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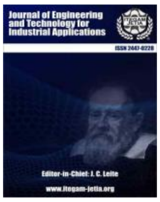

RESEARCH ARTICLE OPEN ACCESS

THE IMPACT OF MOTOR STARTING ON THE QUALITY OF THE INDUSTRIAL ELECTRICITY NETWORK

Hocine Guentri*[1], Bouchra Boutaleb[2], Bouchra Benazzedine[3] and Kabira Ezzaeri[4]

[1, 2, 3] Department of Science and Technology, Institute of Science and Technologies, Abdelhafid Boussouf University Center. Mila, Algeria.
[4] Thermodynamics and Energetic Laboratory, Faculty of Sciences, Ibn Zohr University. Agadir, Morocco.

[1] http://orcid.org/0000-0003-3720-1140, [2] http://orcid.org/0000-0002-6199-8930, [3] http://orcid.org/0000-0001-9787-7324, [4] http://orcid.org/0000-0002-3091-5557

Email: *hguentri2005@centre-univ-mila.dz, bouchraboutaleb08@gmail.com, benazzedinebouchera@gmail.com, k.ezzaeri@uiz.ac.ma

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ABSTRACT

The use of electric motors in the industrial sector has become increasingly important, especially with the development of power electronics. However, the use of these motors poses many problems, including the starting problem. Our work focuses on the study of the impact of the starting of electric motors on the quality of the industrial electricity grid, such as voltage drops during and after the starting, increasing the starting current to exorbitant values, and the starting time becoming too long. Besides, we propose solutions for these problems, such as compensation of the reactive power, insertion of VFD, and lag in the starting time of the motors. In the end, do a comparative study between these different solutions to justify the choice that is the insertion of VFD.

I. INTRODUCTION

Electric motors, due to their robustness and their weight/power ratio, are widely used in industry [1]. Ensuring their continuity of operation requires the implementation of starting systems.

The most important phenomenon is the starting process of electric motors throughout the operation of these motors. Usually, an electric motor started by power-up. However, three possibilities should be considered:

- Interference with the power supply in the form of an excessive voltage drop, which is greater than that which can be tolerated by other equipment or other consumers.
- Starting currents will add to the heating of the motor in an amount that depends on their RMS values and the starting frequency. The currents excessive can damage the motor itself, as well as the connecting cables [2].
- Starting time, which can affect the stability not only of the electric motor but the entire power system [3].

The present paper focuses on analyzing the impact of starting electric motors on the industrial electrical network. Show the different problems caused by the starting electric motors and finding solutions to these problems.

In this paper, we have proposed three solutions. The first solution is to insert batteries capacitors to compensate for reactive power and subsequently improve voltage during starting motors. The second solution is the insertion of the variable frequency drive (VFDs) to motor start gradually. The third solution is shifting the start time of the electric motors in the different production workshops. We have used a practical and powerful simulation tool that is ETAP 12.6.

The remainder of this paper organized as follows: Section II represents different motor starting modes. Section III describes the presentation of the system adopted in this paper. In Section IV the results and discussion are evaluated, and Section V presents the conclusion.

II. THE DIFFERENT MOTOR STARTING MODES

When switching on an electric motor, the current draw on the network has become high, and the section of the supply cable has become insufficient, cause a voltage drop that may affect the operation of the receivers. Sometimes this voltage drop is noticeable on lighting devices. To remedy these drawbacks, we require the use of different starting modes to reduce the current electricity. This section is devoted to the explanation of these starting modes.

II.1 THE STARTING PROBLEMS OF AN ELECTRIC MOTORS

When starting an AC motor, the three-phase asynchronous motor works like a transformer, in which the primary (stator) is under voltage, and the secondary (rotor) is short-circuited the current drawn is then very high [4]. Depending on the type and the power of the motor, the starting current can reach 4 to 10 times the rated full load current. This significant current draw of short duration that the motor could withstand it without risk of dangerous heating. Moreover, it is a hindrance to the distribution of electrical energy and the users in the vicinity on the same line, causing falls excessive voltage, which is then necessary to reduce this starting current [5].

II.2 THE STARTING CHOICE

The choice of starting conditioned by economic and technical criteria that are:

- The Mechanical characteristics.
- The desired performances.
- The nature of the electricity supply network.
- The use of the existing motor in the case of retrofitting.
- The company's maintenance policy.
- The cost of the equipment.

II.3 THE MAIN STARTING MODES

There are various starting modes and the most important starting methods used in the industry are shown below [6]:

Classic start

- Direct start
- Star-delta starting
- Starting by stator resistors
- Starting by rotor resistors
- Start by autotransformer

Soft start (electronic) [7]

- Start by an electronic converter
- Starting by frequency converter

III. SYSTEM PRESENTATION

The system proposed for this study is presented in Figure 1. Which is a small industrial production unit, consists of the following:

- A 30 kV medium voltage distribution network power source.
- Two 30 kV transformers (T1, T2) delivering to the factory 0.38 kV busbar (Bus12, Bus14). With 800KVA of power for each one, connected to the 0.38Kv busbar by two cables (cable11, cable12), with a length of 60 and 90m, respectively.
- Four production workshops:
  - Workshop1: This workshop is supplied by the main switchboard by cable 12. Consists of three production machines delivered with 0.38 kV (Mtr1, Mtr2, Mtr3) of power 60kW each one, connected to the 0.38 kV busbar, each motor connected to the busbar via a cable of a specified length. Plus, a load that represents lighting of 30KVA of power.
  - Workshop2: This workshop identical to workshop 1, is powered by the main switchboard by cable 11. Consists of three production machines supplied with 0.38 kV (Mtr4, Mtr5, Mtr6) with a power of 70KW each one, connected to the 0.38 kV busbar, each motor is connected to the busbar via a cable of a specified length. Plus, a load that represents lighting of 30KVA of power.
  - Workshop 3: This workshop is supplied from workshop 1, 0.38 kV, by cable 9. It is composed of three production machines of 70kW and lighting load of 30KVA.
  - Workshop4: This workshop is identical to workshop 1, except that it is supplied from workshop 2, by cable 13.

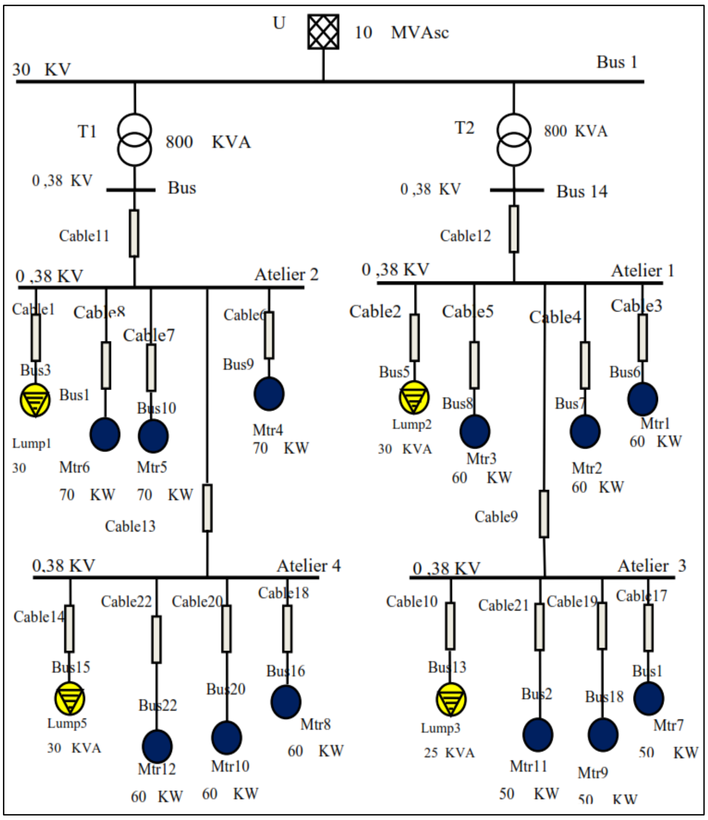

Figure 1: Structure of the proposed industrial electricity network.
Source: Authors, (2020).

IV. RESULTS AND DISCUSSIONS

In this section, simulation studies were carried out. To verify and analyze the impact of starting electric motors on the industrial electricity network, we used practical and efficient software "ETAP 12.6.", by which we ran several simulations to see the problems caused by starting electric motors and their solutions.

IV.1 POWER FLOW

Before starting the dynamic electric motor starting simulations, we found it necessary to perform the power flow simulation to check the voltage levels and see the state of this network. For this purpose, we have inserted the system represented previously in the ETAP software, which is shown in Figure 2. After running the power flow simulation, we got the results shown in the same figure.

From the power flow simulation results, we can see that the voltages are within an acceptable range according to international standard because all the voltages levels from the different workshops are above 90% and below 110%.

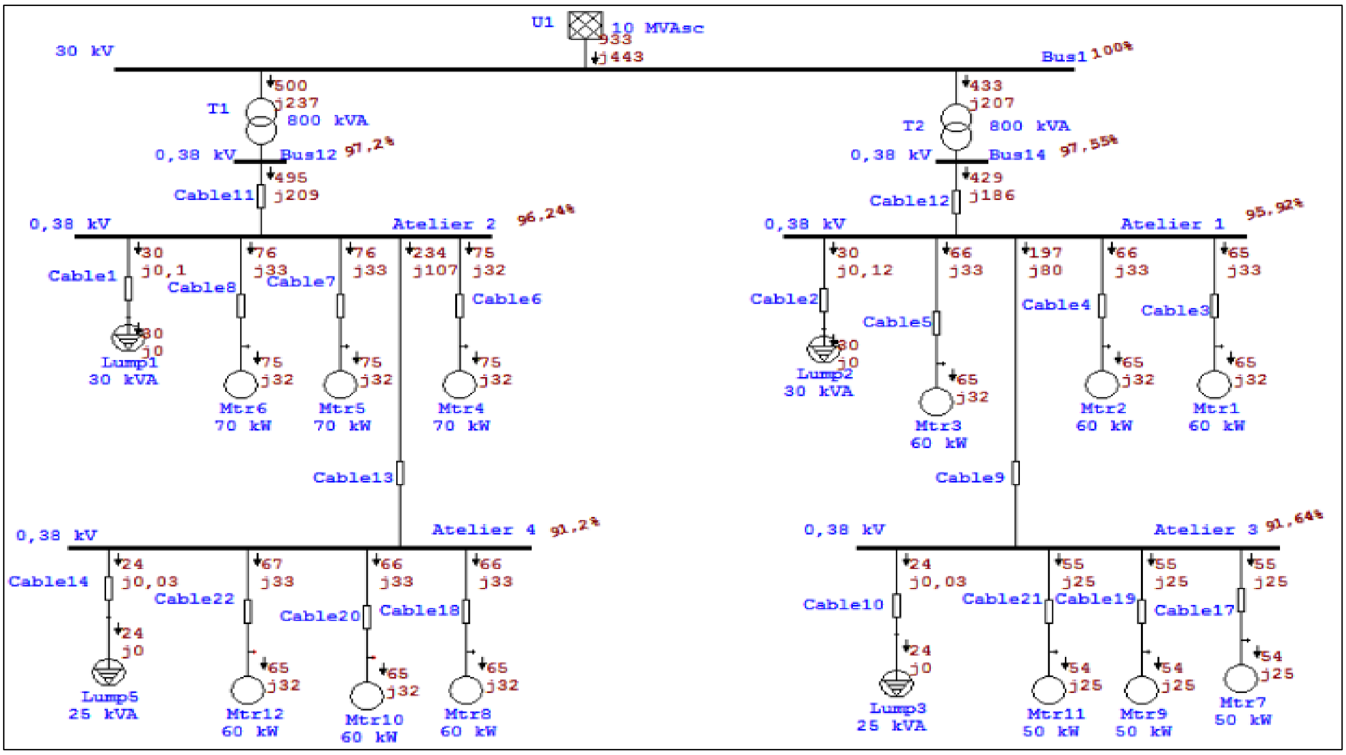

Figure 2: Power flow results.
Source: Authors, (2020).

IV.2 MOTOR START SIMULATION

After checking the condition of our network, we will run the dynamic simulation of the electric starting motor to see the impact of the starting on the industrial power grid.

In this phase, we proceeded to adjust our system, already integrated into the ETAP software, acting on the parameters, the total duration of the simulation, the starting time of each motor. After we performed the starting programming, we launched the simulation. We got the results shown in the following figures.

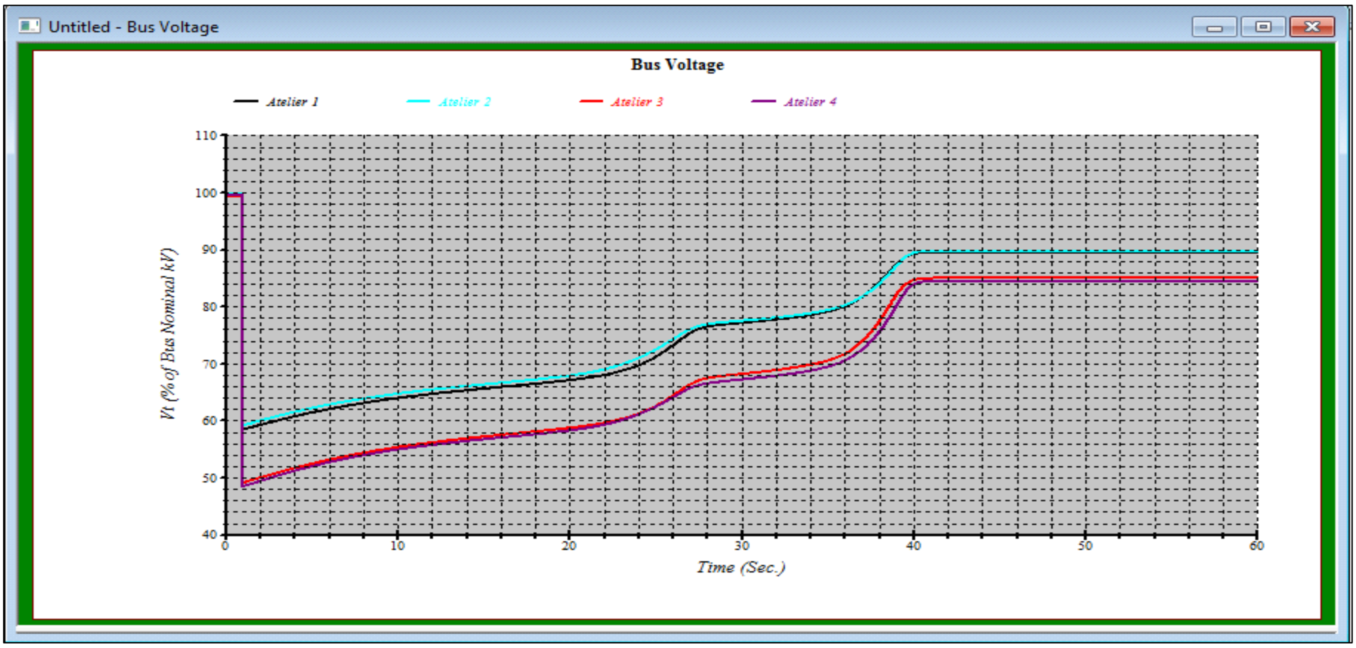

Figure 3: The voltage of the motors during the starting of the motors as a function of time.
Source: Authors, (2020).

According to these results presented in figure 3, we notice that the level of voltages during the starting is less than 60% for the two workshops 1 and 2, and less than 50% for the two workshops 3 and 4. Followed by the increase voltage gradually until the end of the starting period, the voltage reaches a level lower than 90% after a time of 40s from the starting time of the electric motors.

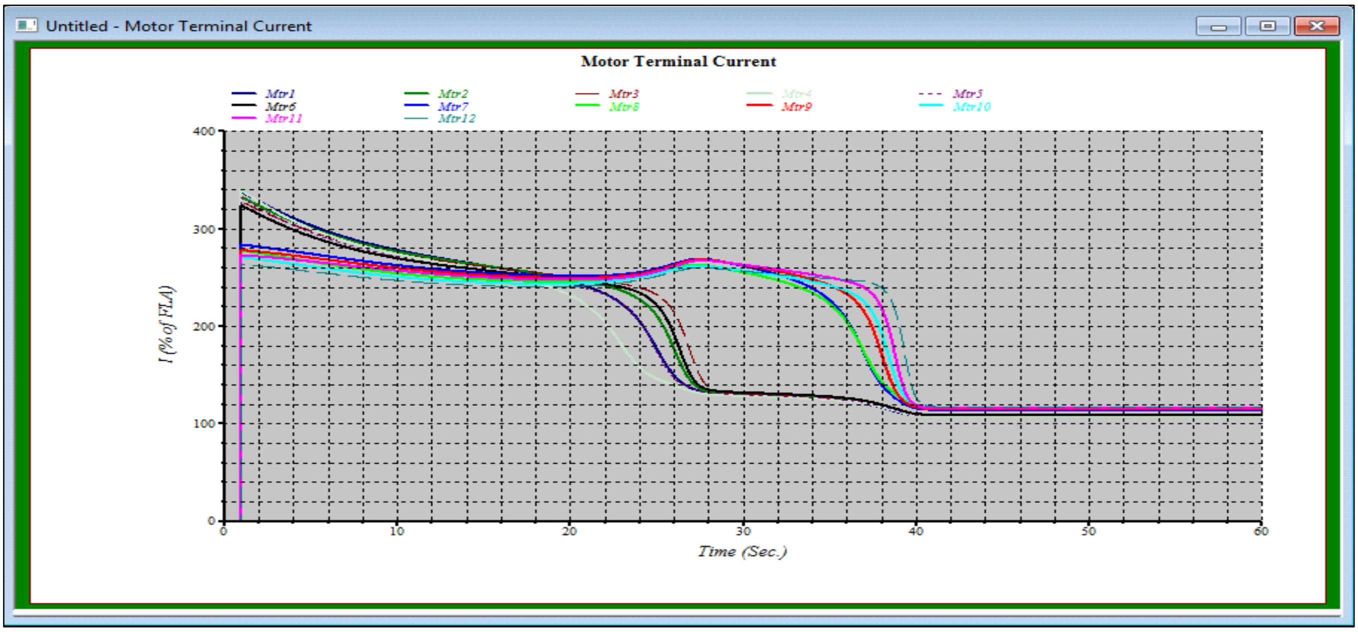

Figure 4: The starting current of the motors as a function of time.
Source: Authors, (2020).

From this simulation result, it can be seen that the starting current is approximately 300%, i.e. the starting current $I_d = 3.I_n$, and decreases to the rated current after 40 seconds.

IV.3 MOTOR STARTING PROBLEMS

From these simulation results, we can see that the starting electric motors cause the following problems:

- The starting current of the motors Id reached (Id = 3In) for a period of 40 seconds. This increase can cause the motors and the power cables to overheat, leading to the deterioration of the latter.
- The starting voltage level is reduced below 90% (less than 90%): by causing excessive voltage drops which have an influence on the industrial electrical network, this voltage drop can lead to a blackout.
- The transient period which is the period of starting motors is too long, during this period the power supply system is unstable, which can cause instability of the whole system.

IV.4 THE PROPOSED SOLUTIONS

In order to resolve the problems mentioned in the previous section, related to starting electric motors, the following solutions are proposed:

1. Insertion of capacitor banks for reactive power compensation since it concerns a voltage drop problem.
2. Insertion of frequency converters to start the machines gradually, VFD (Variation Frequency Driver).
3. The shift of motor starting time.

IV.4.1 Insertion of the Compensation Capacitor Banks

To solve the problem of the voltage drop, we have found it useful to use reactive power compensation by inserting capacitor banks. We have inserted these batteries at the level of the four production workshops, as shown in Figure 5.

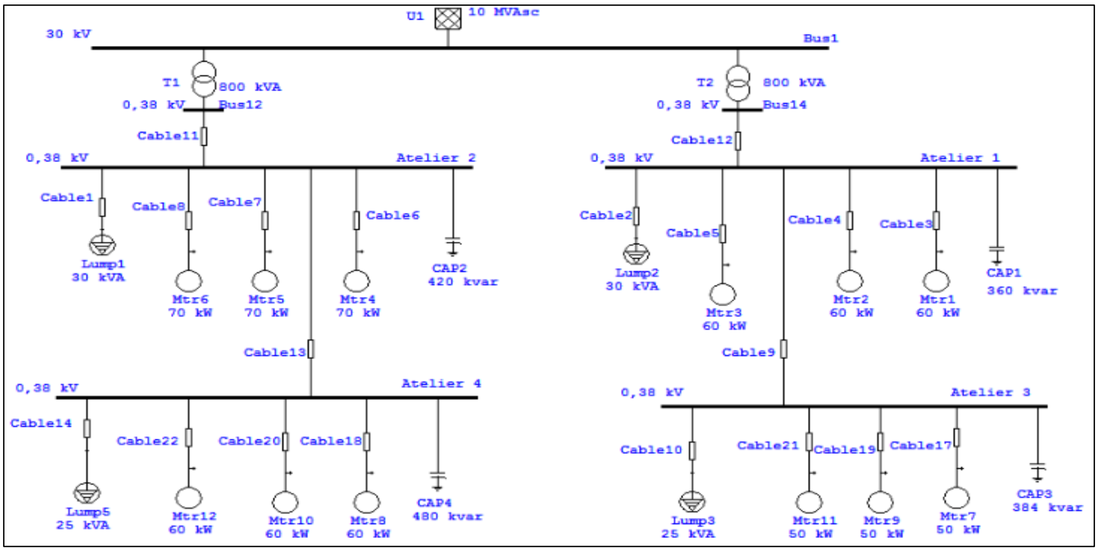

Figure 5: The Insertion of capacitor banks in the workshops.
Source: Authors, (2020).

Before starting the simulation of this part we adjusted the number of capacitor banks to find good results and improve the voltage level during the starting period. After this tuning step we started the power flow simulation, the results are shown in Figure 6.

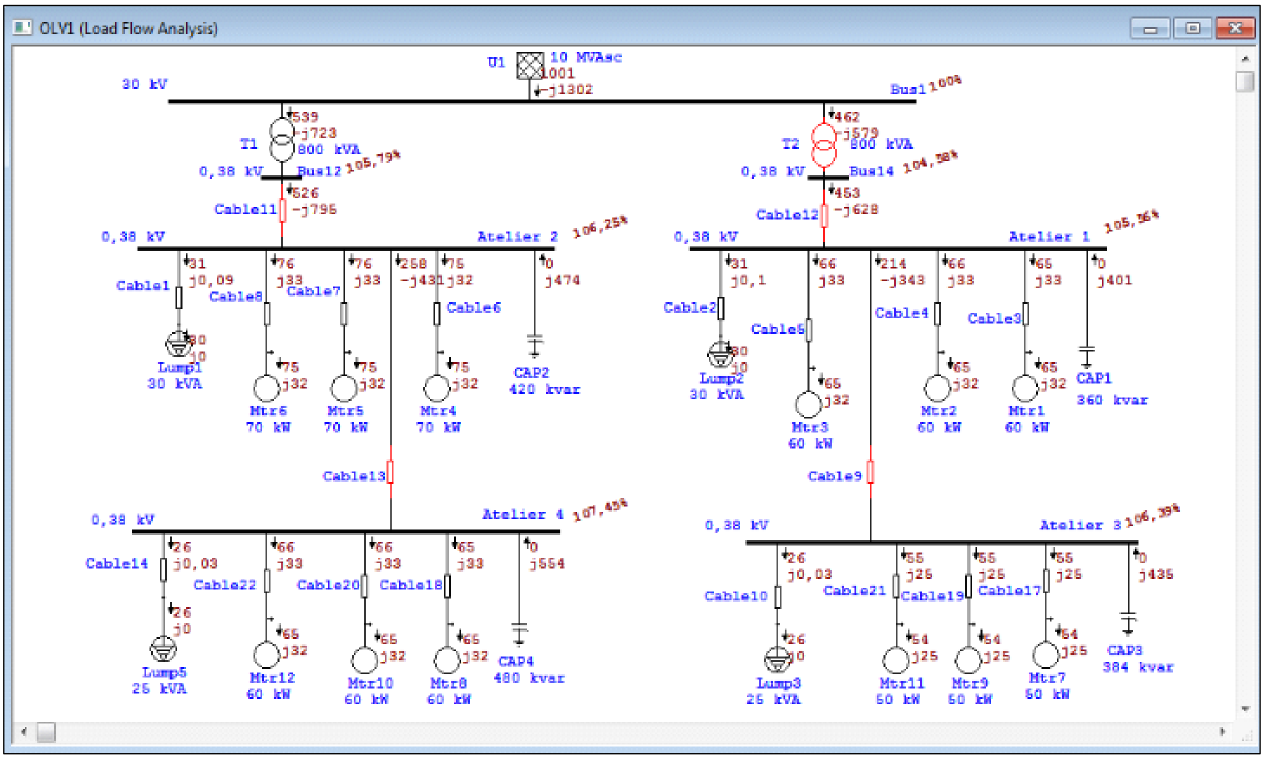

Figure 6: The result of the power flow after inserting the batteries.
Source: Authors, (2020).

From these results, it can be seen that the voltage levels are acceptable, as the voltage levels are> 90% and <110%.

After checking the voltage levels of the different workshops, we launched the dynamic simulation of the starting of the electric motors of the different machines in the different workshops, we obtained the results presented in Figure 7.

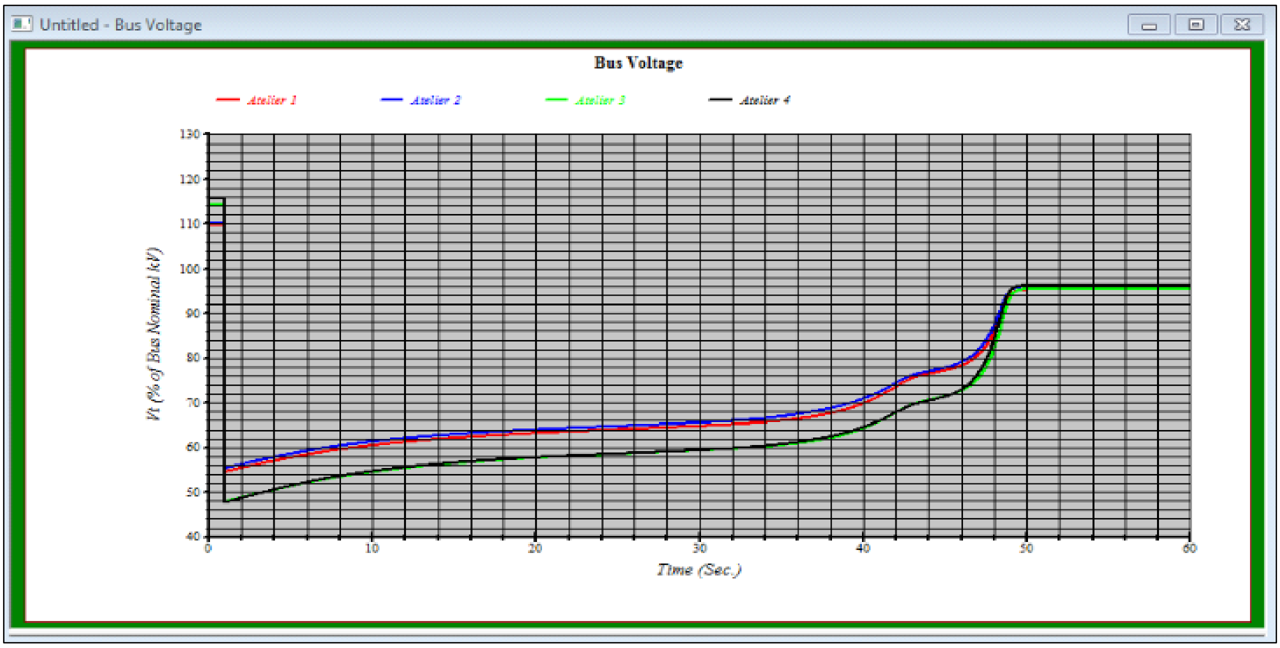

Figure 7: The starting voltage of the motors as a function of time after the insertion of the capacitor banks.
Source: Authors, (2020).

The diagram clearly illustrates that the use of compensation by capacitor banks improves the voltage during the period dynamic, i.e. after the starting period. However, during the starting time, the voltage level remains below 90%. As also seen in Figure 8, the starting current during the starting of the machines equals three times the rated current, i.e. no improvement.

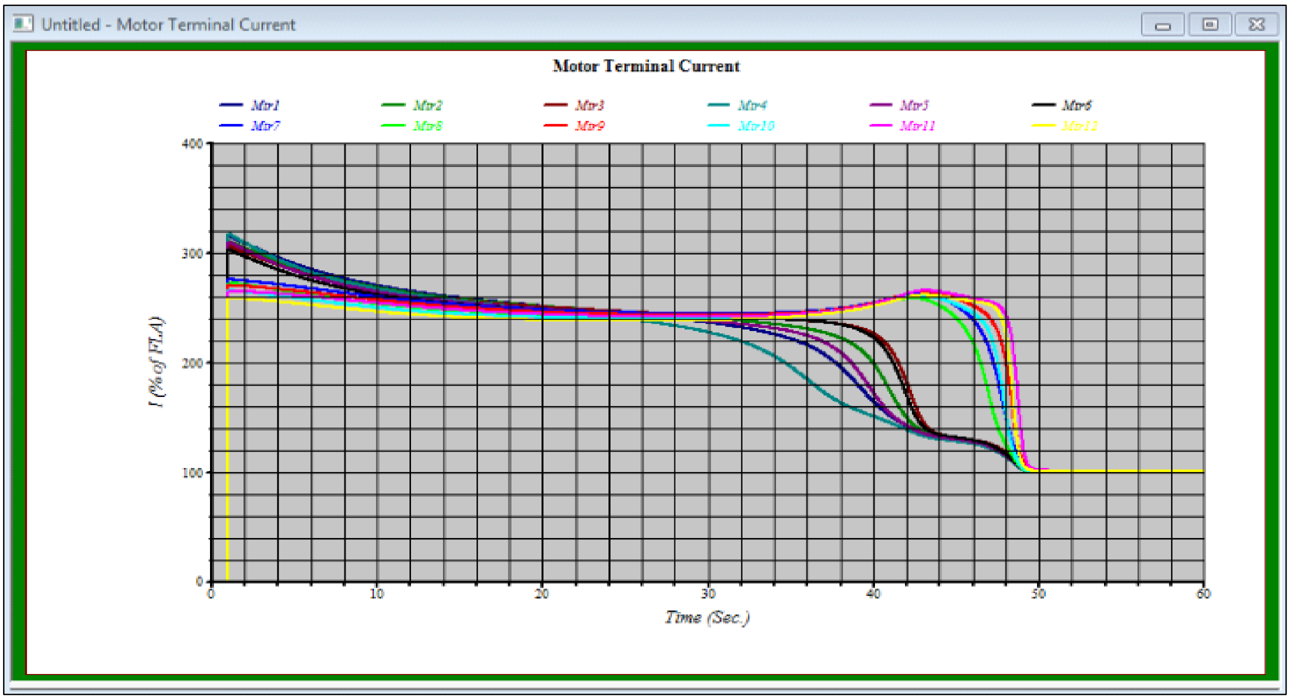

Figure 8: The starting current of the motors as a function of time after the insertion of the capacitor banks.
Source: Authors, (2020).

IV.4.2 Insertion of the Variable Frequency Drive (VFD)

The VFD is an electrical device used to adjust the speed of an electric motor used in industrial electricity. The use of VFDs will allow the acceleration of the controlled motor during the starting time by controlling the frequency [8], [9]. For this purpose, we have inserted these VFDs in series with the power supply of the motors incorporated in the production machines of the different workshops, as shown in Figure 9.

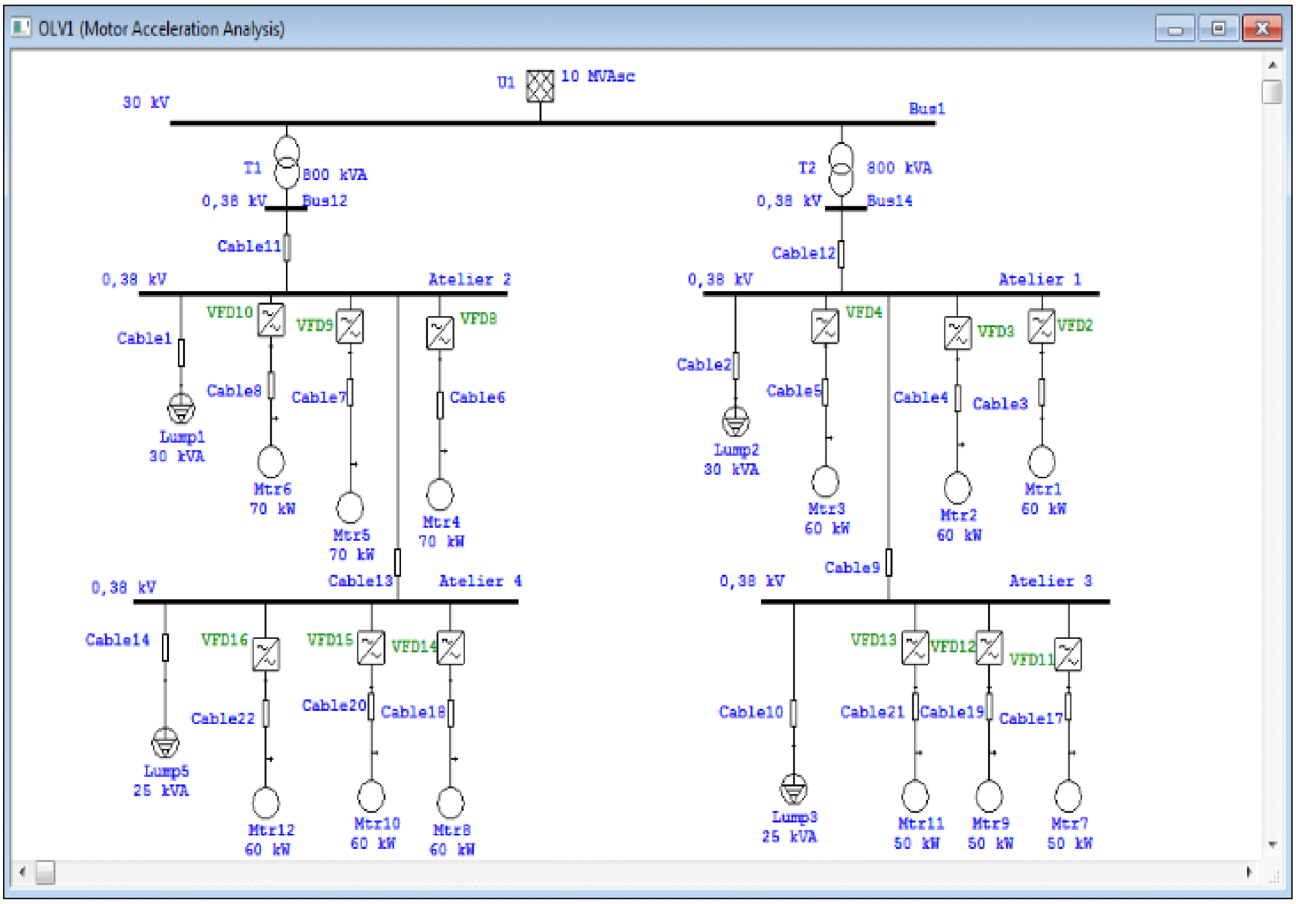

Figure 9: The insertion of VFDs into the industrial electricity network.
Source: Authors, (2020).

We proceeded to adjust these VFDs, starting with the power and supply voltage adjustment shown in Figure 10, followed by setting the start frequencies, as shown in Figure 11.

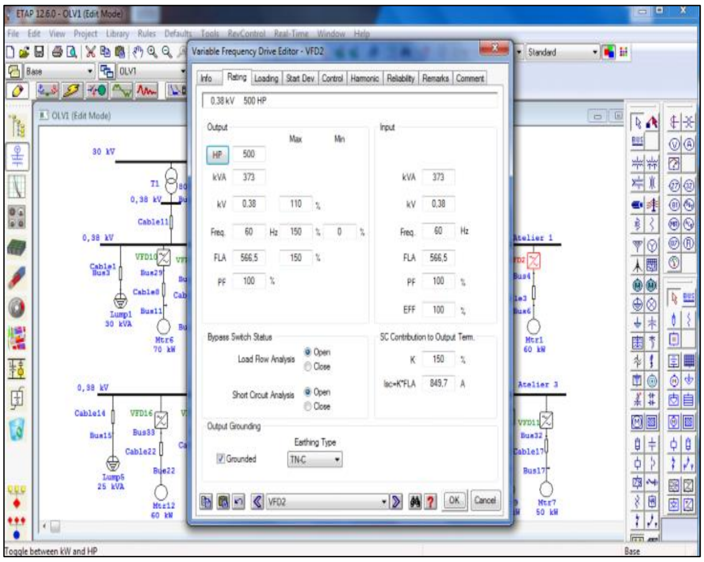

Figure 10: VFD power supply adjustment.
Source: Authors, (2020).

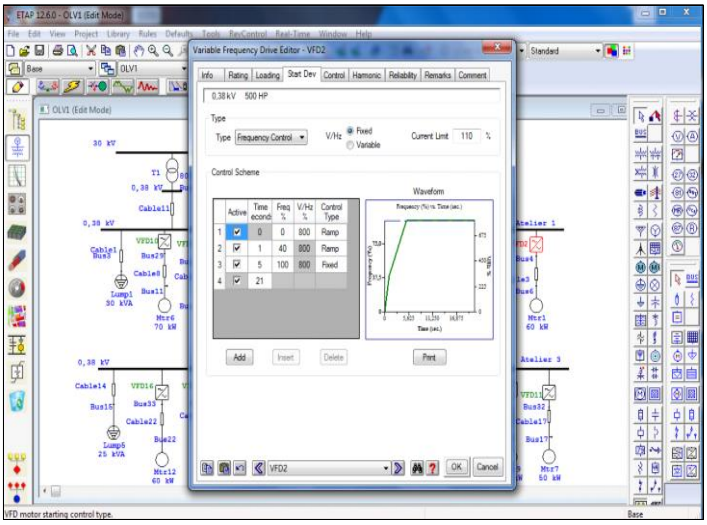

Figure 11: Setting the starting frequencies VFDs.
Source: Authors, (2020).

After this adjustment, we have checked the voltage levels by the power flow simulation, it can be seen in Figure 12 that the voltage level is <100% and> 90%, i.e. that the voltage level is acceptable.

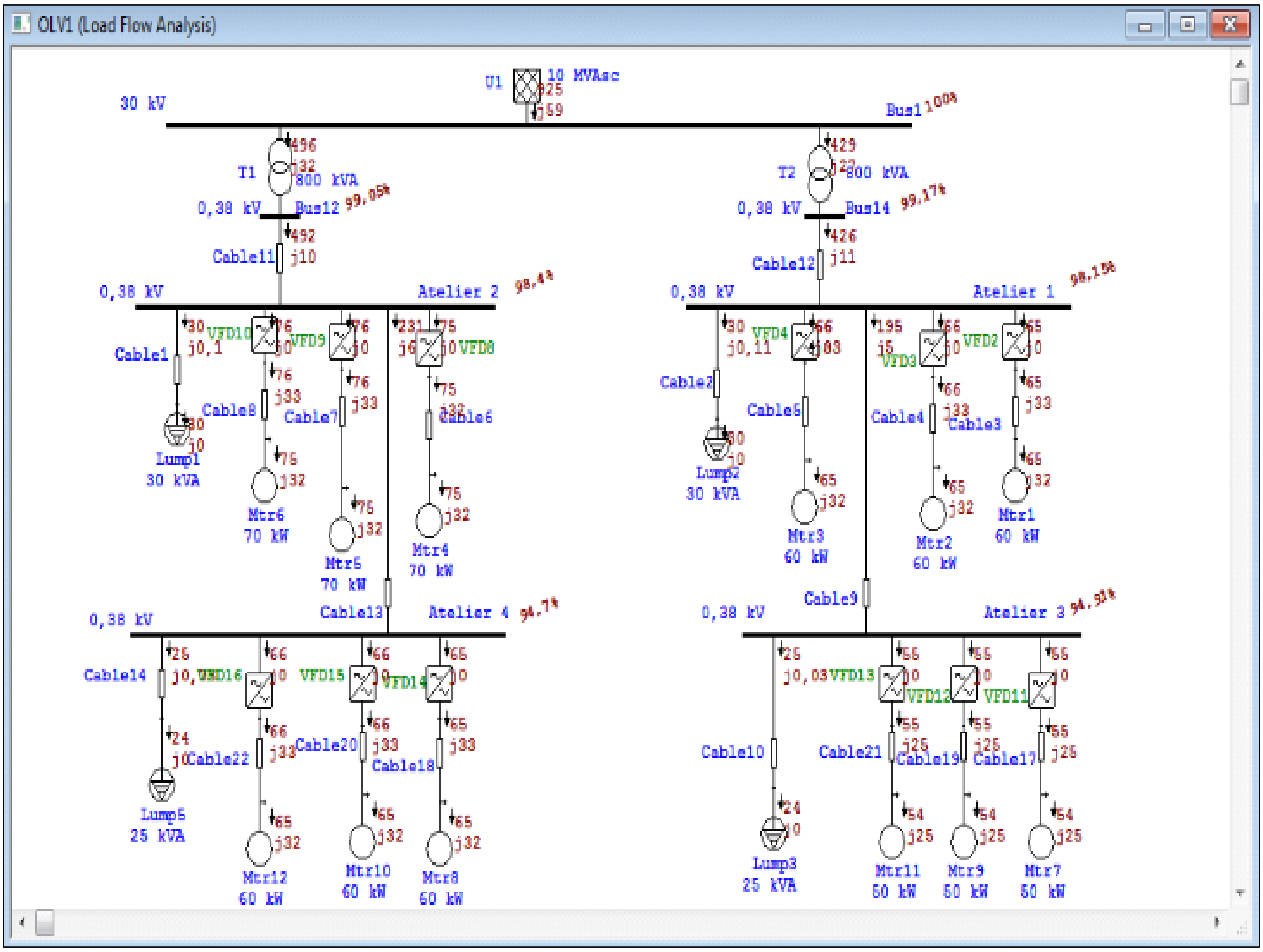

Figure 12: The power flow after insertion of VFDs.
Source: Authors, (2020).

After checking the voltage levels, we launched the dynamic simulation of the starting motor with the insertion of VFDs. The results are shown, in the following figures.

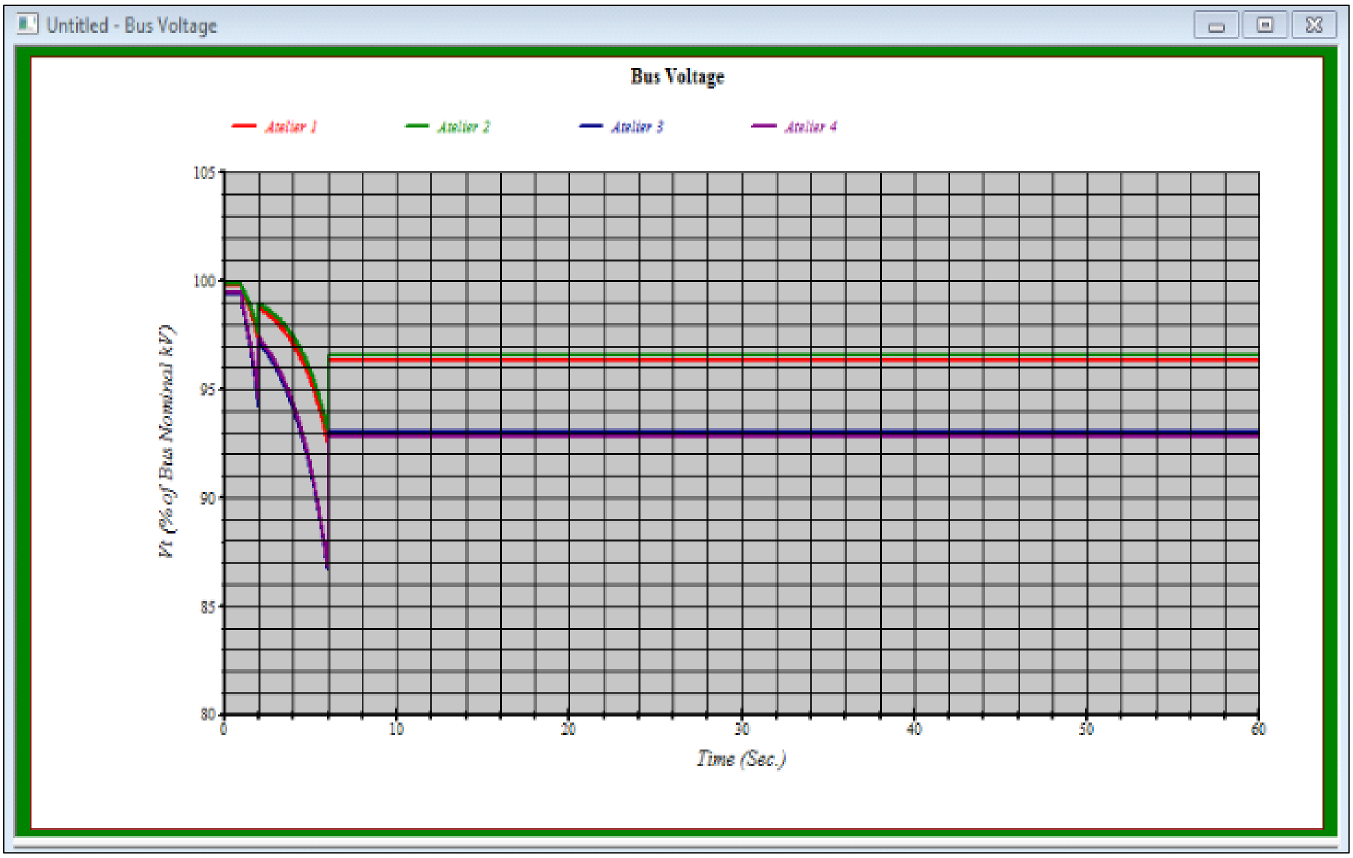

Figure 13: The voltage level after insertion of the VFDs.
Source: Authors, (2020).

Figure 14: The starting current after insertion of the VFDs.
Source: Authors, (2020).

From the results of Figure 13, it can be seen that the voltage during starting increased to 87%, and after starting i.e. during regime dynamic, the voltage level has a fixed value that is 93%. We also notice that the time starting is reduced to 8 seconds.

Also, can be seen, in Figure 14, the starting current is reduced by up to 120%, i.e. 1.2 of the rated current.

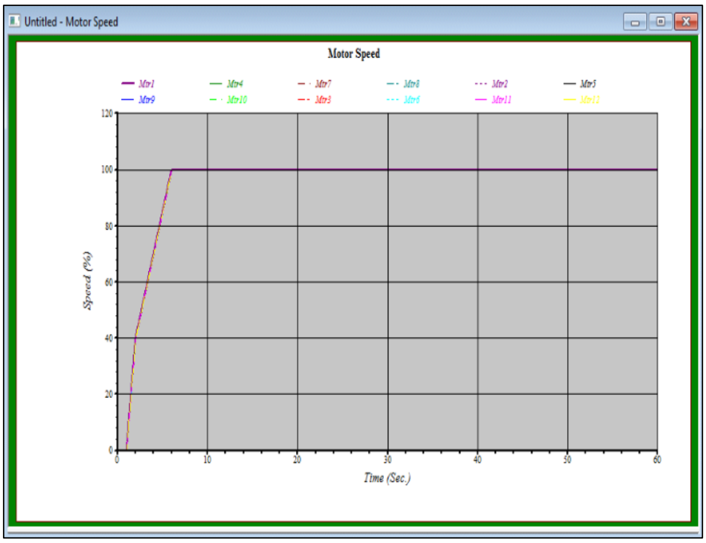

Figure 15: The starting speed after insertion of VFDs.
Source: Authors, (2020).

Figure 15 clearly illustrates that the starting speed followed the frequency adjustment made in the VFD tuning box, so the motors took 8 seconds to start and reach dynamic speed.

IV.4.3 Motors Starting Time Lag

In this phase, we tried to simulate the third part which is the shifting of the motors start time in the different workshops. For this purpose, we have adopted the following setting, as shown in figure 16. We programmed the start of the first motors of each workshop at the first second, then we programmed the start of the second motors of each workshop at the 10th second, finally, the third motors of each workshop at the 20th second.

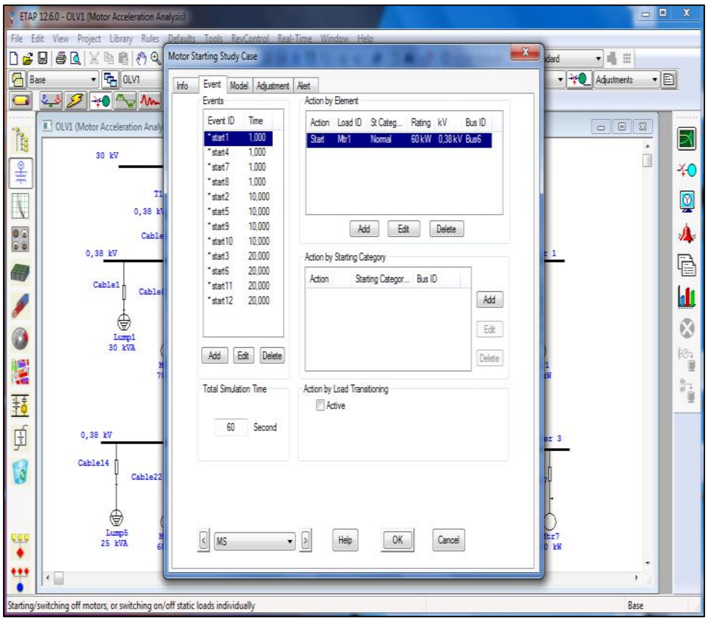

Figure 16: Adjusting the motors starting time.
Source: Authors, (2020).

After setting the starting time setting, the dynamic simulation of the starting of the motors was launched, the results obtained are shown in the following figures.

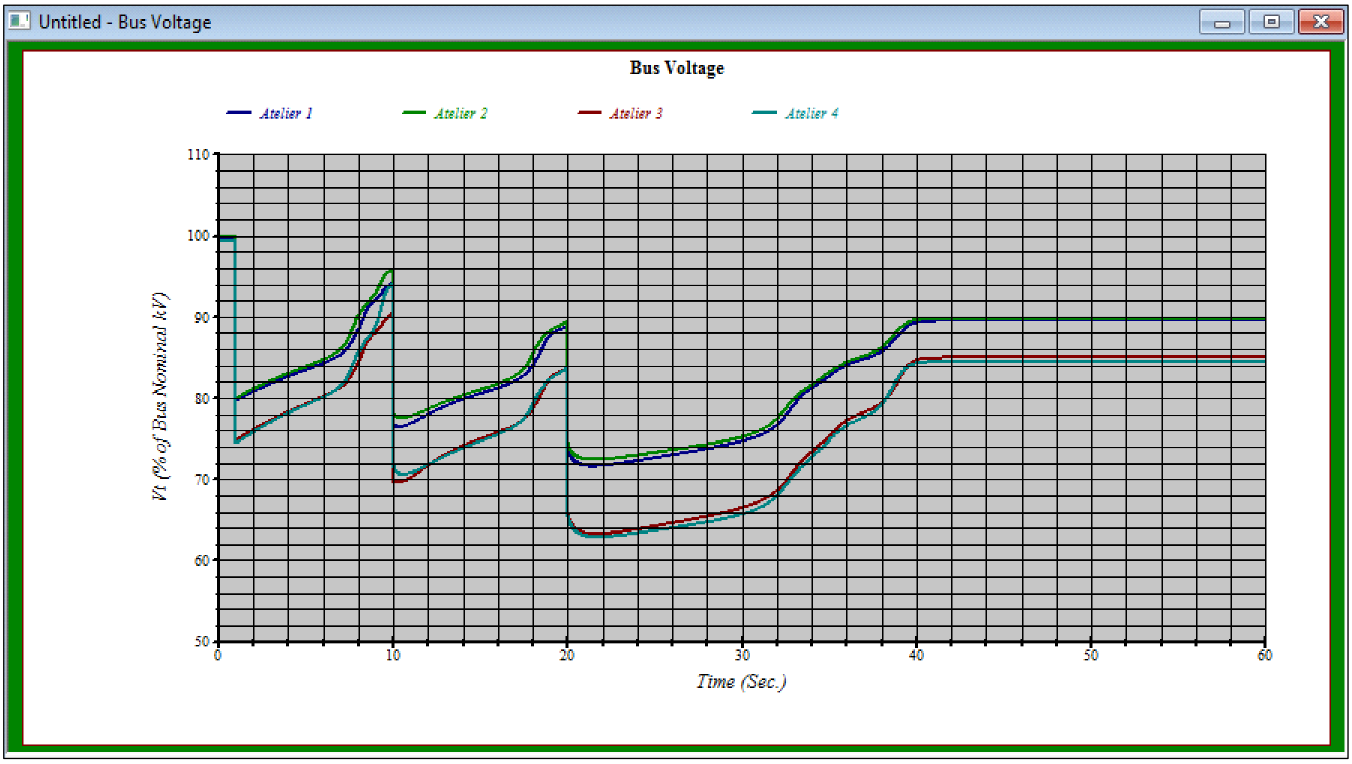

Figure 17: The Voltage level after start time delay.
Source: Authors, (2020).

Figure 17 shows the level of the voltages of the different workshops. We notice that the voltage increased to 61%, the starting period reduced between 10 and 20 seconds.

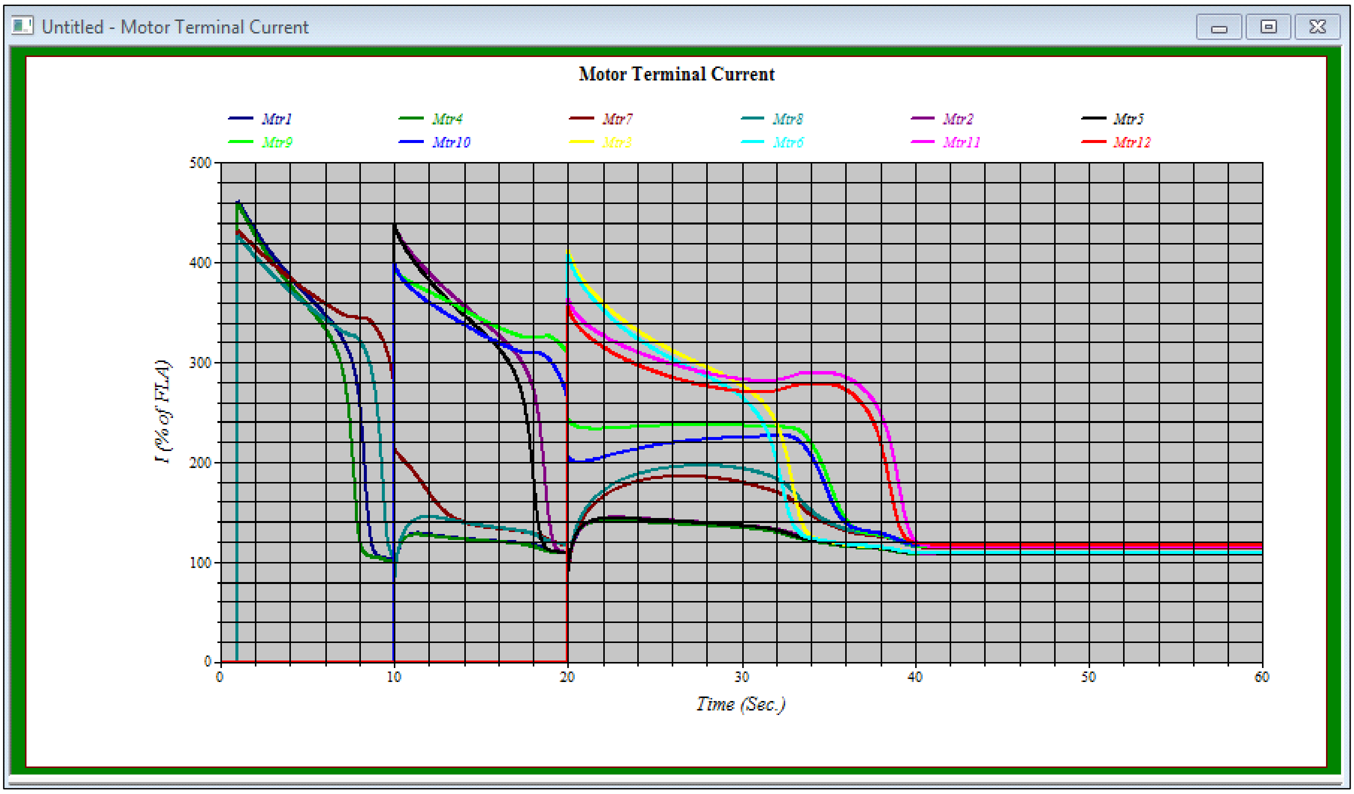

Figure 18: The starting current after the shift of start time.
Source: Authors, (2020).

Furthermore, in Figure 18, we notice that the starting current increased up to four times the rated current.

IV.5 RESULTS INTERPRETATION

It can be seen, from the obtained results, that the insertion of VFDs gives good results. The level of voltages during starting is acceptable as it is higher than 85%, after starting i.e. during steady-state the voltage level reaches a value of 97%, which is a sufficient value. The starting current reaches up to a value of 1.05 of the rated current, which is a very acceptable value. We also note that the insertion of VFDs reduces the starting time (transitional period) up to 6 seconds.

Two criteria must be verified to select and adopt a solution among the proposed solutions, which are technical and economic criteria. Technically, the insertion of the VFDs is better compared to the other solutions, but economically the choice of the start time-shifting is very suitable.

V. CONCLUSIONS

In this study, we started by presenting our system, which is composed of a 30kV power source, two 30kV/380V step-down transformers, four production workshops with their connection to the mainboard, and the various loads (machines, lighting … .Etc.) constituting each workshop.

We have created this overall system in the ETAP software by setting the parameters of each component. We started with the first simulation of the power flow verification. Also, the dynamic simulation of the motors starting launched in 60 seconds. The results obtained show that the system during the starting suffers from the following problems:

- Voltage drop during the starting time and also during the period dynamic.
- Increase in starting current up to 3 to 4 times the nominal current.
- The starting time is too long.

To solve these problems, we have proposed three solutions.

The first consists of inserting capacitor banks for reactive power compensation and subsequently improving the voltage. The second solution, inserting frequency converters to start the motors gradually. Finally, the third solution, the delay in electric motors starting.

The results obtained show that the second solution, which is the insertion of VFDs. is efficient because this solution not only improved the voltage and decreased the starting current, but it also reduced the starting period. The next step of this work is to try the insertion of the static converter.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: H. Guentri, B. Boutaleb and B. Benazzedine.
Methodology: H. Guentri and B. Boutaleb.
Investigation: H. Guentri and B. Benazzedine.
Discussion of results:H. Guentri, B. Boutaleb and B. Benazzedine.
Writing – Original Draft H. Guentri and K. Ezzaeri.
Writing – Review and Editing: H. Guentri and K. Ezzaeri.
Resources: B. Boutaleb.
Supervision: B. Boutaleb and B. Benazzedine.
Approval of the final text: H. Guentri, B. Boutaleb and B. Benazzedine and K. Ezzaeri.

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