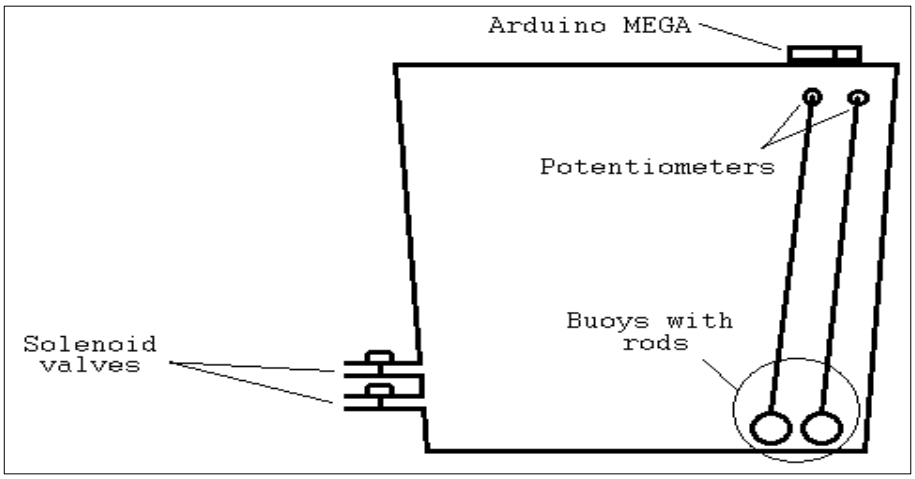

Figure 1: Sketch of the proposed system.
Source: Authors, (2019).

As shown in Figure 1, the tank shall consist of two sensors for level measurement in centimeters, two solenoid flow valves, a micro controller for system automation and a cable for serial communication with the computer and sending information to the tool. MATLAB.

The level sensor is formed by a float attached to one end of a rod that has a potentiometer on the other end. Observing the density of each element, the buoys are filled with oil and air so that they are positioned in the region between the two fluids and on the oil, respectively. They are responsible for rotating the axis of each potentiometer as the levels vary.

The float that is positioned between the two fluids measures the water Height and the float that is on the oil measures the oil Height. The *waterLevel* and *oilLevel* are obtained as follows:

$$waterLevel = waterHeight \quad (1)$$

$$oilLevel = oilHeight - waterHeight \quad (2)$$

In this project, the maximum level is indicated by the height of 50 cm. The tank shall have sides greater than 50 cm wide to facilitate the movement of the buoys in measuring this level.

Solenoid valves 127 V (3/4 x Mang. 1/2) are relay-switched, have diameters of 19.05 mm and positioning between inlet and outlet 180 ° [11]. The water valve covers approximately the height of 2.095 to 4 cm and the oil valve covers the height of 6 to 7.905 cm. They are spaced at 2 cm giving a safety margin as shown in Figure 2.

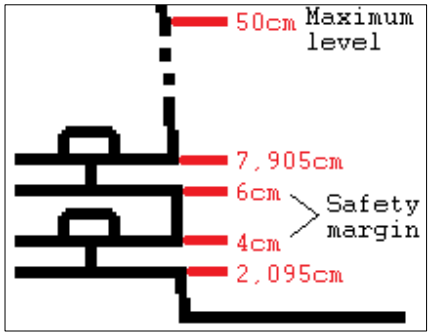

Figure 2: Valve Height.
Source: Authors, (2019).

Arduino Mega is an Atmega1280-based microcontroller board, widely used in academia and open source. It has 54 digital input / output pins (14 of which can be used as PWM outputs) and 16 analog inputs. The Arduino version operates at 5 V voltage and 16 MHz speed [12]. In this system, it processes the level values, sends information via serial communication to the simulated controller and treats the valves according to fuzzy rules. Arduino's connection to MATLAB is based on Serial Communication (UART) via USB with a baud rate of 9600 bits per second.

IV. SYSTEM OPERATION

When starting the system, a time is expected before the separation process, ensuring that the poured heterogeneous mixture stabilizes, leaving the oil above water inside the tank. This time is also required for the sensors to position themselves properly.

The dynamic aspects of the system are represented in the activity diagram of the Unified Modeling Language - UML visual modeling. The interaction of elements of interest and the messages that are exchanged between them is described. Figure 3. The sensors provide the measurement values for the system, the Fuzzy controller analyzes the signals to decide the next task, and the solenoid valves are handled discretely by the system for fluid flow.

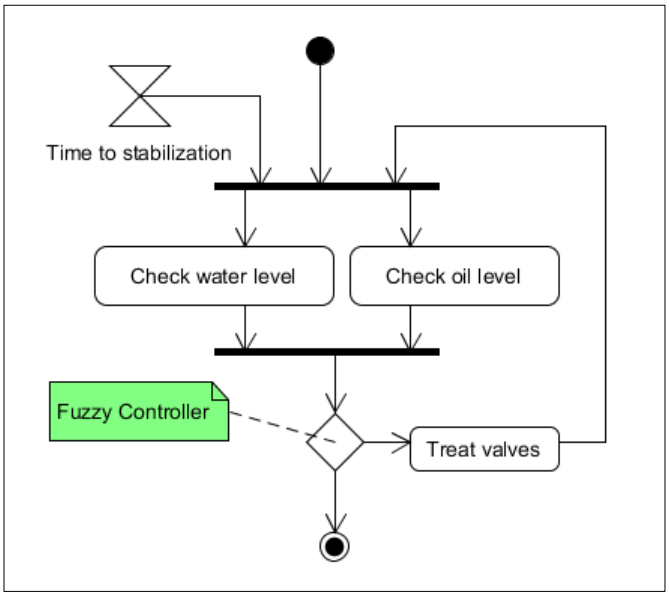

Figure 3: Activity diagram.
Source: Authors, (2019).

The activity diagram facilitates the understanding of the system functioning, presenting the interactions between the elements that must be focused during the algorithm development, which will be embedded in the selected microcontroller.

V. FUZZY SYSTEMS

In this project, the input parameters used are the values of *waterVariation* and *oilVariation*, and used as output the parameter called valves. Variations are differences between fluid levels with respect to heights of 5 and 6 cm, midpoint of safety margin between valves and minimum oil valve height, respectively. They are calculated as follows:

$$waterVariation = waterLevel - 5 \quad (3)$$

$$oilVariation = oilLevel - waterLevel \quad (4)$$

For fuzzification of these variables is used pertinênica functions negative (negative) zero (zero), positive (positive), all closed (CloseAll), open oil (openOil) and open water (Openwater). After assembling the FIS framework in MATLAB's Fuzzy Logical Toolbox [13], system settings and rules can be evaluated using basic commands through Command Window, as well as fuzzy inference calculations can be performed. Below is the readfis command for assigning the system structure to the fis variable.

```
>> fis = readfis ('FluidSeparation')
fis =
            name: 'FluidSeparation'
            type: 'mamdani'
       andMethod: 'min'
        orMethod: 'max'
    defuzzMethod: 'centroid'
       impMethod: 'min'
       aggMethod: 'max'
           input: [1x2 struct]
          output: [1x1 struct]
            rule: [1x9 struct]
```

The designed controller works under the following conditions: In order of priority, because it is in the lower position in the tank, the water must first be treated. For positive water variation values, only the water valve should be opened. For negative or zero values, it must remain closed. Then the oil will be treated. For positive oil change values, only the oil valve should be opened. For negative or zero values, all valves must be closed.

With the data obtained through sensing, 9 fuzzy rules were determined for the fluid separation process. The rules are displayed below.

```
>> showrule(fis)
ans =

1. If (waterVariation is positive) and (oilVariation is
positive) then (valves is openWater) (1)

2. If (waterVariation is positive) and (oilVariation is
zero) then (valves is openWater) (1)

3. If (waterVariation is positive) and (oilVariation is
negative) then (valves is openWater) (1)

4. If (waterVariation is zero) and (oilVariation is
positive) then (valves is openOil) (1)

5. If (waterVariation is zero) and (oilVariation is zero)
then (valves is closeAll) (1)

6. If (waterVariation is zero) and (oilVariation is
negative) then (valves is closeAll) (1)

7. If (waterVariation is negative) and (oilVariation is
positive) then (valves is openOil) (1)
```

```
8. If (waterVariation is negative) and (oilVariation is
zero) then (valves is closeAll) (1)

9. If (waterVariation is negative) and (oilVariation is
negative) then (valves is closeAll) (1)
```

The membership functions associated with the parameters used are illustrated in Figures 4, 5 and 6.

```
>> plotmf(fis,'input',1)
```

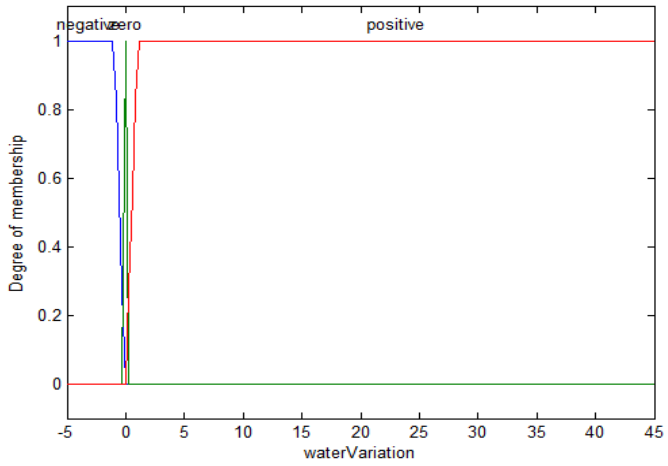

Figure 4: Functions associated with water variation.
Source: Authors, (2019).

```
>> figure
>> plotmf(fis,'input',2)
```

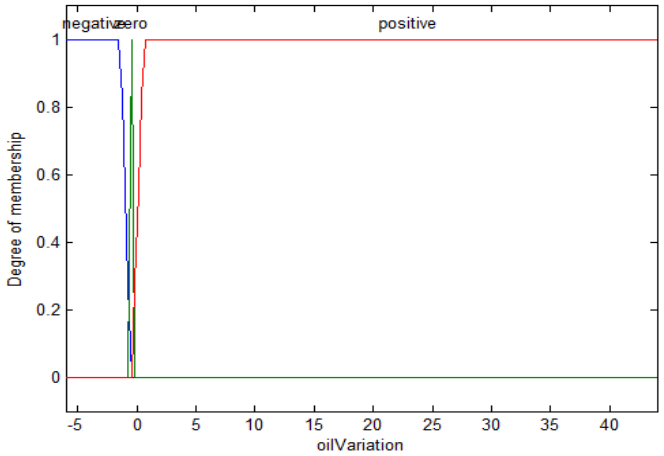

Figure 5: Oil Variation Functions.
Source: Authors, (2019).

```
>> figure
>> plotmf(fis,'output',1)
```

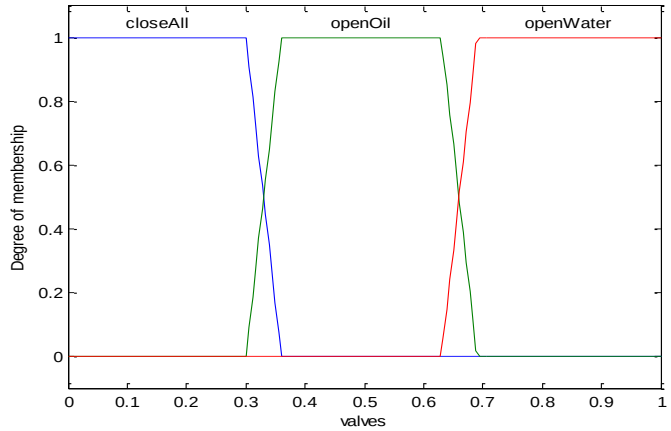

Figure 6: Valve Functions.
Source: Authors, (2019).

For the valves variable the language expressions are closeAll, openOil and openWater trapezoidal and expressed in the ranges of [0 0 0.3 0.36], [0.3 0.36 0.63 0.69] and [0.63 0.69 1 1], respectively.

As stated earlier, diffuse inference calculations can also be performed by commands, so by serial communication the Arduino transfers to the MATLAB the values of the level variations contained in the tank, and in return receives the calculated output value. MATLAB as shown below.

```
>> fis = readfis ( 'FluidSeparation' );
>> out = evalfis ([20 19], fis)
out =
    0.8321
```

Another way to analyze results is through the ruleview command, where inputs can be simulated while rules are displayed. This last form was chosen for analysis and simulation of the inputs. Its syntax is described below:

```
ruleview('FluidSeparation');
```

This way you can illustrate the fuzzy controller outputs that will be presented in the following session.

VI. RESULTS AND DISCUSSIONS

Fuzzy controller responses using the defined rules can be seen in three examples illustrated in figures 7, 8 and 9.

Example 1: When the value of water variation is 20 and oil is 19, both of which are sufficient for flow, then the calculated value for the output variable valves is 0.832, with only the water valve open.

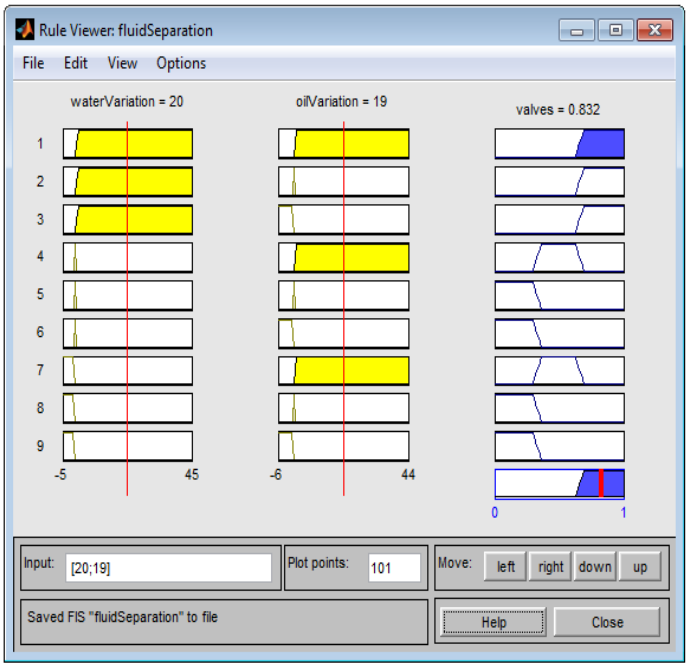

Figure 7: Answer from Example 1.
Source: Authors, (2019).

Example 2: When the water change value is -2 and the oil value is 10, with only enough oil to flow, then the calculated value for the output variable valves is 0.495, with only the valve of the open oil.

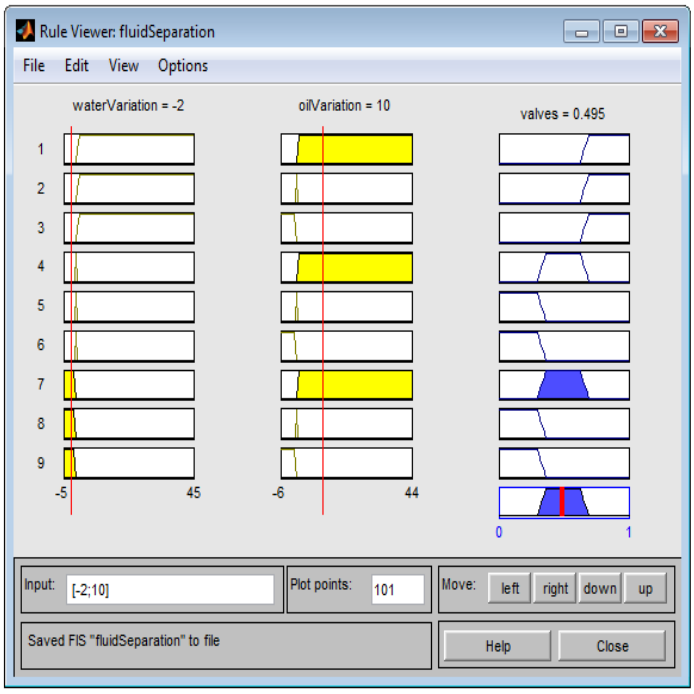

Figure 8: Answer from Example 2.
Source: Authors, (2019).

Example 3: When simultaneously the values of the variations are null, both of which are insufficient to flow, then the calculated value for the output variable valves is 0.163, with all valves closed.

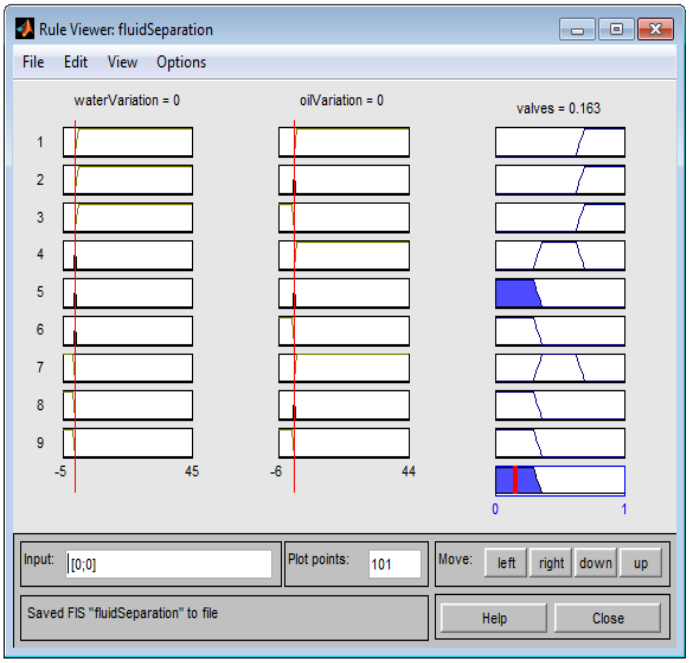

Figure 9: Answer from Example 3.
Source: Authors, (2019).

Given water and oil variation values, the result is the inference of a value in the range [0, 1] representing one of the three subsets of valves and supporting decision-making. This makes it possible to defuzzify and interpret the conditions for valve actuation. The results show that the simulated controller selects output values suitable for the treatment of fluid flow valves.

The simulation in MATLAB engineering software shows that fuzzy controller designed based on the values of all levels results in increased reliability in the fluid separation process, leaving minimal fluid inside the reservoir.

VII CONCLUSION

The improved system proposed in this work was developed with the main objective of contributing to improvements in the separation tower for water treatment in domestic and industrial environments. This paper describes the design using theoretical concepts of fuzzy logic, which is used to make system control smarter. The use of Fuzzy logic can contribute greatly to engineering projects, when control systems are complex to model. Besides having low cost and easy handling, the system proved to be more efficient in fluid separation due to the application of more level sensors, which returns greater reliability in the fluid separation process. Oil level sensing that replaces proper valve actuation time also generates energy savings compared to the previous system when it was also unnecessarily actuated. As future work, it is suggested that the prototype be assembled using a fuzzy library in the Arduino algorithm, eliminating the cable for serial communication with the computer.

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RESEARCH ARTICLE OPEN ACCESS

WASTEWATER REUSE IN THE CLEAN IN PLACE PROCESS OF A BEVERAGE INDUSTRY

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ABSTRACT

Clean in Place is a hygiene process widely used in the food industry, as it establishes operational safety, reduces costs of water consumption, chemicals and energy, as well as it ensures safety and quality in the final product for the consumer. The Clean in Place process follows a standard operation, however the application of the system and procedures are individually designed for each process, according to its needs. In general, Clean in Place consists of water and chemical tanks, feed and return pumps, heat exchangers, conductivity sensors and temperature gauges. The present work addresses an industrial scale study using data from a food industry located in southern Brazil. The objective of this work consisted of the minimization of water consumption and effluent disposal by reusing water in process stages. In addition, it was intended to reduce detergent consumption and total process time through adjustments in detergent concentration, and time reduction in some system steps. The proposed wastewater reuse reduced the consumption of water and effluents discharged by 32.75%, detergent consumption by 37.5% and process time by 34%.

Keywords: Clean in Place, Water Reuse, Wastewater, Food Industry, Beverage Industry, Industrial Scale Study.

I. INTRODUCTION

Freshwater is an essential element for the maintenance of life, as well as for human well-being and sustainable development. This is one of the main current reasons for regional and global crises in the world. For many years water was considered an inexhaustible natural resource, however, recent studies show that water is, in fact, a finite resource and its preservation is necessary [1]. Water global demand is expected to increase by about 55% by 2050, due to increased consumption in industries, thermal power generation, and domestic use. In this way, water must become insufficient to meet the demand growth, which is directly related to the population increase and continuous consumption growth related to the world production structure [2].

Faced with this scenario of water resources scarcity, among the alternatives to reduce water consumption are the rationalization of use and the reuse of this limited resource [3]. Water reuse must be implemented with appropriate precautions and technologies, aiming at the adequacy of quality according to its application [4]. In addition, water recovery is performed in order to reduce impacts to the receiving water body, since a smaller volume of effluents is discharged, besides reducing the withdrawal of water from non-renewable sources [5]. The recovery of treated effluents is an economically viable and sustainable alternative for the preservation of water resources. Through proper management, it is possible to achieve savings of up to 30% of total water consumption [6].

One of the fundamental causes of the current water crisis is the increasing scale and intensity of industrial production activities [7]. Industries in general can use water as raw material, incorporated into the final product, as heating or cooling fluid, or even in internal and external cleaning processes of equipment [8]. In the case of the food, beverage or pharmaceutical industry, water must have a high level of purity if it is introduced into the final product. However, the quality requirements are lower if water is used for other purposes, such as heat exchange systems [9].

In the food industry, hygiene aims to eliminate contamination, reducing the chance of future problems in the final product caused by microorganisms or dirt in general. One of the most widely used methods for internal cleaning of equipment and piping is Clean in Place (CIP). This technique consists of a closed system, avoiding major stops of production and disassembly of

equipment [10]. Beverage, processed food, pharmaceutical and cosmetic industries are the ones most dependent on this process, as they require frequent internal cleaning to meet high levels of hygiene [11].

The performance of Clean in Place method is usually divided into four operations: pre-washing, cleaning with detergents or chemical agents, rinsing and disinfection. By using chemical reagents, the procedure's contact time is not necessarily related to cleaning efficiency. In CIP, the solutions become saturated with the material originated from the reactions, having a greater efficiency in the initial period of the application process of the products [12]. Additionally, excessive use of resources such as water and energy has negative economic and environmental impacts, resulting in loss of production time [13].

Due to increased environmental awareness, water consumption minimization studies have been conducted in different food industries [14]. As an alternative to reduce water consumption in a fish processing industry, the reuse of effluents generated in the industry was proposed, reducing effluent volume and minimizing water consumption [15]. A study in a dairy industry was developed to check the potential for reuse of cheese whey as water in the Clean in Place process operations, using a combined ultrafiltration and reverse osmosis system [16]. An improvement of CIP in a dairy industry was also developed applying mathematical methods for improvement, using the GAMS algebraic modeling software, as well as the treatment of residual water by means of a reverse osmosis membrane, reducing water consumption and wastewater generation [17].

Thus, the objective of this work is to conduct a study of water consumption in the CIP process of a beverage industry, aiming to reduce wastewater generation, water and detergent consumption, besides reducing the time of this operation. This is a study applied on an industrial scale in a large beverage company located in the south of Brazil. The present study is expected to bring relevant information so that it can be replicated in other food industries using the Clean in Place process.

II. MATERIALS AND METHODS

This work was carried out in a carbonated and non-carbonated beverage industry, located in the state of Rio Grande do Sul, Brazil. The studied company is present in 10 countries and globally sells 1.7 billion products per day. In Brazil, it is present in 48% of the national territory, has about 20 thousand employees, serving more than 88 million consumers in the country. The productive capacity of the evaluated unit is approximately 240 thousand liters of beverage per hour.

II.1 DESCRIPTION OF THE PRODUCTIVE PROCESS

The first stage of the present study was the analysis and description of the productive process. The description of the process was carried out by consulting the internal procedures of the evaluated company, as well as field technical visits carried out in the factory.

II.2 CONVENTIONAL CIP PROCESS

The study and data collection of the conventional CIP process in the company was carried out by consulting internal procedures with the detailed description of the CIP operation, as well as the field monitoring of the operational procedure, through technical visits. The company uses different CIP procedures; whose choice depends on which is the change of beverage to be produced. In this work, only the hot cleaning and sanitizing process was studied, since this is the most used procedure of the industry.

II.3 IMPROVEMENT OF CIP PROCESS

The improvement of the CIP process was carried out by studying the process flow diagram and proposing amendments with the objective of reducing the water consumption of this system. Technical documentation of the evaluated industry was used for this study, as well as meetings with operators and supervisors of the operational area.

II.4 MASS BALANCE IN THE CIP PROCESS

The mass balance was performed through the compilation of flow measurements recorded by the flow meters installed in the studied industry. Mass flows used by CIP operation prior to improvement were obtained from data collected in May 2018. For the optimized CIP, the results are the average of a typical CIP operation recorded in December 2018 (after the improvements implementation). These measurements were used to compose the total amount of water used in a CIP operation, as well as the total amount of water discharged as effluent or reused in the process (in tonnes). The mass balance was performed using equation 1.

$$\dot{m}_{accumulated} = \dot{m}_{in} - \dot{m}_{out} \quad (1)$$

Where:
$\dot{m}_{accumulated}$ – accumulation of water and detergent in the system (t);
$\dot{m}_{in}$ – mass of water and detergente entering the system (t);
$\dot{m}_{out}$ – mass of water and detergente leaving the system (t).

II.5 COSTS

The costs of the CIP process were obtained considering costs with water consumption, treatment of effluents, and consumption of detergent. Equation 2 was used to obtain the total cost of each operation of the CIP process.

$$C_{total} = m_{(H2O\ cons.)} \times C_{H2O} + m_{effluent} \times C_{effluent} + m_{detergent} \times C_{detergent} \quad (2)$$

Where:
C_{total} – total cost with water, effluent and detergent (US$);
$m_{H2Ocons.}$ – mass of water consumed (t);
C_{H2O} – cost of water treatment (US$);
$m_{effluent}$ – mass of effluent generated (t);
$C_{effluent}$ – cost of effluent treatment (US$);
$m_{detergent}$ – mass of detergent consumed (kg);
$C_{detergent}$ – cost with the purchase of detergent (US$).

The costs obtained through calculations of water consumption, effluent generation and detergent consumption were used to make an annual comparison between costs generated before and after CIP improvement. The total number of CIPs executed in 2018 was used in order to verify the cost reduction obtained by the company after the improvement of the process.

II.6 MICROBIOLOGICAL ANALYZES

In order to check whether the proposed improvements did not modify the quality of the equipment decontamination, three samples at the final rinse stage and two samples of the recovered

water tank were evaluated. Nasco Whirl-Pak bags were used for laboratory sampling. The samples of the final rinse stage were collected in the filling machine, which is the last equipment before water is transferred to the water recovery tank or discharged. Microbiological analyzes were performed in the Microbiology Laboratory of the evaluated industry, using the membrane filtration method. The results obtained were compared with the specifications established by the company for the microbiological parameters (Table 1).

Table 1: Microbiological specifications for CIP samples.

Sample	Test	Specifications (CFU/Volume)
Recovery Tank	Total Bacteria	<25/1 mL
	Yeasts and Molds	<10/100 mL
	Total Coliforms	0/100 mL
Final Rinse (Storage Tank and Filling Machine)	Total Bacteria	<25/1 mL
	Yeasts and Molds	<10/100 mL
	Total Coliforms	0/100 mL

Source: Authors, (2019).

III RESULTS AND DISCUSSION

III.1 DESCRIPTION OF THE PRODUCTIVE PROCESS

The production process of the evaluated industry can be divided according to the product to be manufactured in: “cola soda” process and “various soda” process. As the volume of cola soda produced is higher, compared to other beverages, this division occurs in order to facilitate the manufacture of the product. The water used throughout the company's beverage preparation process is treated internally at the Water Treatment Plant (WTP) in order to ensure a final product quality standard. This water goes through a conventional process of coagulation and flocculation, sand filters and activated carbon filters. In the final beverage production sector, water also passes through polishing filters and deaerating tanks.

All types of products, soft drinks (carbonated) or juices (non-carbonated), have their respective recipes. The industry receives so-called "parts" of concentrate, and this recipe is used to define the quantities needed to prepare each product.

For the production of cola beverage, cola concentrates (part 1 and part 2) are received from the company headquarters. These streams are stored in stirred tanks with temperature control and then they are mixed with a dissolved sugar stream in a multi-component dosing and mixing unit. The concentrate and dissolved sugar mixture are stored in a tank, cooled using a plate exchanger until reaching a temperature between 4 and 8°C, and sent to a carbonation tank. At this stage, the drink is ready and goes to the filling machine, where it is properly packed.

For the production of “various sodas”, the concentrate parts (liquids and solids) are first diluted and homogenized in BatchMix tanks, according to the recipe of each product, thus forming the syrup. The following steps are the same as the production of the cola soft drinks: the syrup is mixed with the water and the dissolved sugar, the beverage is stored and then refrigerated, carbonated and packaged in the production line.

III.2 CONVENTIONAL PROCESS OF CIP

The CIP presented in this work is the hot cleaning and sanitizing process, the most used in the studied company. This procedure is performed for the beginning of the production of soft drinks, as well as between product and flavor changes. It is responsible for cleaning and sanitizing from the finished beverage storage tank to the end of the packaging system, and contains three cycles: initial rinse, hot detergent and final rinse. Figure 1 shows the CIP process performed in the final stages of preparation of the beverages, as well as their connection with the production process.

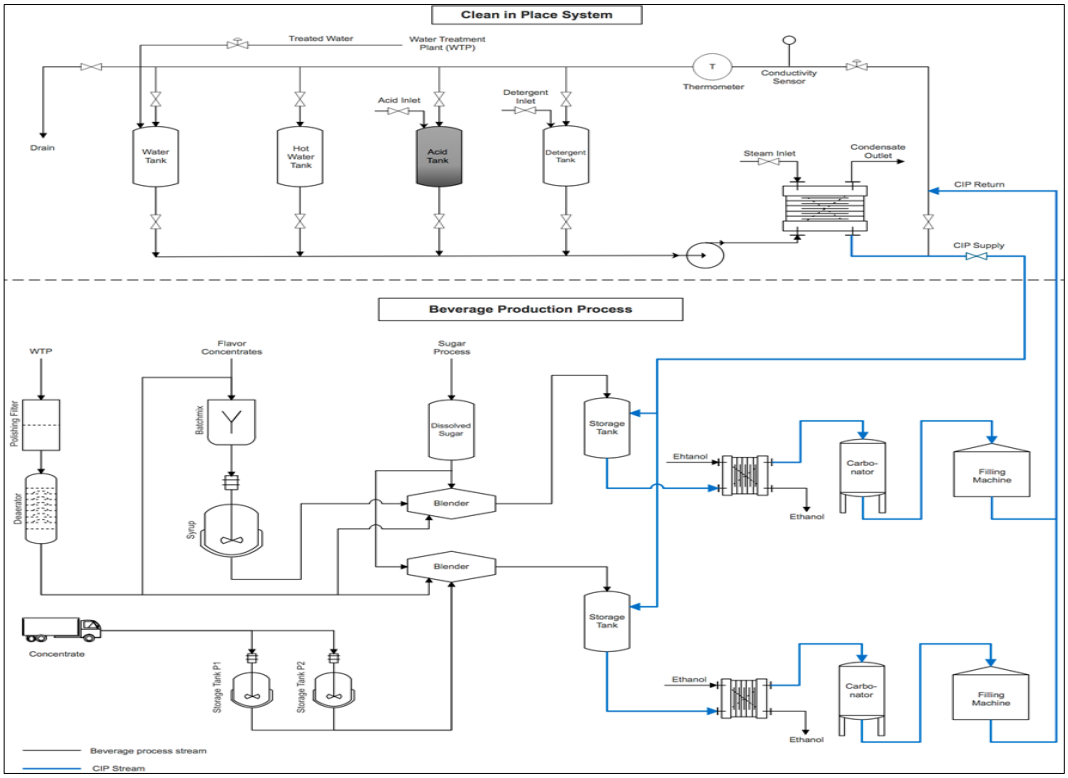

Figure 1: Conventional process of CIP and its operation in the process.
Source: Authors, (2019).

During the initial rinse, only water from the water tank is used, aiming at eliminating the residues present on the surface of the equipment. The complete system rinse occurs for 15 minutes. The second step in the process is the sanitization through the passage of hot detergent, which removes dirt adhered to the surface. At this stage, the detergent tank level must be adjusted to 90% of its capacity, which corresponds to 9 m3. Subsequently, there is a temperature (85°C) and conductivity (38 mS/cm) adjustment of the alkaline descaling detergent, composed of sodium hydroxide. Upon reaching the desired conductivity and temperature, the solution is directed to the beverage processing system, operating this cleaning cycle for 30 minutes. The third and final cycle of CIP is the final rinse. This step aims to eliminate hot water and detergent residues from pipes and equipment for 10 minutes. The final rinse water initially pushes the concentrated detergent into the detergent tank while the conductivity is between 20 and 38 mS/cm, performing a recycle of the detergent. For values below 20 mS/cm, water with diluted detergent begins to be discharged for the effluent treatment system.

Since juices are more sensitive and consequently more susceptible to contamination, it is necessary that the method of cleaning and sanitizing the equipment for this beverage be more rigorous. The juice CIP consists of five steps: initial rinse, hot detergent, intermediate rinse, chemical sanitizer and final rinse. The step that differentiates the other CIP procedure is basically the use of chemical sanitizers, such as peracetic acid, which ensures the sterilization of process equipment. Thus, for the juice CIP, the sanitizer is stored in the acid tank, rarely used in the evaluated industry, due to the low production of juice compared to other products.

III.3 IMPROVEMENT OF THE CIP PROCESS

The improvements proposed in this work were tested and implemented in stages. The first improvement consisted of using the acid tank to store recovered water. This tank receives the water discarded in the final rinse, the third cycle of the process, so that it can be used in the next CIP for the initial rinse step. This change does not affect the CIP process of juices as the chemical sanitizers are currently stored in an IBC tank container.

The second improvement consisted of reducing the initial rinse time from 15 minutes to 10 minutes and preparing the detergent tank by heating the detergent at 85°C before the start of each CIP process. Subsequently, a preheating of the water to complete the level of the detergent tank was also adopted, reducing the time required to reach the specified temperature and initiating the CIP process, causing the production lines to be stopped for a shorter time.

Another improvement was to change the minimum contact time of the hot detergent step. The time of this step was set to 15 minutes, reducing the stage time by half than before the improvement (30 minutes).

The conductivity of the detergent solution was also reduced from 38 mS/cm to 36 mS/cm (since internal company documentation determined a minimum conductivity of the detergent solution of 35 mS/cm). This improvement led to a five minutes reduction of the final rinse time, totaling 30 minutes for this step. That is because a lower time is required for the final rinse water to eliminate detergent solution from the process with a lower conductivity.

Finally, an adjustment was made in programming the process software, defining the detergent recovery in the detergent tank only with values above 30 mS/cm (before improvement the software was programmed to recover detergent with conductivity above 20 mS/cm). This action aimed to avoid sending diluted detergent to the tank, reducing the demand for detergent needed for each CIP cycle. After improvement, detergent with conductivity below 30 mS/cm is directed to the recovered water tank, to be used in the initial rinsing of the next CIP.

Through the adjustments made, the total CIP time went from one hour and thirty-four minutes to one hour and two minutes, representing a 34% reduction in process time. For the validation of the proposed improvements, microbiological tests were performed. The different implementation steps are presented in chronological order in Figure 2 and Figure 3 shows a CIP flowchart after the proposed improvements.

III.4 MASS BALANCE OF CIP PROCESS

III.4.1 MASS BALANCE BEFORE IMPROVEMENT

Figure 4 shows the inputs and outputs of water and detergent in the CIP prior to improvement, indicating a consumption of 7.5 t of water in the initial rinse and 1 t of water in the hot detergent step. To perform this step, there is also an input of 0.32 t of detergent (required to reach the conductivity of 38 mS/cm). In the final rinse, the mass of water consumed for the complete elimination of the detergent in the pipes and equipment is 17.5 t.

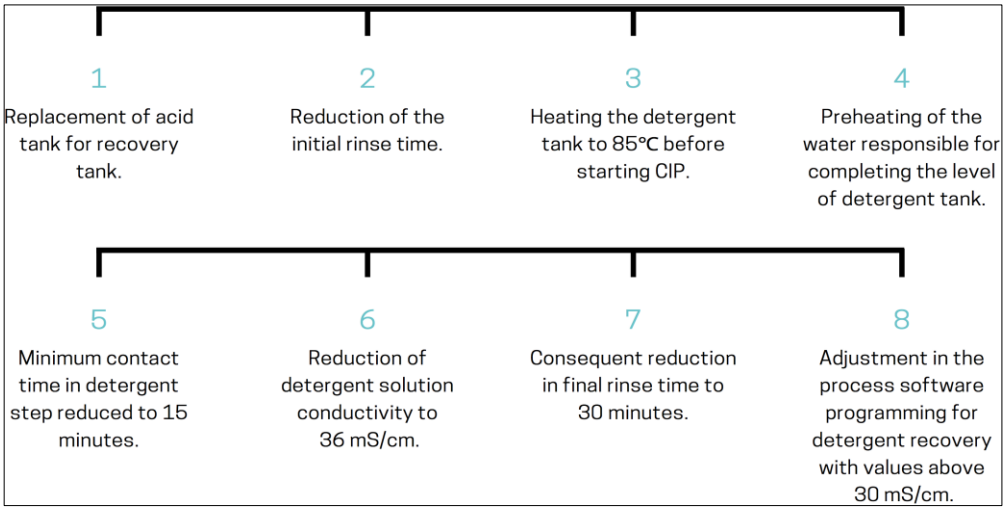

Figure 2: Steps for implementing improvements.
Source: Authors, (2019).

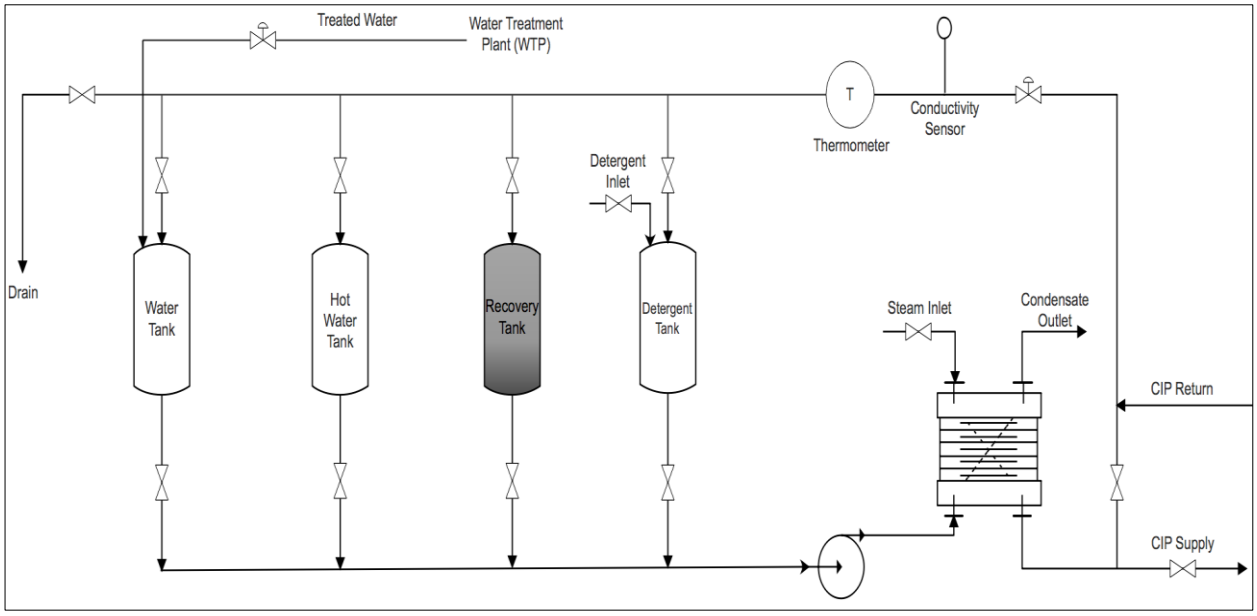

Figure 3: Clean in place process after improvement.
Source: Authors, (2019).

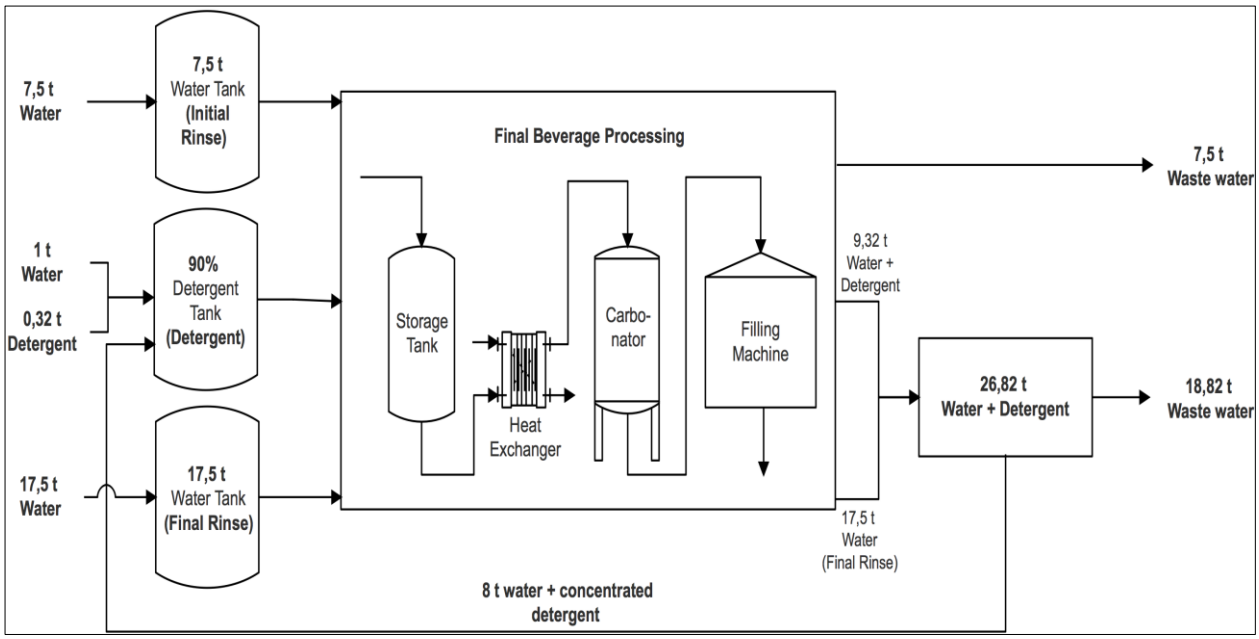

Figure 4: Mass balance of the Clean in Place process prior to improvement.
Source: Authors, (2019).

Without accumulation, the input mass is equal to the output mass. Thus, the 7.5 t of water consumed in the initial rinse is discharged as effluent. The water and detergent consumed in the hot detergent stage and the final rinse water come out in a single mixed stream. This occurs once the final rinse water pushes the detergent solution as a return to the detergent tank until the conductivity reaches 20 mS/cm (below that, detergent residue water is discharged as liquid effluent). Thus, 26.82 t of water with detergent leave the stages of hot detergent and final rinse, with 8 t of concentrated detergent returning to the detergent tank and 18.82 t of water with dilute detergent discharged as effluent.

III.4.2 MASS BALANCE AFTER IMPROVEMENT

Figure 5 shows the consumption of water and detergent and the generation of effluents after the improvement. The water used in the initial rinse is the recouvered water of the the previous CIP final rinse and corresponds to a mass of 5 t. This mass of water is discharged as an effluent after the initial rinse procedure, generating 5 t of liquid effluents.

The detergent tank receives 2.5 t of water and 0.2 t of detergent to achieve the conductivity of 36 mS/cm. It should be noted that a lower mass of detergent is required because of the higher concentration of detergent present in the tank, which corresponds to a conductivity of 30 mS/cm after improvement. In the final rinse, due to the reduction of time, the water usage was reduced to 15 t. At the completion of the hot detergent step, the final rinse water pushes the detergent into the detergent tank, returning 6.5 t of water with concentrated detergent. For the recovered water tank, there is a return of 5 t of water with diluted detergent (conductivity below 30 mS/cm). The remaining mass (12.7 t) is discharged as liquid effluent.

Comparing the masses of water and effluents discharged before and after improvement, there was a reduction of 32.75% per CIP.

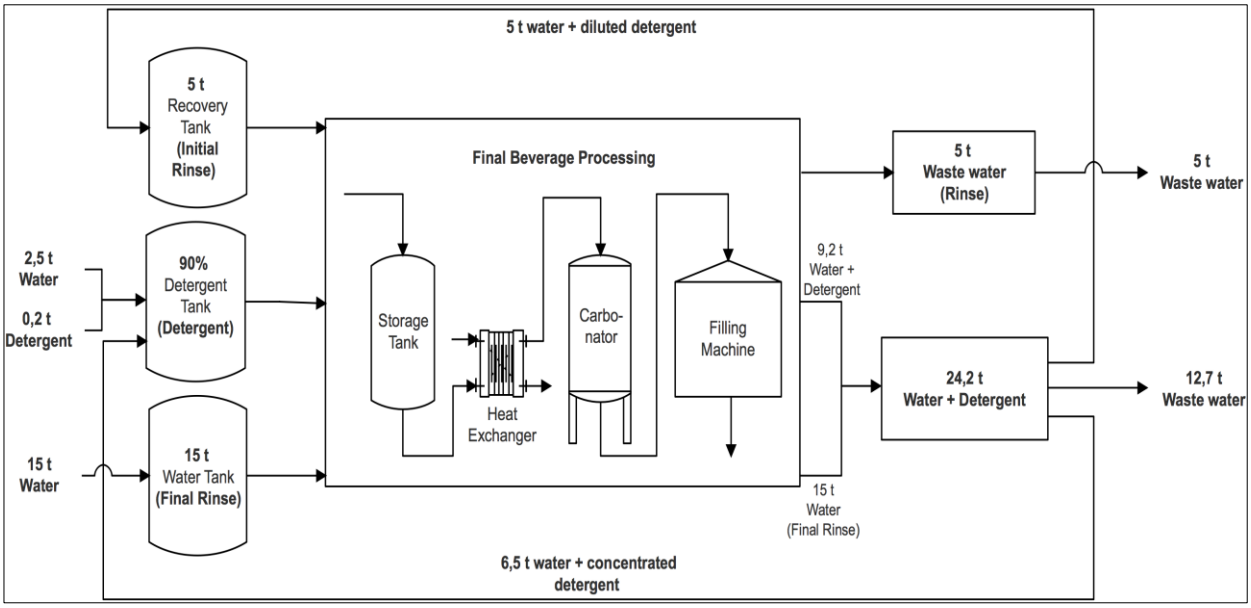

Figure 5: Mass balance of the Clean in Place process after improvement.
Source: Authors, (2019).

A total of 1,614 CIPs were conducted in 2018. Thus, it is verified that approximately 13,912.68 t of water per year are saved after the proposed improvements were implemented. Considering the average water consumption of 153.6 liters per inhabitant per day in Brazil [18], about 248 inhabitants could be supplied for one year with the savings obtained.

A similar work has been developed in a dairy industry, where the potential of cheese whey reuse as water in the Clean in Place process operations was studied. The results indicated that after using a combined ultrafiltration and reverse osmosis system, 47% of the water could be recovered without compromising the safety and quality of the final product [16]. Buabeng-Baidoo et al. (2017)[17] also studied an improvement of CIP in a dairy company through the reuse of the initial rinsing water. Mathematical methods were used for improvement using GAMS algebraic modeling software, as well as the treatment of residual water by reverse osmosis, in order to maximize the opportunities of reuse in the process. The results showed a reduction in water consumption, wastewater generation and a total annual cost of up to 33%. Another study carried out at Ohio State University [18] designed a pilot scale CIP and analyzed the effectiveness of the initial rinse water to remove a film of milk residue on the surface of pipes. It was verified that, by adjusting the contact time and the level of turbulence, there was a 72% reduction in water consumption in the initial rinse, with only a small loss in the removal of microorganisms.

III.5 COSTS

One of the factors that influences CIP costs are the treating water and effluents costs, as well as the purchase value of the detergent. In this way, by reducing the consumption of water, detergent and discharged effluents, there should consequently be a reduction in process costs.

The cost for water treatment and effluent treatment is 1.05 US$/t and the cost of detergent is 0.58 US$/kg. Table 2 shows the costs of the water and detergent consumed and effluent discharged before and after the improvement, applying equation 2. The total cost per CIP before the improvement was US$ 240.76, being reduced to US$ 153.08 after improvement, which corresponds to a reduction of 36.4%.

Table 2: Costs per CIP with water and detergent consumption and effluent treatment before and after the improvement.

	Cost before improvement (US$)	Cost after improvement (US$)	Reduction (%)
Water consumption	27,23	18,32	32,72%
Detergent consumption	185,97	116,23	37,5%
Wastewater effluents	27,56	18,53	32,76%
Total	240,76	153,08	36,4%

Source: Authors, (2019).

Considering the number of CIPs carried out in 2018 (1,614), the cost of the CIP process in 2018 prior to the improvement would be US$ 388,576.84, and it was reduced to US$ 247,085.65 after the improvement, showing an economy of US$ 141,491.19 (Figure 6).

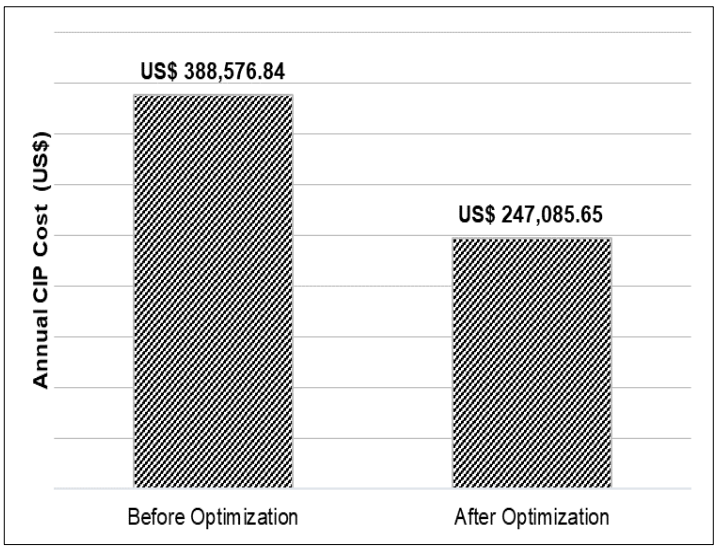

Figure 6: Comparison between costs before and after improvement.
Source: Authors, (2019).

III.6 MICROBIOLOGICAL ANALYZES

The effectiveness of the cleaning and sanitizing process is determined by the results of the microbiological monitoring of the final rinsing water. Detection of microbiological counts outside specified standards indicates the need to review established sanitation procedures.

The results obtained through the analyzes in the company's Microbiology Laboratory are described in Table 3. It is possible to observe that all the results are within the parameters and specifications, ensuring that the improvement can be performed safely, without affecting the quality and integrity of the products.

Table 3: Results of microbiological analyzes.

Samples	Test	Specifications (CFU/Volume)	Results (CFU/Volume)
Final Rinse (Sample 1)	Total Bacteria	<25/1 mL	9/1 mL
	Yeasts and Molds	<10/100 mL	4/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Final Rinse (Sample 2)	Total Bacteria	<25/1 mL	12/1mL
	Yeasts and Molds	<10/100 mL	6/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Final Rinse (Sample 3)	Total Bacteria	<25/1 mL	13/100 mL
	Yeasts and Molds	<10/100 mL	5/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Recovery Tank (Sample 1)	Total Bacteria	<25/1 mL	9/1 mL
	Yeasts and Molds	<10/100 mL	4/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Recovery Tank (Sample 2)	Total Bacteria	<25/1 mL	12/1 mL
	Yeasts and Molds	<10/100 mL	7/100 mL
	Total Coliforms	0/100 mL	0/100 mL

Source: Authors, (2019).

IV. CONCLUSIONS

The improvement study of the Clean in Place process presented in this work demonstrated that it is possible to reduce water consumption, using as an alternative a recovered water tank in order to recycle the final rinse water. In addition, the reduction of the time of the initial rinsing stage, anticipation of water heating for the detergent cleaning stage and reduction of the final rinse time were factors that influenced the reduction of water consumption, detergent, process time and effluents generated in CIP. Through the mass balance, a reduction of 8.62 t was observed in the mass of water consumed and the same mass of effluent is no longer discharged after the improvement of the process. This represents a reduction of 13,912.68 t of water consumed and the same mass of effluents generated in one year (reduction of 32.75%). Regarding the consumption of detergent, there was a decrease from 320 kg to 200 kg, which represents a reduction of 37.5% in detergent consumption per CIP performed. With respect to the costs, the present study generated savings of US$ 141,491.19 per year, representing a reduction of 36.4%. The improvement provided several benefits for the company, minimizing the environmental impacts and the costs associated with this stage the production process hygiene. In addition, a 34% reduction in CIP time was achieved, which represents a significant number, taking into account that the shorter the downtime of the production lines, the greater the efficiency of the industry.

V. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

DUTIES, POWERS AND RESPONSIBILITIES OF THE EXPERT ENGINEER OF TECHNICAL ASSISTANTS IN JUDICIAL DECISIONS WITH THE CONSTRUCTION INDUSTRIES

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ABSTRACT

This work has as its central theme: "The contribution of the expert in the labor court decisions", where it begins to point out that in the work related issues, such as dangerousness and unhealthiness, the expert examinations will be performed by a single expert. For its work consists of a set of technical-scientific procedures designed to bring to the decision-making body the necessary evidence to support the just settlement of the dispute or the finding of a fact. In response to the problem of this study consisting of the following question: What is the contribution of the expert in labor court decisions with a construction company? This study highlights the role of expertise rests in the search for truthfulness linked to the facts that require appreciation of the Occupational Safety sector, which is one of the fundamentals that should be prioritized in the work. In this regard, this study also highlights that the expertise in the Civil Construction industries must be technologically rigorous and closely correlated with the expert records, translating into formal truth, which will assist in the magistrate's conviction regarding the objects in dispute. In this line of reasoning it is understood that expertise can be considered as a product under development, as it is in constant transformation.

Keywords: Judicial Expertise, Report, Expert.

I. INTRODUCTION

With each passing day engineering is striving to add the use of new technologies, mainly due to the globalized scenario in which we are inserted that increasingly strengthens the competitiveness among civil construction organizations. In addition to the need to reinvent itself at all times, through new courses, the engineering professional should be able to answer for the company's management, regarding project compatibility, quality, deadline, among others.

Faced with this scenario the engineering professional tries to walk the fine line between success or error in the execution of their work activities, with risks of technical disputes.

Irregularities can occur in the execution stage, in the acquisition of land, in the choice of materials, and even due to the poor qualification of the workforce selected to perform the services. In addition, the lack of maintenance and preventive correction by those responsible for the assets, compromise the infrastructure and endangers society in various environments, causing numerous questions [1].

In this scenario emerges the role of the Expert Engineer, which was regulated after the validity of the new Civil Procedure Code. The Expert Engineer's work consists of a set of technical-scientific procedures designed to bring to the decision-making body the necessary evidence to support the fair settlement of the dispute or the finding of fact, by means of an expert report and / or opinion, in accordance with the legal and professional standards, and specific legislation as appropriate.

In this regard, the issues of the work performed by the Engineer are currently discussed in the field of professional, organizational and governmental action. Expertise in the field of work is a service provided by the Engineer as an expert to assist decision makers: federal and state judges and members of arbitral tribunals. Thus, expertise in the field of construction plays a

relevant role, especially when it comes to the functionality of its reports, reports and opinion [2].

The expertise among the other areas of Engineering also aims to control the assets of the entities, in the judicial scope that will be judged to decide on certain situations existing in disputes between the parties. Engineering expertise is "the manner of clarifying, demonstrating or proving equity information that is of interest to the parties through the Expert Report" [3].

It is also emphasized that in general the Construction Industries have been receiving sanctions and penalties when they do not bother to respect the current legislation, either for non-compliance or recklessness of the responsible sector. Within this context, this study is justified in contributing, from the theoretical point of view, the activities of engineering expertise by differentiating "right" and "wrong" in the development of their organizational activities, so the expert engineer faces many situations. who demand from him choices, which aim to resolve the doubts raised by the Judgment, and before that involve himself and others, who impose decisions and consequences and in most can benefit one and harm the other [4].

In this sense, the Expert Engineer "is in charge of the exercise of expertise, and should consider the effects for the benefit of society, providing well-being to all who have an interest in the controversy." The process of expertise in court decisions is exercised by a qualified professional, highlighting his contribution in an appropriate manner in the exercise of his profession, as well as the standards of procedure of the class measured by ethics [5].

II. DEVELOPMENT

The Judicial Expertise is that originated from the Magistrate's need to elucidate facts of a case, to clarify and issue a decision, based on this context, this study points out that the expert is a special instrument of scientific, technical, evidence, proof or demonstration. of the veracity of situations, things or facts through the reports [6].

Regarding the meaning of the report, it has that "it consists of an expert document, documenting the facts, the operations performed and the duly substantiated conclusions reached by the expert of the expert" [8]. In this understanding, it is pointed out that the expert report is "a pronouncement or manifestation of an expert, that is, what he understands about a question or several, which are submitted for its consideration" [3].

Another instrument of the expertise is the opinion, which consists of "the work of the technical assistant, who does not lose the characteristics of the report", according to this understanding it is pointed out that the difference between the report and the opinion is in the professional who performs it [1], as follows:

The expert report and the judicial expert opinion shall contain at least the following items:

a) identification of the process and the parties;
b) synthesis of the object of expertise;
c) methodology adopted for expert work;
d) identification of the steps taken;
e) transcription and answer to the questions: for the expert report;
f) transcription and answer to the questions: for the accounting expert opinion, where there is disagreement, transcription of the questions, answers formulated by the accountant expert and the answers and comments of the assistant accountant expert;
g) conclusion;
h) attachments;
i) Appendices;
j) signature of the expert: will indicate his professional category of Engineer and his registration number in the Regional Council of Engineering and Agronomy (CREA), proven by Declaration of Professional Qualification - DHP. The use of digital certification is allowed, in accordance with current legislation and standards established by the Brazilian Public Key Infrastructure - ICP - Brazil.

However, it is noteworthy that "the opinion is broader than the expert report, because it aims to answer the questions, and, if necessary, to oppose opinion about the Expert's answers contained in the report" [7]. Still within this context, it is emphasized that the structure of the judicial report issued by the Expert Engineer, should be presented as follows: in legal size paper, without letterhead, edited in computer, with observation of conventional margins for filing and that its structure meets at least the following set of information:

1) Identification: records, district, sticks, names of the parties, the Expert and the assistants;
2) Summary of the case: summary of the case, in the content related to the objective of the expert;
3) Objective of the expert: extracted from the order of appointment (if in the instructional phase) or the sentence (if in the execution phase);
4) Guidelines: regulatory foundations of expert work (CPC, LTP, NBC, Laws directly related to the object in dispute);
5) Due diligence: expert practices used;
6) Questions / answers: transcript of the question as it is in the case file, followed by the reasoned and commented answer;
7) Closing: conclusive summary, inform, communications with assistants, number of sheets and attachments, place, date, signature;
8) List of attachments: Sheet after the closing term.

In light of what has already been stated, it should also be noted that the expert report is a formal technical piece that presents the result of an expert's report, and it must contain everything that had been subject to expert examination. In this sense, it is commented that the expert Engineer is characterized as a professional who in the exercise of his activities must unceasingly seek the truth in relation to a certain fact and send as evidence to users who use accounting expertise as a basis for decision making [8].

This is because the need for judicial expertise occurs when there is a lack of facts practiced by one of the parties, in this sense, stresses that, "the expertise is necessary to verify situations of administrative and accounting irregularities, resulting from technical imperfections, professional negligence. Technical errors and bookkeeping, infractions, simulations, tampering and fraud, in order to seek the culprits for such acts and their degree of responsibility for such" [2].

In response to the objective of this study, which is to describe the contribution of expertise in court decisions, it is briefly elucidated that expertise in a construction site is a set of experiences that are linked to what they represented (company and worker) in their trajectories. and expressed themselves in the judicial disputes in which they participated.

III. MATERIALS AND METHODS

In this work the research developed was of a qualitative nature, since the data were qualified as to their relevance.

Throughout the research were analyzed the theories of legal researchers, who relate engineering with expertise, which constitute the theoretical framework of this study. Bibliographic archives, available on the Internet, media, companies, public data, libraries and others were employed.

The present work was based on the study of the new Code of Civil Procedure (CPC 2015), Section II - Of the Expert: the attributions and duties of the engineer as subject of the process, and in Section X - The Expert Evidence: the description of the steps in knowledge process. The results were analyzed seeking to highlight the research objectives through bibliographical analysis.

IV. STUDY APPLICATION

For a better understanding, this category of study begins by describing the meaning of judicial expertise, where it is emphasized that the expression expertise comes from the Latin expert, which in its meaning means knowledge, skill, knowledge. A diligence performed or performed by experts, in a generic way for any kind of expertise, since there are several types of expertise all with their own particularities. Also, in questions that may occur disputes in which the expert must resolve the dispute, or will subsidize the decision Judge. To this end, he will seek information necessary to give confidence and full support for the preparation of his expert report, given that it must be prepared by a legally qualified and qualified accounting expert, that this information will count a lot for the Judge's decision making [9].

Regarding this understanding, this study points out that judicial expertise is a technical demonstration of the truth of facts or situations. Expertise in a corner of works, both judicial, extrajudicial and arbitral, is the exclusive competence of the expert engineer registered in CREA (Regional Council of Engineering and Agronomy), because they have distinct characteristics from each other in which allows to observe their characteristics. and the mode of action of each expert. Based on the Fur studies [4] this study highlights some types of accounting expertise with:

- JUDICIAL EXPERTISE: is performed within the procedural procedures of the judiciary, by determination, requirement or need of its active agents, and is processed according to specific legal rules, in which the judge may or may not have the parties present, but professional To perform this function need not be entered into or have employment ties with any entity, it must be clear and objective, because the expertise made will have evidence to the judge's decision.

- SEMIJUDICIAL EXPERTISE: is that carried out within the state institutional apparatus, but outside the judiciary, having as its main objective to be evidence in institutional orders, and can be subdivided into three groups: the Police, Parliamentary and administrative, also they serve as the burden of judicial proof before the Judge, as they are subject to legal and regimental rules.

- EXTRAJUDICIAL EXPERTISE: Extrajudicial expertise is that performed outside the State Powers and the Judiciary Power, since it is born from both individuals and legal entities, as they can be supported by discriminatory, supporting and demonstrative statements.

- ARBITRAL EXPERTISE: is held in the arbitration court - a decision-making body created by the will of the parties, not being framed in any of the above by its special characteristics of acting partially as if judicial and extrajudicial were. It may be subdivided into probative and decisive if it is intended to function as evidence of arbitral judgment, as a subsidiary of the arbitrator's conviction, or is arbitration itself, that is, its active agent functions as the arbitrator of the dispute itself.

The fact is that regardless of the classification of the skill, the method of execution of the skill is basically analytical, not dispensing details whenever necessary. Therefore one must then: identify the objective well; competently plan the work; perform work based on unambiguous, full and fully reliable evidence; be very careful about the conclusion and only issue it after you are absolutely sure about the results; conclude in a clear, precise and unambiguous manner [2].

In light of this caveat, it is noted that in recent years there has been a strong interest in expertise at the construction site in the judicial areas, where the image of the expert Engineer is compulsory, making it highly relevant for performing the calculations and mission of opinion. which will serve to support the decision of the Court.

V. RESULTS AND DISCUSSIONS

- The Expert Engineer

According to the Code of Civil Procedure, The Expert Engineer is the professional regularly registered in CREA (Regional Council of Engineering and Agronomy), who carries out the expert activity on a personal basis, and must be profoundly aware, by his qualities and experiences, of the subject. expert. Within this context, it is further emphasized that the expert Engineer is the one designated by the judge in judicial expertise; contractor is the one who acts in extrajudicial expertise; and chosen is the one who exercises his function in arbitral expertise.

Among the main technical-professional competences to be performed by the expert Engineer, it should be noted initially that the technical competence presupposes that the expert maintain an adequate level of knowledge of the engineering area, occupational safety techniques, the legislation related to the profession and those applicable to the expert activity, being permanently updated through qualification, training, continuing education and specialization programs. To this end, it must demonstrate the ability to:

a) Research, examine, analyze, synthesize and substantiate the evidence in the expert report and expert opinion.

b) Performing their work with respect for equity means that the accountant and the assistant accountant must act with equal rights, adopting the legal and technical precepts inherent to the profession.

According to the new CPC/2015 in art. 156, the judge shall be assisted by an expert when evidence of the fact depends on technical or scientific knowledge thus provided:

Paragraph 1. Experts shall be appointed from among the legally qualified professionals and the technical or scientific organs duly registered in a register maintained by the court to which the judge is bound.

Paragraph 2. For the formation of the register, the courts shall carry out public consultation, by means of disclosure on the world wide web or in widely circulated newspapers, in addition to direct consultation with universities, class councils, the Public Prosecution Service, the Defender's Office. And the Brazilian Bar Association, to appoint interested professionals or technical bodies.

Paragraph 3. The courts shall carry out periodic evaluations and reassessments to maintain the register, taking into consideration the professional training, the updating of knowledge and the experience of the interested experts.

Paragraph 4. For verification of any impediment or reason for suspicion, pursuant to Arts. 148 and 467, the technical or scientific body appointed to carry out the expertise will inform the

judge of the names and qualification data of the professionals who will participate in the activity.

Paragraph 5. In the place where there is not entered in the register made available by the court, the appointment of the expert is free choice by the judge and shall be the responsibility of a professional or technical or scientific body with proven knowledge to carry out the expertise.

The CPC/2015 brought a great and advantageous innovation for all that is the Consensual Expertise according to art. 471, in which the parties may, by mutual agreement, choose the expert, indicating him upon request to the judge, provided that:

I - Be fully capable;

II - The cause may be resolved by self-composition.

Paragraph 1. The parties, when choosing the expert, must already appoint their respective technical assistants to accompany the realization of the expertise, which will take place at a previously announced date and place.

Paragraph 2. The expert and the technical assistants shall deliver, respectively, a report and opinions within a time limit set by the judge.

Paragraph 3. Consensual expertise shall, for all intents and purposes, replace that which would be performed by an expert appointed by the judge.

Expert work begins when, when verifying its need, the magistrate admits or requires the production of the accounting expert evidence and, consequently, appoints the accountant, who may be substituted. After the appointment of the expert, the judge shall grant a period of ten days for the parties to express their views and presentation of the questions (CPC, article 422) and five days for the appointment of technical assistants of the parties (CPC, article 421, paragraph 1). After the deadline, the expert will be informed of his appointment by subpoena, whereby he is summoned to find out about the expert matter assigned to him. This is where the effective involvement of the expert with a given expert process begins.

Upon becoming aware of his appointment, the expert should take charge of the case file and be responsible for his zeal. He must then present the provisional fee proposal, made by his own petition filed with the notary. Once formalized to the petition. The judge will open views to the parties to comment on the fees, agreeing or not with their value. In the event of disagreement, the judge will ask the expert to comment on the allegations, after which he can decide whether to replace it or simply arbitrate the amount, and the expert will accept or give up the work. If there is agreement, the judge will dispatch the petition granting

VI. CONCLUSIONS

The present work had as main objective to analyze the contribution of the Expert Report in the judicial decisions. From this perspective, it is firstly emphasized that accounting expertise must be technologically rigorous and closely correlated with expert accounting records, translating into formal truth, which will assist in convincing the magistrate of the objects in dispute. In this line of reasoning it is understood that the expertise in a construction site can be considered as a product under development, because it is constantly changing. In addition, regarding the standardization of the expert report with the judiciary, there are several guidelines for performing the work of the Expert Engineer. In response to the problem of this study which consists of the following question: What is the contribution of the expert in the labor court decisions with the construction companies? This study highlights the role of expertise rests in the pursuit of truthfulness linked to facts that require factual appraisal, and this pursuit is one of the fundamentals that should be prioritized in the work of both the Expert Engineer and the Assistant Expert Engineer. Thus, the expertise will have its importance, as it will bring to the decision-making body the necessary evidence to support the just settlement of the dispute and will be fulfilling its role in protecting society. In the final analysis, it is pointed out that the main function of the expertise is to generate true information, so it must be composed taking into account the greater responsibility and caution of the professionals involved.

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RESEARCH ARTICLE OPEN ACCESS

MAJOR CHALLENGES FACING CLOUD MIGRATION

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ABSTRACT

Organizations are increasingly dependent on IT (Information Technology) as they seek to invest in technology to improve relationships with customers, suppliers and employees. Looking for improvements in the form of relationship they come across the term Cloud Computing, which is a technology that has made it possible to make work more collaborative, agile, flexible and secure. With all these innovations generated by Cloud Computing, Cloud Computing is gaining more space in the market, but migrating to the cloud requires care and attention. Thus, this paper aims to provide an overview of Cloud Computing and to identify the main challenges faced in cloud migration, serving as a basic guide for cloud adoption.

Keywords: Cloud Computing, Information Technology, Challenges, Migration.

I. INTRODUCTION

Technological evolution has directly influenced the evolutionary process of organizations, new formats and standards are emerging to establish the correct use of IT (Information Technology) in the decision making process. IT is critical to performance improvement and can be considered the backbone of many businesses and used as a competitive differential in the marketplace. Nowadays it is impossible to imagine a company that seeks to optimize its processes without using IT resources, with all this importance comes the need to make it more flexible by incorporating strategies so that it can optimize the expected results. In this modern scenario where IT is directly connected with the companies' strategy and objectives, it is necessary to reduce costs and risks generated by its use.

Cloud computing may be an alternative to meet the need for more flexible, aligned with organizational policies IT, although it is a new and evolving concept. Cloud computing is no longer a trend but a reality, it is responsible for changing how organizations relate to their customers, suppliers and employees. This new way of relationship, provided by Cloud Computing, allows data, information and IT resources to be accessed from any devices, such as a computer, smartphone or tablet, that have network access. It can reduce costs with acquisition, operation and equipment maintenance, it is also possible to ensure greater flexibility with regard to infrastructure, as resources can be increased or decreased according to business needs quickly and ensuring continuity of services.

Research by Forrester Research shows that the global cloud computing market is expected to grow by $ 241 billion from 2010 by 2020. In Brazil, industry-leading companies are 71% more likely to use the cloud. 65% of leading companies use the cloud for decision making [1].

Cloud computing represents a break from the conventional way companies acquire and use technology [2]. The traditional IT infrastructure model is all the hardware, software, and networking resources needed to store, process, and analyze data, typically these resources are centralized in large data centers that have large computers, these environments require a rugged, non-stop, high-power cooling system, tight access control is also required, and a skilled and trained staff to keep the environment running smoothly all these factors make the traditional model very complex and expensive. With the adoption of the cloud there is a huge paradigm shift and IT infrastructure, computing resources are consumed as a service through a network where you pay for what you consume, all this paradigm shift makes the process of migrating to cloud a arduous task to accomplish.

This article will identify the challenges encountered in the complex task of migrating to the cloud, serving as a basic guide for organizations looking to adopt cloud-based services.

II DEVELOPMENT

II.1 CLOUD COMPUTING

Despite all the repercussions and popularity that cloud computing has gained in recent years, its real operation is not yet well known, even among information technology professionals there is still much doubt and lack of clarity, knowing the concept, characteristics and the working way is key to planning a cloud migration.

According to [3], Cloud Computing is a set of easily usable and accessible virtual resources such as hardware, software, development platforms and services that aims to improve resource usage and make IT operation more cost-effective.

ISO/IEC 17788: 2014 defines Cloud Computing as a paradigm that allows internet access to a group of physical or virtual resources, with provisioning and administration on demand.

Basically Cloud Computing is the term used to describe different ways in which computing resources are shared as a service over a network connection.

The [4] determines five essential characteristics for a cloud service:

- Self service on demand
- Broad network access
- Resource Group
- Fast elasticity
- Measurable services

The concept of turning IT products into services is named Everything as a Service or Enterprise as a Service. This concept where everything can be put as a service is divided into three categories, Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS).

Another model has been considered by some players in the IT market, such as Business Process as a Service (BPaaS), in which consumers outsource part of the business process to an external provider [2].

Also according to [4] the cloud computing implementation forms are divided into four different types:

- Private Cloud
- Public cloud
- Hybrid Cloud
- Community Cloud

These models are basically the way services are delivered. Each type has unique characteristics and advantages. Choosing the implementation model requires a clear definition of what kind of application the customer needs, and what kind of implementation will meet their needs and expectations.

II.2 SERVICE MODELS

Cloud computing service models are a substitute for conventional IT infrastructure, with the distinction of the commercialization model, which instead of licensing uses a model that pays only for what is consumed.

We'll look at what cloud computing service models are and how these service models work.

II.2.1 SaaS (SOFTWARE AS A SERVICE)

This service model is aimed at the distribution of applications or software over the internet, on demand, usually based on subscriptions. The Software as a service model offers a complete product, run and managed by the service provider, typically end-user applications. In the SaaS model, you don't have to think about how the service is maintained or how the underlying infrastructure is managed, you just need to think about how you will use this particular type of application. According to [4] in the SaaS model, [...] applications are offered as services by providers and accessed by customers by applications such as the browser. All control and management of the network, operating systems, servers and storage is done by the service provider. In this model, organizations reduce costs with software and development resources, upgrades are simplified and interactive, availability is independent of geographic location, there is less investment in infrastructure and people management.

Microsoft defines Software as a Service (SaaS) as the model in which the user uses cloud-based applications connected over the internet. The SaaS model is probably the most commonly used model, if you use a web based email service then you have certainly made use of SaaS.

In short SaaS is the model that makes an application or set of applications available through a cloud service provider. The model is characterized when the service provider makes the application available, which includes all the infrastructure required to use the tool. The features offered meet a wide range of needs. Examples are seen in e-mail tools and software for CRM (Customer Relationship Management), human resources, accounting, among others.

II.2.2 PaaS (PLATFORM AS A SERVICE)

The PaaS model is a model that offers a complete cloud development and deployment environment. The PaaS service model, which focuses on application and data management rather than the structure needed to deliver it to the end customer, basically enables you to deploy and manage your own or third-party software or applications using your provider infrastructure. Cloud In other words, the provider provides and manages the entire hardware and software infrastructure, as well as the suite of applications and programming languages needed to support customers' application deployment.

According to [2] PaaS is between SaaS and IaaS. In this view, the software layer is above and the infrastructure layer below. As such, PaaS occupies an intermediate space between the three main types of cloud offerings available. In general, PaaS is characterized by offering a robust and flexible platform that allows the execution and development of various application services (middleware). This includes the use of application, integration, process management, business, and database services platforms.

The model has many advantages, but the most outstanding are the very high level of programming, low complexity, the possibility of decentralized development and within the same standards of quality and safety.

II.2.3 IaaS (INFRASTRUCTURE AS A SERVICE)

According to [2] in the IaaS Infrastructure as a Service model, the cloud service provider is responsible for providing full capacity for processing, storage, networking and other key features. With these features, the customer utilizes the operating system and applications that allow them to deploy and run software freely. IaaS is characterized when a service provider's computing resources make infrastructure, storage, and network tools accessible to customers' demand. It is a standardized, flexible and highly

automated offering that allows customers to provision through a simple self-service interface.

The infrastructure as a service model basically guarantees the operation and performance of cloud computing, in this model a hardware capacity is contracted, the contracted package may include servers, routers, racks and other equipment.

Amazon Web Services describes the IaaS model as containing the basic components of cloud IT, often giving access (on virtual or dedicated hardware) to network resources and computers, as well as space for data storage. Infrastructure as a service gives you the highest level of management flexibility and control over your IT resources and closely resembles the current IT resources that many IT departments and developers are familiar with today.

In this model, organizations reduce capital expenditures on hardware and human resources, improve business continuity and disaster recovery, reply faster to changing needs, and increase business focus.

II.3 CLOUD DEPLOYMENT MODELS

As described in section II.1 last paragraph, cloud deployment models determine how services are delivered, in more detail models addressing access, constraints, and availability of cloud computing environments.

Currently three models stand out, but a quarter is growing and being widely used by organizations, we will describe the operation of these models and their characteristics.

II.3.1 PUBLIC CLOUD

In the public cloud model, the service provider makes shared resources, such as hardware and software available to multiple customers, these resources are accessed via the internet. This model basically modifies the standard concept of IT infrastructure. It is a resource sharing model with well-defined access and utilization layers.

The [2] Defines public cloud as a cloud environment with ample data processing and storage capacity, offered by public organizations or large industry groups. It is made available through the "pay per use" model. It features IT capabilities and capabilities that are easily scalable and resiliently enabled. It is a service linked to the use of the internet and directed to external customers. Public cloud models, such as Google Compute Engine or Amazon Web Service models, share a gigantic computing infrastructure with different users, business units, or companies.

II.3.2 PRIVATE CLOUD

Also known as internal or corporate cloud private cloud is a model that is not open to the general public, is managed by an organization or group of organizations with common goals. [3] Defines private cloud as the model that comprises a cloud infrastructure operated and almost always managed by the client organization.

The services are offered for internal use by the organization itself and are not publicly available for general use. In some cases it may be managed by third parties. By providing services to a limited number of organizations, the private cloud creates greater security and ensures direct control over data, so the private cloud model differs from the public model, in the public model IT infrastructure is the responsibility of the service provider. In the private model, the cloud is managed by the internal IT department, generating the same personnel, management and maintenance expenses as the traditional infrastructure model.

II.3.3 HYBRID CLOUD

The hybrid cloud model is basically a junction of the private cloud and public cloud models, the ability to allow workloads to be balanced between private and public cloud gives organizations greater flexibility and more data deployment options.

Conceptualize hybrid cloud as a composition of two or more clouds (private, public, or community) that remain single entities but are connected through proprietary or standardized technologies that provide data and application portability [3].

Gartner research reveals that the hybrid model is the model that best fits the needs of organizations of all segments and sizes, and that by 2020 90% of organizations will adopt the hybrid cloud model. According to Gartner Research Director, DD Mishra, as greater the demand for agility and flexibility, more organizations will embrace the hybrid cloud. Organizations adopting hybrid infrastructure will optimize costs and increase efficiency. However, there is increasing complexity in selecting the right set of tools to deliver end-to-end services in a multifunctional environment.

Figure 1 graphically represents the concept of hybrid cloud, highlighting the characteristics inherited from the junction of the public model with the private model.

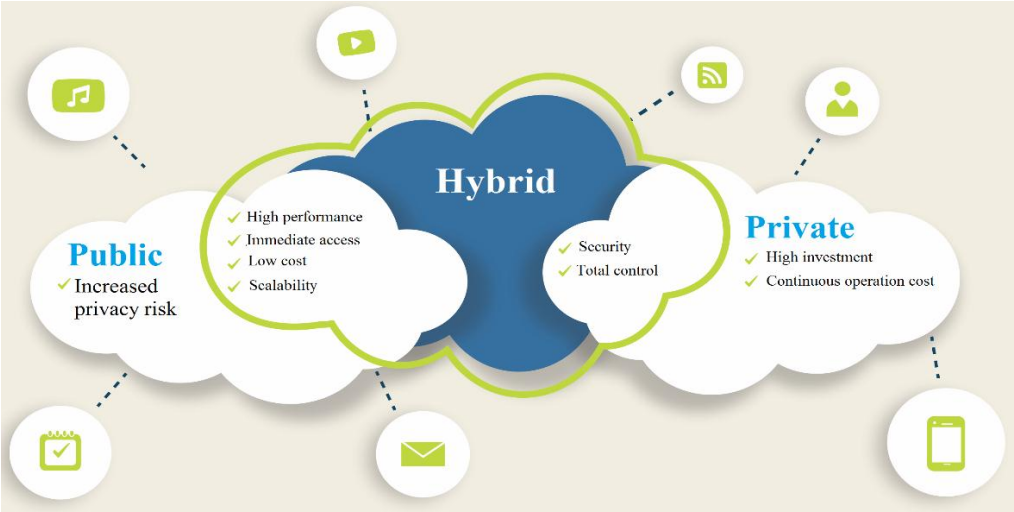

Figure 1: Hybrid Cloud.
Source: [8].

II.4 CHALLENGES IN THE CLOUD MIGRATION PROCESS

Despite all the benefits that cloud adoption generates, it is also possible to identify some aspects that can be seen as limitations or even challenges encountered in the cloud migration process.

It is important to make clear that the challenges faced in migrating to the cloud are different from the risks inherent in cloud computing, which according to [10] they are divided into three major groups:

Operational Risks

- Lack of privacy
- Integrity failures
- Error
- Inappropriate Support
- Low performance
- Saturation Attacks
- Difficulties to climb
- Low interoperability

✓ Business Risks
✓ Unavailability
✓ No continuity
✓ Structural Risks
✓ Non-compliance
✓ Software Licensing
✓ Imprisonment
✓ Bad reputation

The challenges faced in migration are basically steps that must be taken and performed with extreme caution in order to be successful in the cloud migration process. Bibliographic research has led us to three fundamental challenges for migration:

- IT Governance Maturity
- Plan the migration
- Select Supplier

II.4.1 IT GOVERNANCE MATURITY

IT governance is a concept derived from corporate governance, its role is to facilitate strategic alignment between business and IT by providing decision support and business strategies. IT governance addresses not only the definition of decisions and responsibilities in this area, but also its aspects and forms of control over service procurement, application development standards and general procedures to ensure better alignment and compliance corporate demand.

During the literature search we found statements in the analyzed texts that made clear the need to have maturity in IT governance before migrating to the cloud. According to [11] it is mandatory that companies are able to control the use of productive capacity that will be acquired in the cloud and, in turn, keep in mind that the increased maturity of IT governance must be improved to ensure the follow up each step of using these features. Already [2] points out that the migration to cloud computing has a significant business impact, reflecting on the IT technical base used to operationalize organizations.

The [5] describes that the Information Systems Audit and Control Association (ISACA) suggests that when adopting and using cloud services, companies should:

Treat the adoption and use of cloud computing as a strategic business decision.

Make informed decisions, considering the operational, business needs and benefits that can be gained from cloud computing.

Based on all of this information found in the literature review, we realize that the decision to migrate to the cloud must be directly linked to the organization's strategic goals and that quality IT governance will facilitate this alignment between IT and organizational goals, enabling The user company is able to focus on the core business and that migration follows the focus of the organization, matching the models offered by cloud computing with the objectives of the organization

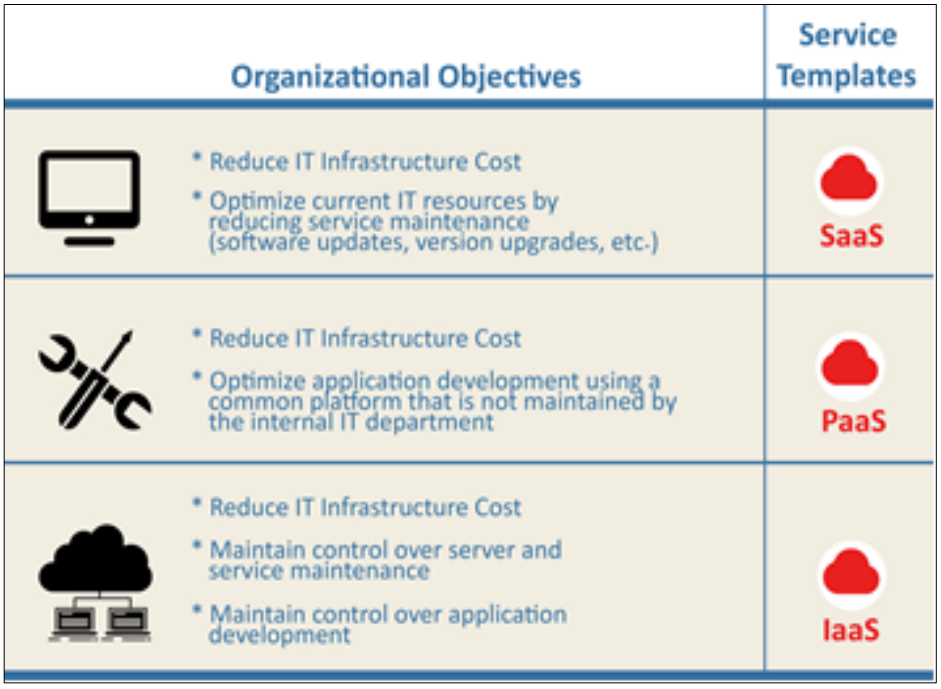

Figure 2: Organizational Objectives x Service Templates.
Source: [11].

II.4.2 PLAN MIGRATION

Adopting cloud computing is a process that involves many changes, risks, and benefits. To be successful in the cloud adoption process, it is critical to plan for the decision to invest time and money in a new project.

For [14] the planning process is responsible for defining the ways in which project objectives are achieved, and that the depth and complexity of planning is directly linked to the size of the project. It is crucial when it comes to reducing waste, which provides a higher return with the lowest possible investment. Before you start migrating to the cloud, you must have a well-designed strategy for everything to happen safely and quickly. The strategy should take into account what should be migrated to the cloud, rate costs and risks, define a pilot project.

The selection what will work in the cloud is a critical process for the success or failure of the cloud migration project, [2] highlights that not all applications or services are eligible for the cloud and organizations do not migrate data and applications to the cloud overnight as there are solutions that require dedicated hardware or proprietary solutions that cannot take advantage of cloud benefits, based on this statement we realize that a rigorous assessment of today's IT infrastructure is needed to determine the which should go to the cloud and what should continue offline. For [2] when a service or application is “mission critical” and may affect strategic value or is integrated with other applications, cloud migration is not the most appropriate or needs to be evaluated with the utmost care. Applications that do not have such complexity are the best candidates to be transported to the cloud environment, it is recommended to migrate software that is completely independent and that do not require data or applications from other programs.

Also according to [2] the assessment of cloud computing adherence goes beyond the technical issues it is necessary to make a comparison between costs and benefits. The analysis must go beyond the competitive return, also looking at the financial return on the investment, but one cannot close the eyes to all the investment already made by the organization over time. It's hardwares, servers, peripherals, computers, softwares, licenses, and even all the time and money invested in developing specific, business-critical applications. Each deployment of cloud resources needs to consider the need to retrofit or redo the existing structure and the financial cost of it. To measure costs and the way investments are used, we recommend using financial indicators with ROI, CAPEX or OPEX.

Inside the migration's planning a key factor to take into account is the risks associated with adopting cloud computing, according to [11] the risks associated with adopting cloud computing should be taken into account when assessing the benefits of using cloud computi, understanding this technology is the best way to prepare for and ensure a stable environment, especially at this step of migration.

Efficient cloud migration planning requires a pilot project that enables the migration team to learn how applications will behave in the cloud environment, what errors are presented, and how those errors are corrected. It is not recommended to perform migrations by Big Bang project (all at once) to prevent the amount of errors from making the migration path to the cloud unviable [11].

According to [2] knowledge and antecipate learning about cloud technologies for practical verification are the fundamental objectives in carrying out a pilot project. Some steps are fundamental for the implementation of a pilot project, the first is the implementation stage where the organization will be prepared for practical learning, allowing to verify the real potential of cloud utilization, in this stage goals, objectives and metrics are established, which will determine whether the focus of the analysis was successful or not. Business models need to be simulated and tested, even at a smaller size and controlled scope, to create a foundation that provides statistical data. The second stage is the learning stage where the organization creates a knowledge base based on the experiences gained in the implementation stage creating conditions to develop the learning, in order to consolidate a defined position for evaluation, this stage should provide answers to questions such as:

Is the organization ready to use this new feature?

What is the learning got from this cloud pilot?

Were the tests enough?

Did the cloud solution deliver effective solutions to technical and operational challenges?

Are the organization's business and IT aggregated in the solution?

The third and final stage of a pilot is decision making [2] in this step, the answers obtained through the experiments need to be organized. This will be the main input to the conclusions about the projected benefits of meeting business requirements. By reaching this point, there is clarity about the conditions and potential of technical and operational solutions, as well as the risks involved. From such an analysis, the impediments, if any, can be understood. In this process, obstacles such as governance requirements and the level of knowledge and training required to use the cloud tool are detected. Obtaining these definitions, such an implementation will move from theoretical projection to technical reality, making executions plausible and perfectly achievable.

II.4.3 SELECT SUPPLIER

After maturing IT governance and planning to migrate to the cloud comes the challenge of selecting the provider, it is critical to select providers that have a service model that meets the needs of the organization, in the selection process it is not enough to consider only technical issues It is critical to assess the capacity and reliability of the provider that the organization intends to hire. For [5] selecting a provider is very complex and requires a lot of effort.

In the current scenario of cloud computing there are several providers, among which we can mention the main ones as:

- Amazon
- Microsoft Azure
- Google Cloud Platform
- IBM Cloud (Brasil).

It is important to note that these providers automatically provision and release resources, key features for cloud computing providers, [15] points out that some traditional data center hosting and outsourcing providers insist on presenting their offerings as “Cloud Computing”, which makes it difficult for the market to understand the difference between this new model and the traditional one.

Microsoft suggests that organizations evaluate four key areas for selecting a cloud computing provider:

- Business Processes and Integrity
- Administration Support
- Technical Features and Processes
- Safety Practices

Each of these areas has requirements that must be evaluated in the provider selection process. Within the area of processes and integrity should be evaluated:

The financial health of the provider should keep a record of stability and have a sound financial position with sufficient capital to operate successfully in the long run.

The provider should have a clear management structure, well-established risk management policies, and a formal process for evaluating third party service providers, thereby ensuring the organization, governance, planning and risk management.

Trust is another fundamental requirement in this area, the provider must have a good reputation among its partners, the provider principles should be aligned with the principles of your organization so it is crucial to find out the level of experience of this provider. Read reviews and talk to customers whose situation is similar to yours.

Business and technical knowledge, providers must understand their business and objectives and be able to relate all this information to their technical knowledge. The provider should be able to validate compliance with all of its requirements through a third party audit, which characterizes a provider's compliance audit requirement.

In the support area to administration we should evaluate the following requirements, service level agreements (SLAs) providers should be able to promise a basic level of service that you are used to, there should be sufficient controls for the provider to track and monitor customer service and changes to their systems to ensure resource monitoring and configuration management. The billing and accounting process must be automated so that you can monitor which resources you are using and their costs so that you do not accumulate unexpected accounts. There should also be support for billing issues. The provider should also be able to provide performance reports.

The functionalities area and technical processes require ease of deployment, management, and upgrade requirements, the provider must have mechanisms that facilitate the deployment, management, and upgrade of their software and applications. The provider must use standard "APIs" interfaces and data transformations so that your organization can easily compile cloud connections, you also need to have a formal event management system that is integrated with your monitoring / management system. The provider must have formal documents and processes for requesting, logging, approving, testing, and accepting changes to ensure change management. Even if you do not plan to use a hybrid starter cloud, you should be sure that the provider can support hybrid functionality. This model has advantages that you may want to explore in the future.

The security practices area may have the most important requirements in the provider selection process, in this area the security infrastructure requirement should be evaluated, the provider must have a comprehensive security infrastructure for all levels and types of cloud services

Provider must have well-defined security policies, there must be comprehensive security policies and procedures in place to control access to client and provider systems. Changes to any application service or hardware component must be authorized on a group or personal role basis, and authentication must be required for anyone changing an application or data to ensure identity management. Another very important requirement is data backup and retention, the provider must have policies and procedures to ensure the integrity of customer data must be in place and in operation.

Controls ensuring physical security must be in place, including for access to installed hardware. In addition, data centers must have environmental protections to protect equipment and data from disruptive events. There must be redundant networks and power, as well as a documented business continuity and disaster recovery plan.

III. CONCLUSIONS

Because it is a technology that is expanding the boundaries of its adoption, there needs to be constant work to improve governance and also the adaptability needed to support this adoption curve. Information technology professionals today devote much of their time to gaining more and more knowledge and skills required in a cloud computing migration job. Based on the three major challenges found in the research we can see that the cloud migration process is not one of the simplest tasks, it is important for organizations to mature their IT governance by aligning business and information technology with this makes the decision to migrate to the cloud a strategic decision for the business, thereby gaining the benefits of using the cloud. It has also been noted that in order to realize all the advantages offered by cloud computing, detailed planning is required before performing the migration, planning will be responsible for ensuring the success of the project avoiding waste and minimizing risks. You can say whether or not your organization is ready to migrate to the cloud. It can be concluded that the provider selection process is the most complex challenge faced by organizations wishing to migrate to the cloud, selecting a provider that does not have a service model that meets the needs of the organization will lead to the steps IT governance and planning have been carried out in vain, so it is critical that the provider has the capacity and reliability. In the vendor selection process it is important to note whether the provider automatically offers provisioning and release as these characteristics are critical for cloud based services, otherwise this provider does not actually offer cloud based services. It has become clear that the stages of maturing IT governance, planning, and vendor selection are essential to successfully migrate to the cloud. These steps are complementary and must be well designed to achieve a successful migration, enabling a migration under the cloud the facet of the lowest risk of negative impact and even more likely to succeed on this journey.

IV. ACKNOWLEDGMENTS

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RESEARCH ARTICLE OPEN ACCESS

MAPPING PROCESS IMPROVEMENT AND SEQUENCING ANALYSIS FOR PRODUCTIVE DEFINITIONS: A CASE STUDY IN A METALLURGICAL INDUSTRY

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ABSTRACT

With a constant and complex change in the manufacturing market, it is essential that companies are always growing steadily and looking for internal improvements not to lose their place in the market. These improvements initiated by organizational management, to make the company more competitive in the market that is inserted. For this, everyone involved in the process must know exactly how the information flow, the sequencing of operations and the expected result at the end of them. Knowing this importance, the present study deals with a process mapping and analysis, where we observed the problems faced in a metallurgical industry located in Curitiba-PR, and based on a theoretical framework on this approach and how its application is made. Defining the company flowchart from the process mapping, as a result, several failures and opportunities for improvement were found, generating a new proposal of a process flowchart that has already been implemented and is having positive organizational results for the industry in question.

Keywords: Process mapping, Organizational Management, Metallurgical industry.

I. INTRODUCTION

Process is a set of activities/operations together with people, equipment, procedures and information flow, transforms an input (an input) in a product or service (output), according to customer needs. It is necessary for this product or service, add value and bring positive results for the company.

With the current market increasingly competitive, it is essential to good management and business administration at all for you to be ahead of your competitors to guarantee the standardization of internal processes is necessary because with this, the company can achieve greater efficiency with the reduction of costs, resulting in productivity gains and a more competitive price in the market, thus ensuring greater customer satisfaction.

Nowadays, with advances in technology and business management, we see how the market competitiveness has been growing in many areas, thus causing increasingly necessary, the company is in constant search for knowledge and marketing strategies for do not end up wasting your space for the other competitors.

For an essential business development that the company can identify their shortcomings in the production system in order to make the necessary improvements in its productive and organizational processes. A very effective remedy to observe these flaws is the process of mapping, which is to establish an organized manner the steps and sequencing of activities that sustain the company.

Disorganized company can generate low productivity, unmotivated employees, no information operations, which directly affects the quality of the product or service, and the loss of time and money for the company, so that there may be an increase of quality and that the production process is the best and fastest is necessary organization and sequencing of all processes.

This study deals with an analysis and modification of a mapping process for a company in the metal industry that suffers from problems caused by lack of standardization of its processes, in which there is no documentation that defines the exact sequence to be followed after each operation executed, as the company is a service provider in the machining industry, and its products end unique pieces and cannot therefore be held to standardize processes for each final product, so in order to facilitate the flow of

information, will be conducted research and created a stream of general processes in order to improve the current situation of the company, and make the information flow more facilities between one operation and another, giving a better quality in service, in a shorter interval of time between the service request and the issuance of the final product, as now, no proper sequencing, the product ends up getting lost during a process and another, thus causing a delay of the application and consequently discontent and bad view of the customer to the company.

This article is structured as follows: Section 1 presents the introduction, in which there is exposure of the subject matter; Section 2 presents a literature review of research; Section 3 exposed the materials and methods used in the preparation of the article; In Section 4 we have the statement of conclusions and then are cited the references used.

II THEORETICAL

II.1 MANAGEMENT ORGANIZATION

According to [1] organizational management is nothing more than the management of a business, company or organization in order to achieve goals and conquer positive and profitable results.

The function of this type of management philosophy is to lead people and processes effectively, encouraging improvements, create a collaborative environment, motivated, conducive to self-development and, consequently, the achievement of results.

The management concept aims to achieve the most satisfactory results possible. However, they are only achieved when the strategies and processes are in tune. The company builds its own set of principles and values that result from the interaction of people.

II.2 PROCESS CONCEPT

Process is related to everything that exists in life, considering that for everything there is a precedent stage, a processing step and a consequent step. They reach this conclusion based on the understanding that everything that makes up life is based on a succession of events, either in the relationship between the animals in natural phenomena, or behavior and human relationships, everything is constantly changing, ie, the observed object has a previous format, undergoes a modification step and molds with another format (be it physical format, behavioral, technological or material) [2].

To [3] process is a group of activities in a logical sequence in order to produce a good or a service that is of value to a specific group of customers.

The [4] addresses that process is a set of sequential activities that present logical link between them, in order to meet and preferably surpass the needs and expectations of internal and external customers of the company.

The [5] state that a process consists of a sequence executed set of tasks in order to generate an identifiable result, which can be a good, a service, data or information. The result of the process is always directed to a client, whether internal or external, that is who defines and evaluates this result.

We conclude then that process is a set of tasks performed in a logical sequence that has a goal of generating an identifiable outcome that meets the previous settings by the customer, whether internal or external, thus generating a value for a specific group of customers and adding value the company.

II.2.1 PROCEDURES FOR ENTERPRISE SERVICES PROVIDER

To [6] in the service companies, the concept of process is of fundamental importance, since the sequence of activities is not always visible, or by the client or by the people who perform these activities.

For personal service companies, processes are activities sequences that are necessary to carry out the transactions and provide the service [7].

The service sector is a very sensitive market segment the customer because it is intangible, the buying process is always well researched and studied by consumers. Being intangible, which is sold is a promise according to what was requested by the client (other than a tangible product that proves it before buying).

According to [8] in this business segment the weakness is in ensuring compliance with the agreed promises to customers and so the contractors investigating the company to be deeply engaged in order to check on other services already performed before delivery capacity than is being promised also consult reviews and opinions of those who have received the provision of the same services to make sure they are minimizing the margin of error at the time of purchase.

For the service provider company to fulfill its promise to the right customer, this should have consolidated two major assets: People and Processes.

People who carry out the agreed activities shall be satisfied, motivated, skilled and engaged and processes must be mapped, modeled, diagrammed, adjusted, tested and automated.

The combination of these two well-structured assets allow the company to fulfill its role and deliver what has been agreed, exceeding customer expectations, making money from it (cashing) and continuously improving its image in the market competition.

Therefore, in the case of services, customer satisfaction goes through human interaction (people) that is directly linked to quality of service provided by the company.

Thus, it is essential that the company has a staff of skilled employees, trained, motivated and prepared for such service, and that communication client/company is very well defined, taking into account that the issue listen to the customer is an important step the service.

II.3 PROCESS MAPPING

To [9] process mapping is a management and communication tool intended to help improve existing processes or implement a new structure facing processes. Their analysis allows to reduce costs in product development and services, reducing integration gaps between systems and improves the performance of the organization as well as being an excellent tool to enable better understanding of the current processes and eliminate or simplify those require changes.

Map helps identify sources of waste, providing a common language to address the manufacturing processes and services, making decisions on visible flow so they can discuss them, adding concepts and lean techniques, which help to avoid implementing some isolation techniques forming the basis for an implementation plan and showing the relationship between the flow and the flow of information materials [10].

II.3.1 MAPPING CURRENT PROCESS (AS IS)

The first step to be taken when doing a project is to understand the existing process and identify their weaknesses so

that the present situation (As Is) process is thoroughly documented in order to have a common definition and shared the process [11].

The effect of mapping the current state, is expected to achieve [12].

• The model of the process currently in use;
• Metrics appropriate and sufficient to establish a basis for future measures to improve processes;
• Metrics and the current process performance documentation;
• Documentation of what is working well and what needs improvement.
• Identification of the most significant and rapid return items, which can be easily implemented;
• Not return to mistakes of the past.

II.3.2 PROCESS MAPPING THE FUTURE (TO BE)

According to [11] to model the future state should create a space for discussion and exchange of information between those involved in order to improve processes, Inova them and question whether it is necessary and actually adds value required the company. It is expected the modeling of the future state, the following steps.

• Process redesign or realization of a new process;
• Documentation of modifications or creation process;
• Simulation models;
• Confirming expectations of those involved regarding the changes;
• Confirmation alignment with the strategy;

II.3.3 FLOW CHART

The [2] define as flowchart a picture made with standard symbols and texts properly arranged to show logical sequence of conducting process steps or activities. Still they say that the graphic display is always a powerful communication channel, to be better absorbed and better understanding of the written texts, which require mental effort and are more subjective.

For [13] The flowchart is described as an imaging technique, in which use is made of previously agreed symbols, allowing clear and precise description of the flow of a process or sequence, as well as their interpretation and drawing.

II.3.3 USE OF BENEFITS FLOW CHART

According to [2] flowcharts insert is enriching for the working environment, because it facilitates the interpretation joint and contributes to the display of the workflow process documented. Therefore, the flowchart of use provides the following benefits: Process overview, critical details of the process visualization, process flow identification and interactions between sub-processes, identify potential control points (indicators) and identification of inconsistencies and weaknesses.

The [14] points out the following advantages regarding the flowchart: check how the components of a system; It proposes a simpler understanding and objective; facilitates the location of the deficiencies; It can be applied to any system, from the simplest to the most complex and enables rapid understanding that any changes to existing systems is proposed.

II.3.4 THE IMPORTANCE OF FLOW CHART

The [14] identifies the flow charts are important for the improvement of business processes in order to understand the inner workings and relationships between them. The flowchart then allows, through the documentation of processes, identify bottlenecks and points for improvement, areas that need to be improved.

To [15] the flowchart is important to determine the starting point; to gather, select and elect the problems priorities; to identify which activities are possible simplification and power to extinguish activities that are not being more useful and inefficiency end up bringing the proceedings. Next to that, the use of it allows us to identify the operation of any operation, regardless of its degree of complexity, allowing understanding through visual representation of how the process is run, since it maps the processes and explicit the inputs and outputs of all sub-processes.

III. MATERIALS AND METHODS

III.1 CLASSIFICATION OF RESEARCH

The study in question is classified as exploratory research, as suggested by the name, the exploratory research seeks to explore a problem or a situation to provide criteria and understanding. According to [16] it is simply used to find the cause of a problem. Exploratory research uses methods very spacious and versatile. The methods used include: surveys on secondary sources (bibliographical, documentary, etc.), experience surveys, selected case studies and informal observation (to the naked eye or mechanical).

III.2 COMPANY DESCRIPTION STUDY

This study was conducted in a metalworking company located in Curitiba- PR.

The company has mainly focused on general machining, and a service provider that provides unique pieces not so can the standardization of items produced will cease after the purchase order of its customers, therefore, has no stock of raw materials, which is only purchased to meet the application requested.

To develop the study, was analyzed as was the business process flow from the customer's purchase order to the final part of the delivery of the finished material, after this analysis was created flowchart processes of the present situation in which the company and later found to this it was an analysis of all stages and where was the opportunities for improvement.

III.3 FLOW CHART OF THE COMPANY BEFORE THE STUDY

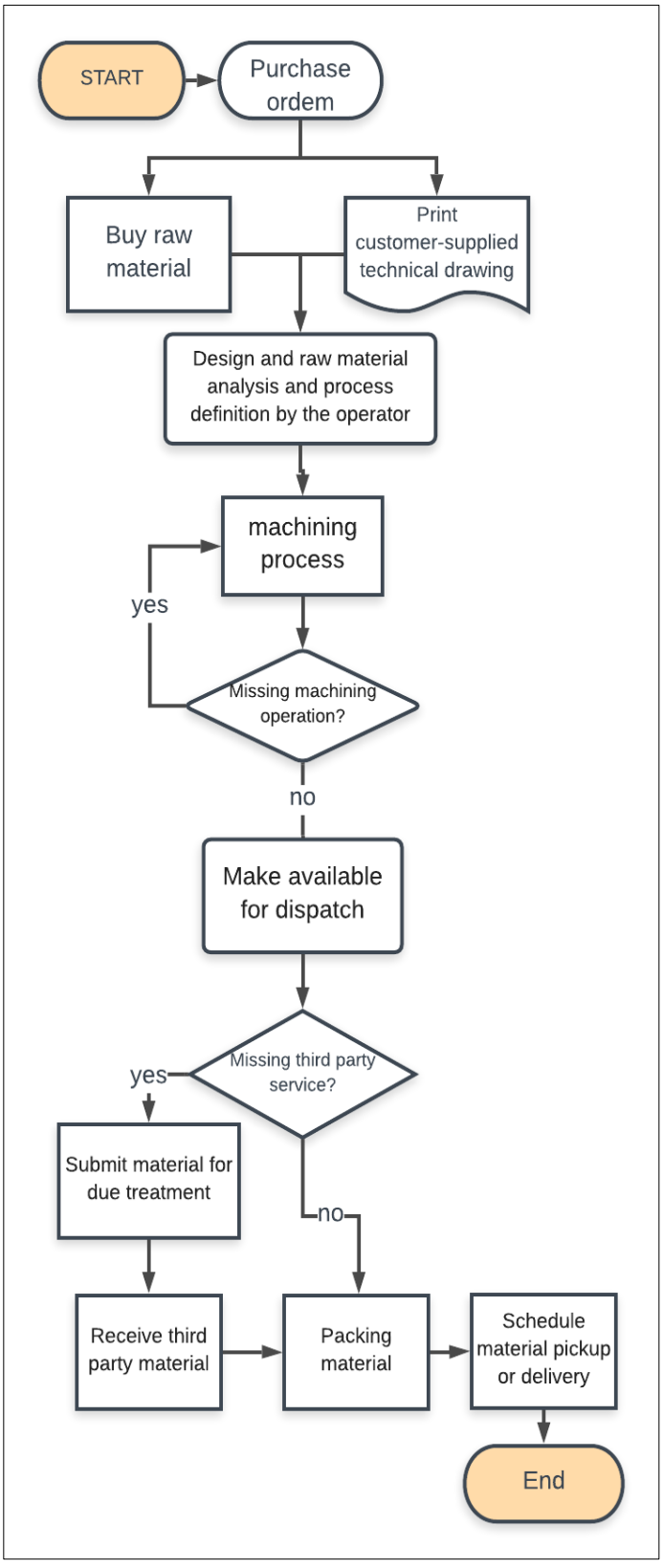

Figure 1: Flow chart of the company at an early stage.
Source: Authors, (2019).

III.4 CURRENT FLOW CHART AFTER ANALYSIS OF FAILURES

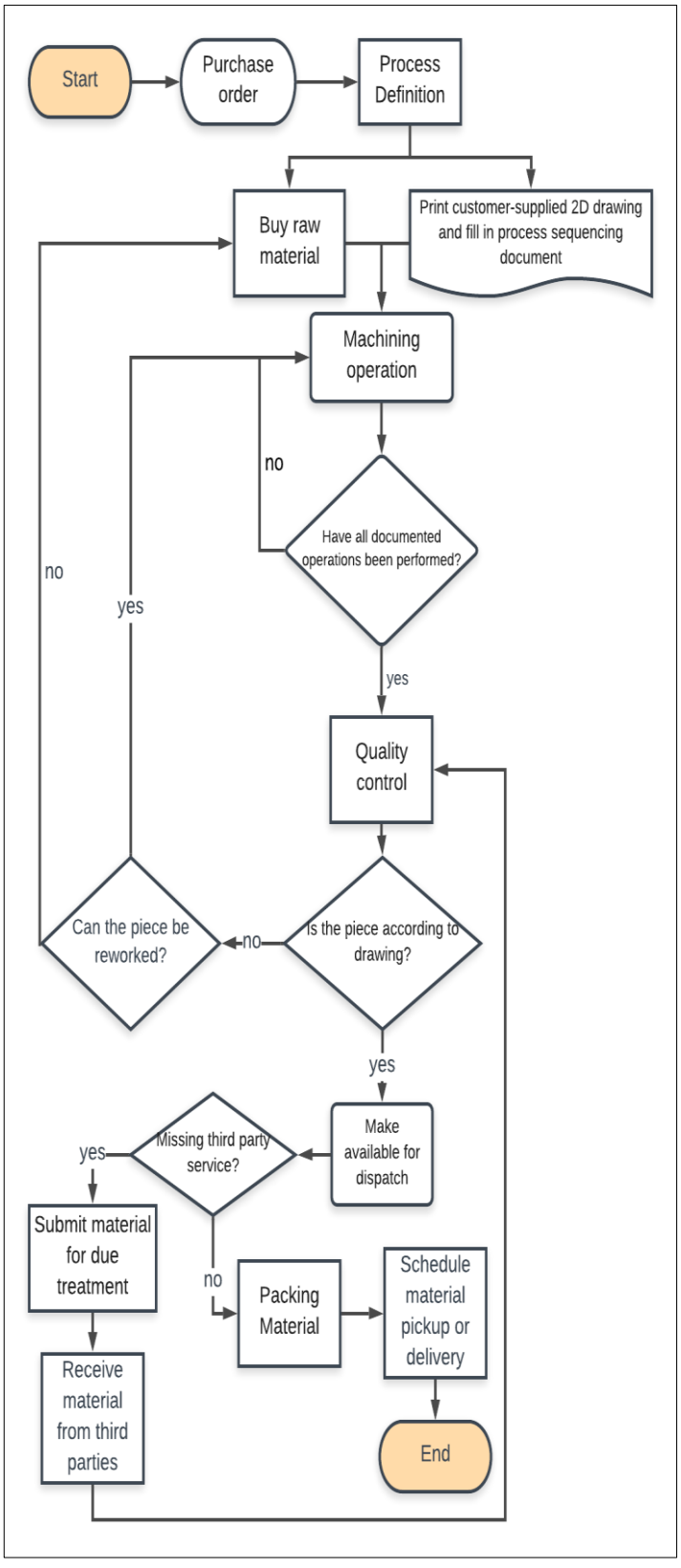

Figure 2: Current Flow chart of the company.
Source: Authors, (2019).

III.5 IMPACTS CAUSED BY CHANGES

Overall, the major improvements made were as follows:

• Every drawing sent by the customer, being attached to your back, a firm internal document where it is shown the period of delivery, the order number of production and operations to be performed for the part in question, where the operator registers its name and the time taken for such service.

- Problem: Before applying this method, the company suffered daily with the lack of a definition of what operations would be carried out as a single piece, can be reality in several different machines, thereby causing a mess in the process and even the incorrect fabrication material.

• With the date set by the customer clearer to operators, is more visible for them to know and define which parts have to be prioritized, and even set a deadline to end its operation.

-Problem: Previously, operators had no clear sequence of what parts would be machined in the day, so after finishing each task, was lost time to the definition of the next material to be machined

• With the document marking all necessary operations, reduces the risk of the piece to be released to the quality lacking some type of operation and have to return again to the factory.

- Problem: As before the implementation of this document there was still no quality control, some of the time, responsible for shipping any non-compliance found in the material, thus making the piece back to the factory, thus compromising the day of planning and preparing machine.

• With a person responsible for quality control, many errors are found before the part is delivered to the customer, was also deployed a measurement report, where 100% of the dimensions specified in the drawing are controlled in that report and sent together with the material to the customer, through greater assurance that the material is supplied according to their needs.

- Problem: Before the company count on quality control, the quality of the materials supplied were guaranteed only by the measurement of machine operators, and due to lack of time, correct tools and measuring availability, often the material was not supplied according to the specifications, generating complaints from some customers return the material after delivery, and a bad view of customers about the company.

• Any material that is carried to third parties for surface treatment, heat treatment, welding, grinders, among others, have to return to the company, and be analyzed by the quality and the dimensional also be completed report.

- Problem: It has been observed that sometimes, the stuff went straight to third parties for the client without any quality control and even look, and when he returned to the company, it was just packed with no verification.

Above was introduced some improvements made possible by the visualization of the flow chart that was the company in the initial stage, it is noteworthy that with the view clearer process to all involved, it becomes easier to see new opportunities for improvement, as the process of mapping assists in the continuous process improvement and may thus arise new idea and fixes the right time.

IV. CONCLUSIONS

In this study, we made a literature review on the mapping topic and improvement process in which after research and studies on this subject, created the flow chart in which the company was, therefore, be found numerous shortcomings and opportunities for improvement in the process, thus demonstrating the importance of a process flow well defined and as the organizational management is the basis for a company that seeks growth and competitiveness in the labor market. The presented improvements were qualitative fist, as each change made after the creation of the flowchart served as an improvement in the quality of the work environment, the quality of the supplied product and the best service in relation to the deadlines set by customers considering an improvement in the flow information and sequencing process. Note that the flowchart shown in this article, was not used in the company for analysis and process improvement, as the present study focused on demonstrating the importance of a business organization and how to create a flowchart can help companies to find gaps and opportunities for improvement, thus the flow diagram is a simplification, since the focus of the work is not complete description of operations and details that would flee the main subject matter.

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