



OPTIMIZATION OF ACTIVE POWER FILTERS USING BENDERS DECOMPOSITION FOR IMPROVED STABILITY AND RELIABILITY OF CURRENT-PULSED POWER SUPPLIES

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ABSTRACT

The increasing use of advanced nonlinear power supplies in applications such as electric heaters, switch-mode power supplies, fluorescent lamps, and air conditioning voltage controllers has led to notable concerns regarding power quality in distribution networks. These systems often inject harmonic currents, resulting in waveform distortion and energy inefficiency. Current-Pulsed Power Supplies (CPPS), which are extensively utilized in industrial processes, are particularly prone to producing such distortions. To overcome these challenges, this research proposes the use of Active Power Filters (APFs) for simultaneous harmonic mitigation and reactive power compensation. The APF design incorporates a three-level NPC inverter, where PWM techniques are applied to maintain balanced dc-link capacitor voltages while functioning in parallel with the CPPS. To further enhance system performance, the study introduces the Benders decomposition theorem as an optimization framework for achieving reliable power flow management. PI controller is utilized to regulate the DC bus voltage of the APF, selected for its fast dynamic response and ability to minimize control delays in nonlinear load environments. The proposed strategy confirm by Simulation results that significantly improves stability, reduces harmonic distortion, and strengthens the overall reliability of CPPS, thereby contributing to improved power quality in modern electrical systems.



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I. INTRODUCTION

Power quality is increasingly recognized as one of the most pressing challenges in modern power distribution systems due to the rapid proliferation of nonlinear loads and power electronic devices. The extensive adoption of semiconductor-based technologies across industrial and household applications such as switch-mode power supplies (SMPS), fluorescent lamps, electric heating systems, and air-conditioning voltage controllers—has led to significant waveform distortion and energy inefficiencies [1]. These devices, while enabling improved efficiency, are inherently nonlinear in their current-voltage characteristics. Consequently, they inject harmonic currents and reactive power fluctuations into distribution lines, resulting in voltage distortion, equipment overheating, malfunctioning of protective relays, and increased system losses [2], [3]. Traditional mitigation methods relied heavily on passive filters composed of inductors and capacitors. While simple and low-cost, passive filters suffer from notable drawbacks including fixed compensation characteristics, resonance issues, and limited adaptability under dynamic load variations [4]. To overcome these limitations, APFs have gained prominence as a flexible and dynamic solution. APFs use power electronic converters to generate and inject harmonic currents that match the magnitude of the unwanted harmonics, but opposite phase to those generated by nonlinear loads, effectively cancelling them at the point of common coupling. In addition to harmonic suppression, APFs can simultaneously provide reactive power compensation, thereby improving both system efficiency and voltage stability [5], [6].

The performance of APFs has been significantly enhanced by the evolution of multilevel inverter technologies. Compared to traditional two-level inverters, multilevel configurations generate output voltages with lower harmonic distortion, reduced switching losses, and improved efficiency. Among the different topologies, the three-level NPC inverter has become a standard choice for medium-to high-voltage applications due to its ability to share voltage stress across devices and deliver improved power quality [7], [8]. Recent innovations, such as space vector modulation and zero-sequence voltage injection, have further improved NPC inverter stability by addressing the challenge of dc-link neutral point voltage balancing [9], [10]. Another critical area of focus involves Current-Pulsed Power Supplies (CPPS), which are widely applied in electrochemical industries, including electro-deposition and surface treatment. CPPS units are designed to provide pulsed currents that enhance coating uniformity and deposition efficiency. However, the non-periodic and high-amplitude nature of these pulses contributes to severe harmonic distortions in supply networks [11]. These effects highlight the necessity of advanced harmonic mitigation strategies capable of adapting to highly dynamic nonlinear load conditions.

To address these challenges, this research proposes the integration of a shunt-configured APF based on a three-level NPC on PWM-VSI, operating in parallel with a 1 kW CPPS. The APF compensates for reactive power demand while mitigating harmonic currents. Through PWM-based control, precise regulation of dc-link capacitor voltages is achieved, thereby ensuring stability under nonlinear operating conditions [12]. The system's dynamic performance is further enhanced by incorporating a Proportional–Integral (PI) controller, which provides rapid response and eliminates steady-state error in regulating the dc bus voltage [13]. In addition to filtering and control strategies, large-scale nonlinear systems demand efficient optimization frameworks. To this end, the study employs the Benders decomposition theorem, a mathematical programming method used to decompose complex optimization problems into smaller, tractable sub problems [14]. Originally applied in mixed-integer and stochastic programming, Benders decomposition has shown promise in diverse fields such as energy markets, power system scheduling, and communication networks [15]. Its application here enables effective optimization of harmonic mitigation and reactive power compensation, ensuring both reliability and computational efficiency [16]. This research focus is especially relevant in electro-deposition applications, where pulsed power sources create highly irregular current waveforms. By combining PI-controlled NPC-based APFs with Benders decomposition optimization, the proposed methodology provides a comprehensive framework for enhancing stability, improving reliability, and mitigating harmonic distortions in CPPS-driven systems.

II. METHODOLOGY

To improve power distribution using the Bender Decomposition technique. The three-level diode-clamped inverter functions as an active harmonic compensator [17], efficiently minimizing the displacement power factor issues and mitigating the harmonic current distortions introduced by the Current-Pulsed Power Supply (CPPS). Also, utilising sophisticated methods to improve power quality and efficiency in electrical systems.

II.1 NEUTRAL POINT CLAMPED (NPC) INVERTER (3 LEVEL)

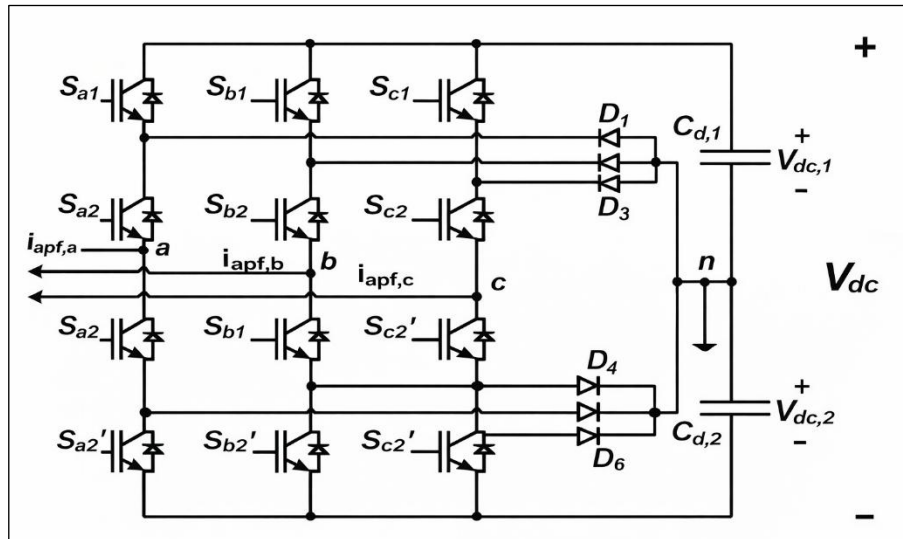


Figure 1: NPC inverter topology with Active Power Filter.

Source: Authors, (2026).

APF is connected in parallel with the CPPS to mitigate the adverse effects of harmonic distortion and reactive power demand generated during pulsed load operation as shown in Figure 1. The inverter operates on a regulated DC bus sustained bulk capacitors by two series-connected, C_{d1} and C_{d2} . These capacitors split the total DC bus voltage, V_{dc} , into two equal segments (V_{dc1} and V_{dc2}), with the midpoint 'n' serving as a neutral reference. Clamping diodes ($D1$ – $D6$) facilitate voltage equilibrium across the capacitors, allowing the inverter to produce three distinct voltage levels ($+V_{dc}/2$, 0, and $-V_{dc}/2$) for each phase. Through PWM-based switching of semiconductor devices (S_{a1} , S_{a2} , S'_{a1} , S'_{a2} , etc.), the APF injects compensating currents ($i_{apf,a}$, $i_{apf,b}$, $i_{apf,c}$) into the grid. These currents are meticulously regulated to mitigate the harmonic and reactive components in the CPPS output, thus restoring sinusoidal current profiles at the point of common coupling (PCC). This methodology enables effective harmonic suppression, balanced reactive power compensation, and improved power quality under CPPS-based operating conditions. illustrates how temperature affects lithium-ion battery performance by showing trends in battery capacity, cycle life, and internal resistance.

As temperatures rise, battery capacity generally increases, while the cycle life reaches a peak around 25 °C and then declines at higher temperatures. Internal resistance remains relatively stable but shows slight variations. This underscores the importance of optimal thermal management for battery efficiency and longevity.

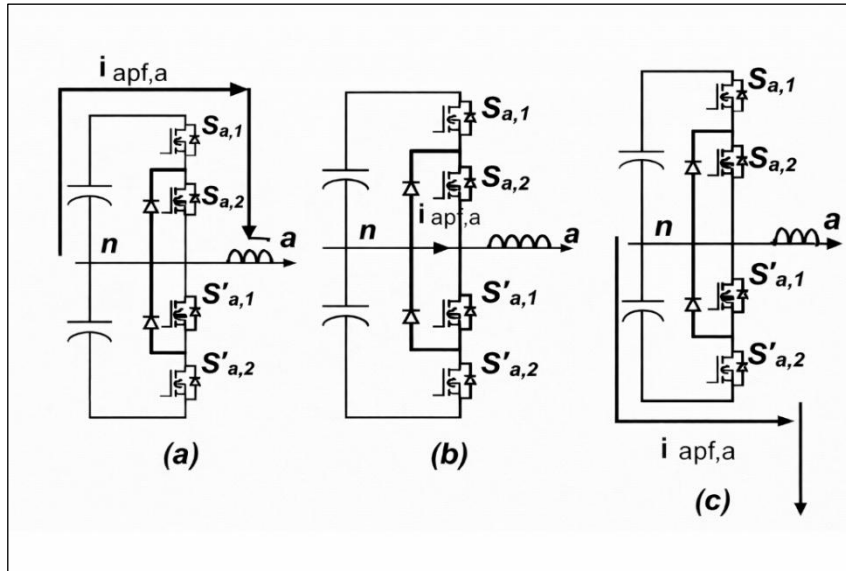


Figure 2: Operation modes of NPC -PWM –VSI.

Source: Authors, (2026).

The operation of the proposed NPC Pulse Width Modulated Voltage Source Inverter is illustrated in Figure 2. Each phase leg of the inverter is capable of generating three distinct voltage levels across the terminals, thereby enabling effective compensation of reactive power and harmonics. In Figure 2(a), the switching sequence for generating a positive voltage level is shown. When switches S_{a1} and S_{a2} are turned ON, the phase terminal 'a' is connected to the positive dc-link voltage, resulting in $v_{an}=+V_{dc}/2v$. For achieving a zero-voltage state, as represented in Figure 2(b), the switches S_{a2} and S'_{a1} are activated along with the clamping diodes, ensuring that the terminal 'a' is clamped to the neutral point. This condition maintains $v_{an}=0$ allowing current to flow through the appropriate path depending on the direction of the load current $i_{apf,a}$. In Figure 2(c), the negative voltage level is obtained by switching S'_{a1} and S'_{a2} . Under this mode, the terminal 'a' is connected to the negative dc-link, resulting in $v_{an}=-V_{dc}/2$. The switching devices operate at the carrier frequency f_{sf} to ensure SPWM. A similar control strategy is employed in phases 'b' and 'c' to produce balanced three-phase voltages v_{bn} and v_{cn} .

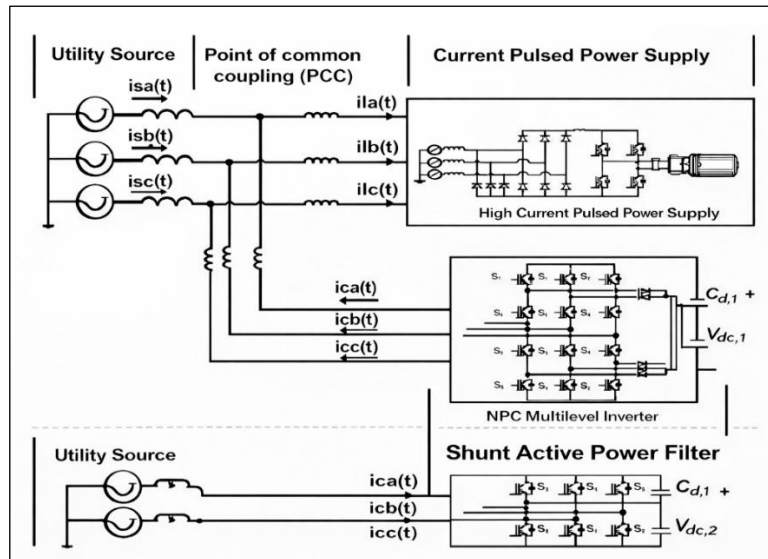


Figure 3: Three-level NPC APF and CPPS Parallel connections.

Source: Authors, (2026).

The integration of the inverter with the CPPS is depicted in Figure 3. The CPPS is directly connected to the PCC with the utility grid. Due to the highly non-linear characteristics of the CPPS, significant current distortions are introduced into the supply system. To mitigate these distortions, a shunt APF based on a three-level NPC inverter is employed. The APF, consisting of twelve IGBT switches and six clamping diodes, is connected in parallel with the CPPS. By injecting compensating currents ($i_{ca}(t)$, $i_{cb}(t)$, $i_{cc}(t)$) in opposition to the harmonic components drawn by the CPPS, the APF ensures that the source currents ($i_{sa}(t)$, $i_{sb}(t)$, $i_{sc}(t)$) remain sinusoidal and in phase with the supply voltages. This configuration enhances the power quality at the PCC by reducing THD, providing reactive power compensation, and improving the overall stability of the system under non-linear loading conditions.

II.2 METHOD OF APF CONTROL

The control strategy employed for the proposed system ensures rapid and accurate calculation of reference currents [18] to maintain the stability of the dc-link voltage (V_{dc}) and to generate appropriate gating signals for the APF. This is achieved using a PWM-based current modulation approach, which not only facilitates precise reference tracking but also incorporates modulation principles suitable for the three-level NPC inverter structure. The use of a multilevel PWM inverter offers significant advantages when operating as a current compensator. First, it reduces the generation of harmonic currents, thereby minimizing the stress imposed on the utility supply. Second, it enables effective handling of higher power ratings, resulting in improved efficiency, enhanced power quality, and overall system stability. Figure 4 illustrates the system configuration, where the APF operates in equivalent with a non-linear Current Pulsed Power Supply (CPPS) at the PCC. The APF is regulated by deriving reference currents from the supply voltage signals, while a three-phase SPWM generator develop the gating pulses for driving the inverter switches. Initially, the APF supplies compensating current towards the CPPS non-linear load [19]. When the inverter-generated currents are injected through the PCC, the source current components $i_{sa}(\omega t)$, $i_{sb}(\omega t)$, and $i_{sc}(\omega t)$ are corrected. This compensation process ensures that the input currents drawn from the utility remain sinusoidal supply voltages, effectively mitigating the harmonic distortions and reactive power demands introduced by the CPPS. Through this coordinated operation, the APF maintains stable dc-link voltage, ensures efficient compensation of load-induced disturbances, and significantly enhances the overall quality of power delivered at the PCC.

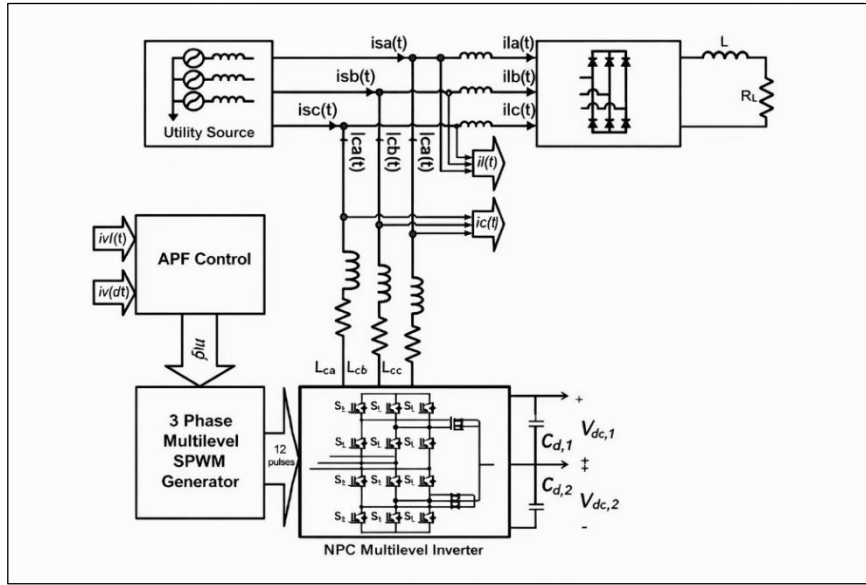


Figure 4: Circuit diagram of APF connected to CPPS.
Source: Authors, (2026).

II.3 OPTIMIZATING POWER USING BENDERS DECOMPOSITION THEOREM

In this research, the Benders decomposition algorithm is employed as an effective tool for power optimization [20], particularly in addressing the complexity of Mixed Integer Programming (MIP) problems that involve both integer decision variables and coupling constraints. Instead of solving the entire problem directly, the approach decomposes it into two smaller, more manageable parts that are solved iteratively. The master problem deals with the binary or integer variables, such as switching states and discrete control actions of the inverter, while the subproblem focuses on continuous variables, including voltages and currents, formulated as a linear programming task to ensure compliance with system constraints. During each iteration, feasibility and optimality cuts are generated to progressively refine the master problem, thereby accelerating convergence toward the optimal solution. In this study, the measured supply currents and voltages at the PCC are considered as inputs, while the optimized voltage reference serves as the output that governs the modulation of the three-level NPC inverter. By applying this decomposition strategy, the computational burden of the optimization process is significantly reduced [21], allowing parallel solution of sub problems, improving convergence speed, and enhancing the precision of voltage reference generation. Consequently, the method ensures improved harmonic suppression, reactive power compensation, and stability of the Active Power Filter (APF), thereby maintaining high-quality power delivery under nonlinear loading conditions.

$$\min_{(x,y)} c^T x + f^T y$$

$$\text{s.t. } Ax + By \geq b$$

$$\forall x_i \geq 0, \forall y_j \in \{0,1\} \quad (1)$$

Here, x and y are vectors of continuous variable x_i and binary variable y_j (representing voltage) and current sources), the coefficients of the objective function are denoted by c and f , while the constraint equations are defined by the coefficient matrices M and N . The notation $(\cdot)^T$ denotes the transpose operation. The solution to this equation is derived through iterations using Benders' Decomposition concept. For the k -th iteration, the first sub-problem is formulated as:

$$\text{s.t } M^T u \leq c,$$

$$\max_u (b - Ny^{(k-1)})^T u \quad (2)$$

And the second sub-problem is the relaxed master problem:

$$\min_{y, \theta} z + f^T y$$

$$S.t. (b - Ny)^T \bar{u}^{(m)} \leq z, \forall m = 1, \dots, k_1,$$

$$(b - Ny)^T \bar{u}^{(l)} \leq 0, \forall l = 1, \dots, k_2,$$

$$\forall y_j \in \{0,1\} \quad (3)$$

II.4 POWER QUALITY IMPROVEMENT WITH PI CONTROLLER

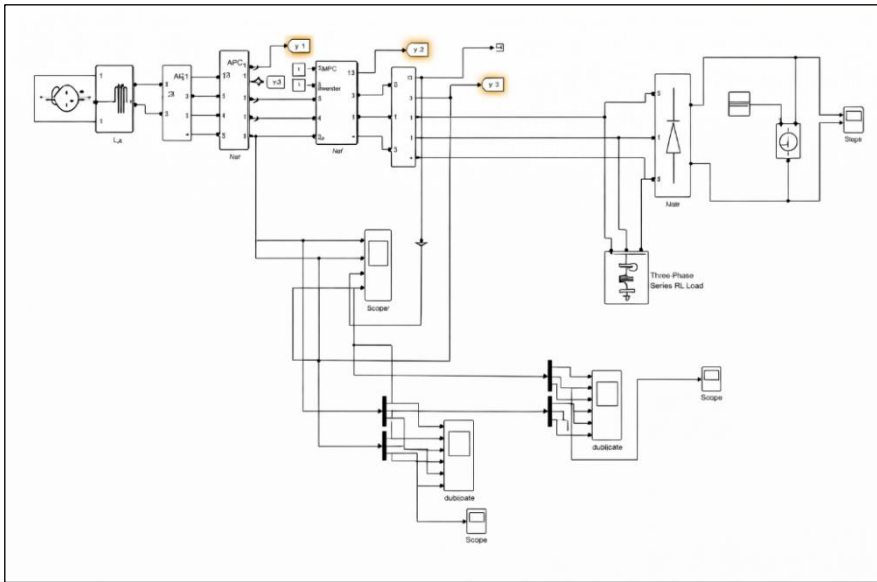


Figure 5: Benders decomposition theorem based active power filter with CPPS.
Source: Authors, (2026).

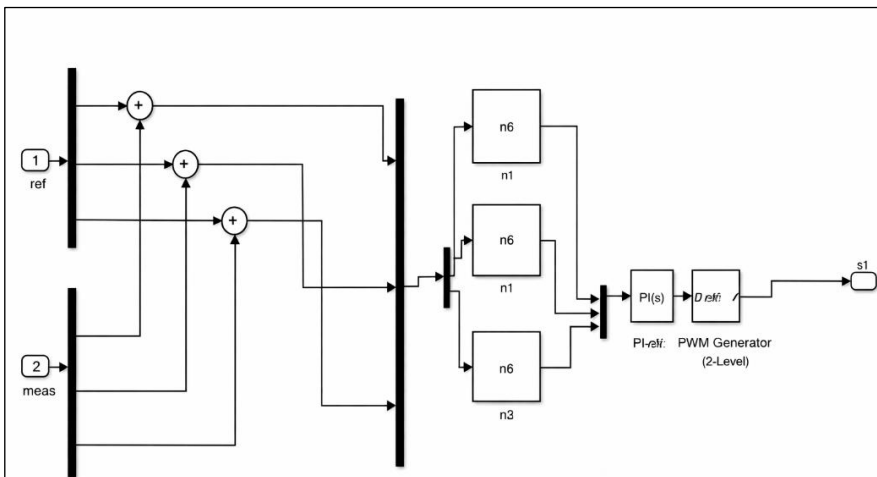


Figure 6: Schematic of Benders decomposition theorem along with PI controller.
Source: Authors, (2026).

In the proposed approach, a PI controller is integrated with the regulated DC-link voltage of the APF (Figure 5) to enhance power quality by suppressing harmonic distortions and compensating reactive power associated with nonlinear loads. The controller operates by constantly monitoring the capacitor voltage and comparing it with the reference value. The resulting error signal is then utilized to regulate and stabilize the DC bus voltage as shown Figure 6. To prevent the influence of high-frequency components, this error is filtered through a Butterworth LPF, allowing only the essential control signals to pass through. Based on this processed signal, the PI controller determines the necessary peak reference current required to maintain stability of the DC-link voltage.

$$H(s) = K_p + K_i/s \quad (4)$$

Where $K_p=0.7$ and $K_i=23$ define the proportional and integral gains, respectively. The proportional action ensures a rapid dynamic response to sudden changes, while the integral component eliminates steady-state error, thereby maintaining the voltage at its desired level. Once the voltage regulation is achieved, the controller output is converted into Pulse Width Modulation (PWM) gating signals. These PWM signals, consisting of pulses with varying widths, govern the switching of the inverter devices and allow precise control of the DC-side voltage, leading to effective compensation and improved system performance.

III. RESULTS AND DISCUSSION

Extensive simulations were performed to evaluate the effectiveness of a three-level NPC Pulse Width Modulation VSI combined with the Benders Decomposition technique for Active Power Filtering (APF). The system was modeled and analyzed using MATLAB/Simulink, and the initial outcomes demonstrate highly encouraging results. The findings clearly indicate that the application of a shunt APF considerably minimizes harmonic distortions present in the source current. This validates the effectiveness of the proposed methodology in improving power quality and highlights its capability to mitigate the adverse impacts of harmonic disturbances.

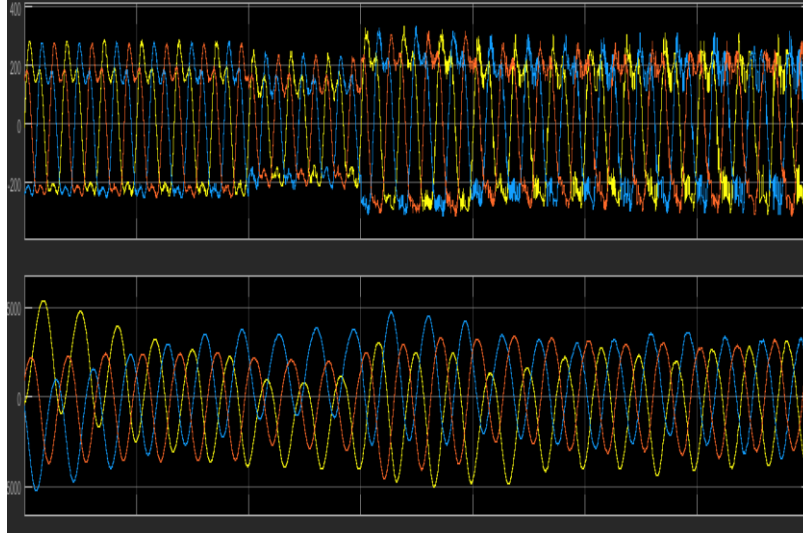


Figure 7: Voltage and Current without Compensation.
Source: Authors, (2026).

Figure 7 shows the behaviour of the system when no compensation technique is applied. The voltage waveform remains nearly sinusoidal, but the corresponding current waveform is highly distorted because of the nonlinear characteristics of the Current Pulsed Power Supply (CPPS). These distortions indicate the presence of significant harmonic components, which not only degrade the quality of power but also increase the Total Harmonic Distortion (THD) beyond acceptable limits. Such conditions can lead to overheating of equipment, additional losses in the distribution network, and reduced overall efficiency of the power system. The results emphasize the necessity of incorporating an Active Power Filter (APF) to counteract the adverse impact of nonlinear loads on source currents.

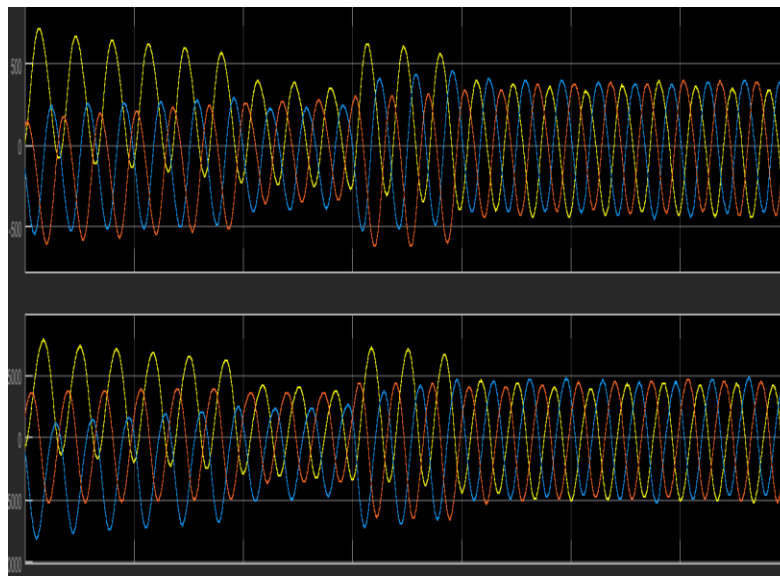


Figure 8: Voltage and Current with Compensation (Using APF).
Source: Authors, (2026).

Figure 8 presents the compensated waveforms when the proposed three-level NPC inverter-based APF is introduced into the system. It is evident that the current waveform is now much closer to a sinusoidal profile and is well aligned with the supply voltage. This improvement is achieved because the APF delivers compensating currents at the PCC, which match the harmonic components of the nonlinear load in magnitude but are phase-shifted by 180° , thereby neutralizing their effect.. As a result, the distorted load current is effectively neutralized, leading to smoother current flow and improved power factor. Moreover, the dynamic response of the system is enhanced, ensuring that even under sudden load variations the APF continues to maintain waveform quality. These results highlight the capability of the proposed control approach to stabilize system performance and improve the quality of power delivered to the grid. Figure 9 depicts the harmonic spectrum analysis, focusing on the THD levels of the source current. Without compensation, the THD is considerably high, confirming that nonlinear loads severely distort the current waveform. After applying the APF, the THD value is drastically reduced, validating the efficiency of the proposed method in suppressing harmonics. The significant reduction in THD ensures that the source current complies with IEEE-519 harmonic distortion standards, thereby protecting both the grid and connected equipment from the negative effects of harmonics. Lower harmonic distortion also translates into reduced power losses, minimized stress on transformers and cables, and extended lifespan of sensitive electronic devices. The results collectively confirm that the APF not only restores sinusoidal current waveforms but also ensures stable voltage regulation, improved system efficiency, and consistent operation of the overall system.

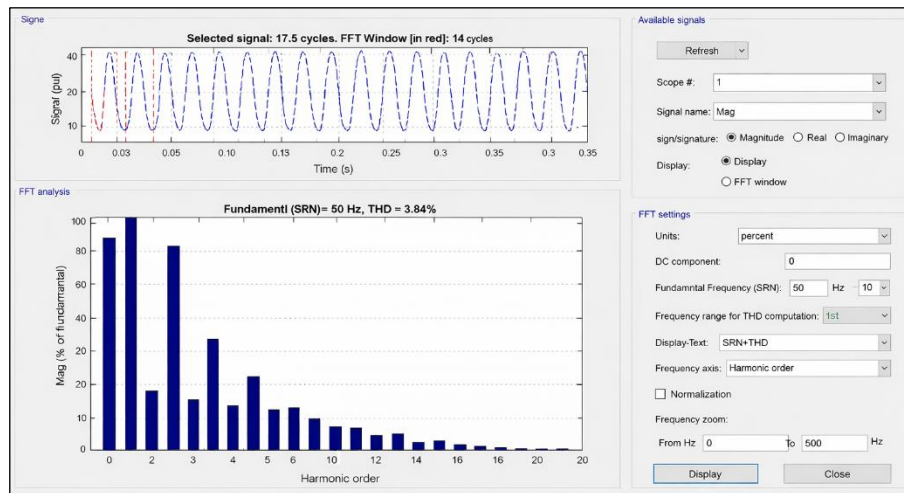


Figure 9: Harmonics (THD value).

Source: Authors, (2026).

IV. CONCLUSION AND FUTURE WORK

This research presented a novel approach that integrates the Benders Decomposition algorithm with a three-level NPC Pulse Width Modulation VSI based APF to improve the performance of Current-Pulsed Power Supply systems operating under nonlinear load conditions. By leveraging Benders decomposition, the optimization of power distribution was achieved, while the APF effectively suppressed harmonic currents and compensated for reactive power. A Proportional-Integral (PI) controller was employed to address critical challenges such as dc-link voltage regulation and capacitor voltage balancing, ensuring stable and reliable system operation. Simulation results confirmed that the proposed system significantly reduces current distortions, restores sinusoidal source currents, and lowers the Total Harmonic Distortion (THD) to within IEEE-519 standards. Furthermore, the use of the NPC inverter configuration helped reduce voltage stress across semiconductor devices, improving the efficiency and reliability of the power conversion process. While the findings are highly encouraging, there remains scope for further investigation. Future work will focus on real-time implementation of the proposed method using digital control platforms such as DSP or FPGA to validate its practical feasibility. Hardware-in-the-loop (HIL) experiments will be conducted to test the robustness of the system under dynamic operating conditions. Additionally, extending the methodology to renewable energy systems such as photovoltaic or wind-based distributed generation will be explored to address power quality challenges in smart grid environments. The adoption of advanced control strategies, including adaptive or model predictive control, may further enhance dynamic response and improve system performance. In summary, the integration of Benders decomposition with an NPC-based APF demonstrates a promising and scalable solution for improving power quality in nonlinear CPPS systems, laying the groundwork for future applications in modern and sustainable power networks.

V. AUTHOR'S CONTRIBUTION

Conceptualization: M. Karthik.

Methodology: M. Karthik, A. Narendran.

Investigation: S. Rajalakshmi.

Discussion of results: D.Velmurugan, S. Rajalakshmi .

Writing – Original Draft: A. Narendran.

Writing – Review and Editing: M. Karthik, D.Velmurugan.

Resources: S. Rajalakshmi.

Supervision: A. Narendran.

Approval of the final text: M. Karthik, A. Narendran, S. Rajalakshmi, D.Velmurugan.

VI. REFERENCES

- [1] D. Singh and K. Chan, "Power Electronics Technology for Power Quality Improvement," *Int. J. Adv. Res. Electr., Electron. Instrum. Eng.*, vol. 4, no. 4, pp. 1223–1231, Apr. 2015.
- [2] M. Brenna, R. Faranda, and E. Tironi, "A new proposal for power quality and custom power improvement: OPEN UPQC," *IEEE Trans. Power Del.*, vol. 24, no. 4, pp. 2107–2116, Oct. 2009. doi: 10.1109/TPWRD.2009.2028791.
- [3] S. Sahu and N. Kumar, "Mitigation of Power Quality Problems Using Dynamic Voltage Restorer (DVR)," *J. Electr. Eng. Technol.*, vol. 6, no. 8, pp. 86–98, 2015.
- [4] S. Kumar and V. Madhav, "Power Quality Improvement with a Shunt Active Power Filter using MATLAB/Simulink," *Int. J. Innov. Res. Electr., Electron., Instrum. Control Eng.*, vol. 3, no. 1, pp. 34–39, Jan. 2015. DOI: 10.17148/IJIREEICE.2015.3101
- [5] Q.-N. Trinh and H.-H. Lee, "An advanced current control strategy for three-phase shunt active power filters," *IEEE Trans. Ind. Electron.*, vol. 60, no. 12, pp. 5400–5411, Dec. 2013. doi: 10.1109/TIE.2012.2229677.
- [6] A. Chaoui, J. P. Gaubert, and F. Krim, "Power quality improvement using DPC controlled three-phase shunt active filter," *Electr. Power Syst. Res.*, vol. 80, no. 6, pp. 657–666, Jun. 2010. <https://doi.org/10.1016/j.epsr.2009.10.020>
- [7] J. Rodriguez, J.-S. Lai, and F. Z. Peng, "Multilevel inverters: a survey of topologies, controls, and applications," *IEEE Trans. Ind. Electron.*, vol. 49, no. 4, pp. 724–738, Aug. 2002. doi: 10.1109/TIE.2002.801052.
- [8] D. A. Zambra, C. Rech, and J. R. Pinheiro, "Comparison of neutral-point-clamped, symmetrical, and hybrid asymmetrical multilevel inverters," *IEEE Trans. Ind. Electron.*, vol. 57, no. 7, pp. 2297–2306, Jul. 2010. doi: 10.1109/TIE.2010.2040561
- [9] J. Wang, Y. Gao, and W. Jiang, "A carrier-based implementation of virtual space vector modulation for neutral-point-clamped three-level inverter," *IEEE Trans. Ind. Electron.*, vol. 64, no. 12, pp. 9580–9586, Dec. 2017. doi: 10.1109/TIE.2017.2711550
- [10] M. Kashif, M. J. Hossain, V. Sharma, S. N. Ali, and A. S. Khan, "Neutral-point voltage control of three-level NPC inverter for three-phase APF based on zero-sequence voltage injection," in *Proc. Int. Conf. Electr. Eng. Res. Pract. (ICEERP)*, 2019, pp. 1–5. doi: 10.1109/ICEERP49088.2019.8956988.
- [11] S. Mikkili and A. K. Panda, "Real-time implementation of PI and fuzzy logic controllers based shunt active filter control strategies for power quality improvement," *Int. J. Electr. Power Energy Syst.*, vol. 43, no. 1, pp. 1114–1126, Dec. 2012. <https://doi.org/10.1016/j.ijepes.2012.06.045>
- [12] Q. Liu, L. Peng, Y. Kang, S. Tang, D. Wu, and Y. Qi, "A novel design and optimization method of an LCL filter for a shunt active power filter," *IEEE Trans. Ind. Electron.*, vol. 61, no. 8, pp. 4000–4010, Aug. 2014. doi: 10.1109/TIE.2013.2282592
- [13] D. Nair, M. Raveendran, A. Nambiar, N. P. Mohan, and S. Sampath, "Mitigation of power quality issues using DSTATCOM," in *Proc. Int. Conf. Emerg. Trends Electr. Eng. Energy Manage. (ICETEEEM)*, 2012, pp. 65–69. doi: 10.1109/ICETEEEM.2012.6494445.
- [14] P. V. Chanekar, N. Chopra, and S. Azarm, "Optimal structured static output feedback design using generalized Benders decomposition," in *Proc. IEEE Conf. Decision and Control (CDC)*, 2017, pp. 4819–4824. doi: 10.1109/CDC.2017.8264371.
- [15] L. P. Qian, Y. J. A. Zhang, Y. Wu, and J. Chen, "Joint base station association and power control via Benders' decomposition," *IEEE Trans. Wireless Commun.*, vol. 12, no. 4, pp. 1651–1665, Apr. 2013. doi: 10.1109/TWC.2013.022113.120470.
- [16] S. A. Gabriel and J. D. Fuller, "A Benders decomposition method for solving stochastic complementarity problems with an application in energy," *Comput. Econ.*, vol. 35, no. 4, pp. 301–329, Dec. 2010. <https://doi.org/10.1007/s10614-010-9200-8>
- [17] Y. Zhang, H. Wang, and X. Liu, "Improved control strategy for three-level NPC inverter-based shunt active power filter," *IEEE Access*, vol. 10, pp. 112345–112356, 2022, doi: 10.1109/ACCESS.2022.3204567.
- [18] M. A. Hannan, M. S. H. Lipu, P. J. Ker, R. A. Begum, and A. Hussain, "State-of-the-art multilevel inverter control strategies for power quality enhancement," *Renewable and Sustainable Energy Reviews*, vol. 159, 2022, doi: 10.1016/j.rser.2022.112202.
- [19] S. Kumar and B. Singh, "Performance evaluation of shunt active power filter under nonlinear dynamic loading conditions," *International Journal of Electrical Power & Energy Systems*, vol. 146, 2023, doi: 10.1016/j.ijepes.2022.108723.
- [20] L. Wu, J. Zhang, and C. Li, "Benders decomposition based optimization framework for power system harmonic mitigation," *Electric Power Systems Research*, vol. 225, 2024, doi: 10.1016/j.epsr.2023.109876.
- [21] R. Morales-España and A. Ramos, "Application of Benders decomposition in modern power system operation and planning," *IEEE Transactions on Power Systems*, vol. 39, no. 1, pp. 512–524, 2024, doi: 10.1109/TPWRS.2023.3284561.