ABC-control algorithm-based PV-Shunt APF for enhance performance of Weak grid systems

BATHULA SUSHMA [1] | T.PRATHYUSHA[2]

[1]Pg Scholar, Dept of EPS, Kodada Institute of Technology & Science for Women-Kodad, Telangana.

[2] Assistant Professor, Dept of EEE, Kodada Institute of Technology & Science for Women-Kodad,Telangana.

ABSTRACT: In this work, an artificial bee Colony (ABC) control algorithm is modelled for a Shunt Active Power Filter (SAPF) to control a grid-connected photovoltaic (PV) system. The nonlinear load draws distorted and reactive currents from the grid, which leads to current harmonics, poor power factor, and voltage distortion, especially when the grid is. Particularly, in a weak grid, the presence of these power quality issues is significantly high. To mitigate these effects, enhance the power quality of the weak-grid system, an advanced ABC control approach is presented in this current work. Instead of using a traditional energy storage-based SAPF, the PV energy source is utilized to enable the SAPF. The proposed ABC control algorithm provides a simple and effective solution for PV-integrated SAPF systems. Compared to the standard PI controllers, the ABC control algorithm optimally regulates the dc-link voltage and generates appropriate reference signals, enabling accurate compensating current injection by the SAPF. As a result, the proposed control strategy ensures improved power quality performance under weak grid conditions. To extract peak power from the PV module, the perturb and observe MPPT approach is employed. To determine the efficacy of the proposed ABC-based PV-SAPF, a simulation case study is conducted under various weak grid operating conditions, such as voltage sag, voltage swell, and unbalanced load conditions.

KEYWORDS: SAG, SWELL, ABC, SAPF, DC-LINK, PV SYSTEM.

I.INTRODUCTION: Over the past ten years, the conventional power system has undergone changes due to the increased use of electric vehicles, charging stations, storage systems, and distributed generators (DG) powered by renewable energy. A innovative idea for a "microgrid" is the use of power electronic converters to connect several DGs with nearby loads [1], [2], [3], [4]. The microgrid's response in both grid-connected and islanded modes is covered in [2]. For reactive power regulation, the switching process in both modes is examined. A storage system, a photovoltaic (PV) system, and loads make up the master/slave control microgrid in [3]. It can be run in either islanded or grid-connected mode. Grid-connected and islanding types of microgrid operation can be distinguished in [4]. Nonlinear loads like diodes and thyristor-based circuits are becoming more prevalent in the distribution system, which leads to problems with power quality [5]. It is described how to construct a shunt active power filter (SAPF) for pulsing load needs [6]. The system's overall efficiency has been lowered by problems with power quality (PQ), reactive power burden, poor power factor (PF), voltage harmonics, current harmonics, and increased heating. Reactive power, harmonic distortions, and other issues with power quality are addressed in the electrical grid by a new device known as a shunt active power filter. By adding compensating currents to the system, it successfully lessens disruptions and ensures a steady supply of power.

SAPF is a perfect option for reducing current-related power quality issues because it provides features including tailored filtering, flexibility to operate under system disruptions, and quick dynamic response [7]. Notably, active power filters perform better than those with light loads [8]. A PV-connected SAPF model with a 3 ¹ power supply, customer loads, and a voltage source inverter (VSI) in shunt with the source is depicted in Fig. 1. In order to eliminate harmonics from the grid current, SAPF is appropriately adjusted to introduce equal amplitude harmonics into the current with a 180° phase shift. Power quality issues can be categorized as issues relating to voltage or current, and they can lead to end-user equipment malfunction. Current harmonics, reactive power consumption, and insufficient power factor are the PQ problems related to current. Voltage sags, voltage swells, notches, voltage harmonics, flickers, and so forth are examples of PQ characteristics associated with voltage.

A percentage of the fundamental is used to describe the ratio of the root mean square of the harmonic content, taking into account harmonic components up to the 50th order and especially excluding interharmonics. When required, harmonic components of order higher than fifty may be added. The literature has addressed a number of SAPF control techniques. Instantaneous reactive power theory (IRPT) [9] and synchronous reference frame (SRF) theory [10] are the two most widely used conventional control techniques. The essential load component for reference current generation for SAPF is computed using these two control techniques. For power conditioning, the IRPT control method is examined. Because of its foundation in the dq0 frame of reference and its usage of the phase-locked loop (PLL), the SRF theory is also known as the dq theory. The effectiveness of the SRF theory in enhancing aspects of power quality must be assessed, though. Contrarily, the IRPT uses computations in a fixed reference frame without the need for a PLL; as a result, it is frequently employed in SAPF control.

Because PLLs are not necessary, the IRPT requires significantly less computation time. Sensitivity to harmonics, implementation complexity, and dynamic response problems are a few of IRPT's drawbacks. Bernoulli's polynomial-based artificial neural network controller is used to manage the PQ enhancement of a single-phase grid-connected PV inverter. A Hermite polynomial-based controller is used to extract the essential active load component in shunt active power filtering. A fuzzy-tuned PI controller for dc bus voltage suggested an improved filtering generalized integrator-based filtering technique to filter the source voltage from harmonic content, and another significant current control method is based on a second-order generalized integrator for harmonic extraction.

The PQ problems in grid-tied PV systems are improved by this control technique. In order to condition the control system to extract the maximum power point associated with the P-V and I-V characteristics of a PV module, a number of maximum power point tracking (MPPT) algorithms, including perturb and observation, hill climbing (HC), and incremental conductance, have been developed. In order to further create the reference source current under different grid disturbance situations, a modified decorrelation normalized least mean square (LMS) algorithm is employed for load compensation. In the DSTATCOM operation, the LMS control mechanism is frequently employed as an adaptive controller. The filter is adaptive. Adaptive filter theory has advanced to the forefront of research due to changes in the environment and the characteristics of an unknown system that uses this filter. System perturbations cause the filter constants to self-adjust, maintaining the proper operation of the system's environment and filter. It is also generally known that when the time constant values for both methods are the same, the LMF approach produces substantially less noise in the weights than the standard LMS algorithm. Therefore, the strategy is to find the optimal learning rule that, in comparison to the traditional LMS-based control system, results in a reduced steady-state error and superior tracking.

Since the LMS algorithm functions as a lower-order adaptive filter, a low signal-to-noise ratio prevents it from achieving suitable steady-state performance. Therefore, a fourth-order power expansion was employed to mitigate this issue and enhance the system's steady-state performance. The LMS algorithm is easier to create and yields consistent and dependable results when tested against various inputs. The LMS's rate of convergence is poor, though. For the lowest possible mistake rate, a generally smaller step size is advised. A faster convergence rate (CR), a smaller step size, and improved control performance all depend on an equilibrium. It is found that, in comparison to CR equal to one, the convergence rate is significantly better with superior tracking capabilities if CR is less than zero or approaches zero. By choosing a suitable convergence coefficient, a conflict between these two algorithmic goals can be resolved. Changes in its control parameters have attracted the attention of many scholars. Normalized LMS, leaky LMS, variable step size LMS, kernel LMS, and least mean mixed norm (LMMN) are the most well-liked and extensively utilized LMS algorithms for enhancing power quality. Self-governing tracking, less real-time processing, robustness to system parameter changes, and good response even under dynamic load situations are all made possible by these methods.

Adaptive algorithms with high-order errors, like LMF, outperform traditional LMS algorithms (MSE) in terms of mean square error. For channel identification, a new family of control-based stochastic gradient algorithms based on q-least mean fourth (q-LMF) is suggested. The LMF approach is further expanded by the q-LMF method on the q-calculus, also known as Jackson's derivative. Additionally, whitening filters and system identification have been developed using the q-LMS algorithm. This study's proposed algorithm offers a novel approach to error correlation energy, resulting in a fast rate of convergence, improved stability, and decreased steady-state error. Even with bigger step sizes, the proposed technique offers more flexibility than classical LMF. The stochastic gradient descent method, which is commonly employed in LMF or LMS-based control schemes, is enhanced by the q-steepest descent approach. Compared to the LMS method, the typical LMF algorithm can obtain higher convergence. Numerous disciplines, including number theory, adaptive filtering, operational theory, mechanics, and relativity theory, have effectively used it.

II.PROPOSED SYSTEM: Fig. 1 illustrates the schematic configuration of the ABC control-algorithm-based PV-SAPF system for operation under weak grid. The system configuration consists of a PV module, an ABC-controlled voltage source converter (VSC), LCL filter units, a utility grid, and nonlinear diode rectifier loads. The PV-fed VSC operates as a SAPF, which injects active power from the PV source while simultaneously mitigating current harmonics and compensating reactive power at the PCC.A DC–DC converter is adopted to stabilize the PV module output voltage. Perturb and observe MPPT technique utilized to track more power from the PV module. In this approach, the perturbation step size is carefully selected to ensure fast tracking of the MPP point and regulated dc-link voltage V_{dc} at a constant value. During the switching operation of the VSC, high-frequency harmonics are generated, which are effectively attenuated by the LCL filter units.For reliable and efficient operation of the VSC, the switching states are generated using the ABC control algorithm.

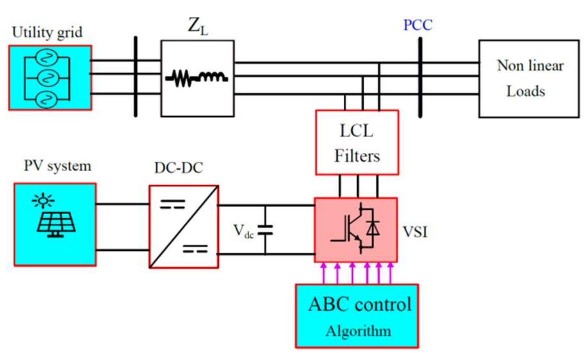


Fig.1 Circuit-diagram of the ABC control algorithm-based PV-SAPF for grid system.

III Proposed method:

For smooth operation of the SAPF, an ABC control scheme presented in this section. The control algorithm ensures effective dc-link voltage regulation and improved current compensation under normal and weak grid conditions. In addition, the proposed method generates reference current for operate the VSC precisely.Fig.2 presents the proposed ABC control framework for the SAPF.

The ABC approach is a population-based stochastic optimization technique inspired by the foraging behavior of honeybees and is particularly suitable for nonlinear and multi-objective control problems.

In this approach, the dc-link voltage error is computed as

$e_{dc}(t) = V_{dc}^{*} - V_{dc}(t),$

where $V_{dc}^{*}$and $V_{dc}(t)$represent the reference and actual dc-link voltages.

The control objective is to minimize a Integral of Time-weighted Absolute Error (ITAE) performance index, defined as

$J = \int_{0}^{T} t \mid e_{dc}(t) \mid \, dt,$

which ensures fast dynamic response with minimal overshoot and steady-state error. Each food source in the ABC algorithm represents a candidate solution, such as the inverter loss controller parameters $x_i = [K_p, K_i]$, and new solutions are generated in the adopted bee phase using $v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj})$, where $\phi_{ij} \in [-1,1]$ is a random number to ensure exploration.

The fitness of each solution is determined as $\text{Fitness}_i = \frac{1}{1+J_i}$, and onlooker bees probabilistically select better solutions based on $P_i = \frac{\text{Fitness}_i}{\sum \text{Fitness}_i}$. Scout bees introduce new random solutions to avoid local minima, thereby enhancing robustness. Once the optimal loss component (I_p) is obtained, it is added to the average fundamental active current component $w_p$to form the equivalent active weight $w_{eq} = w_p + I_p$, which is then multiplied with unit voltage magnitudes to generate reference source currents.

The optimized loss component obtained from the ABC controller is added to the average active current to form the equivalent current reference. This reference is multiplied with unit voltage signals to generate balanced 3-ph reference currents in the abc domain. The VSC tracks these references through a PWM controller and injects compensating currents into the network. As a result, the grid supplies only fundamental active current, ensuring improved power quality at the PCC.

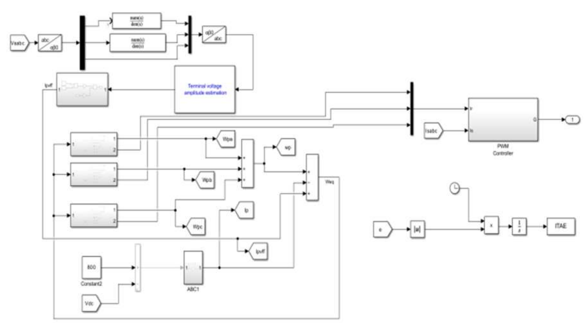


Fig.2 Proposed ABC control framework.

III.SIMULATION RESULTS:

Fig.3 represents the MATLAB circuit layout ABC controller-based PV fed SAPF for grid system. The simulation case study is carried out under normal grid conditions and weak grid conditions such as voltage sag, swell and unbalanced load operating conditions.

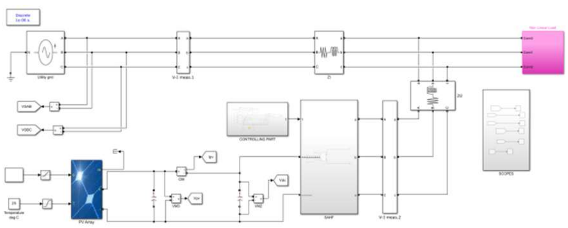
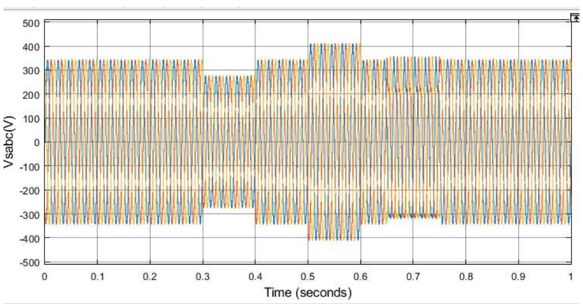
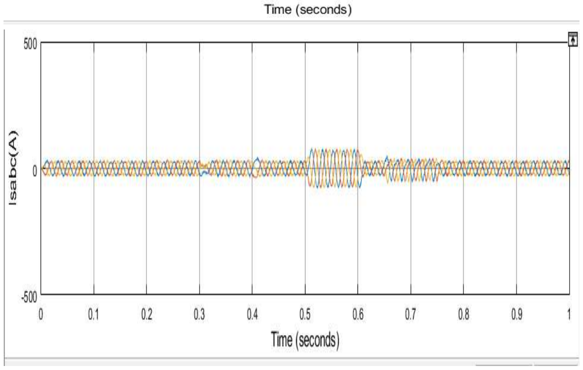
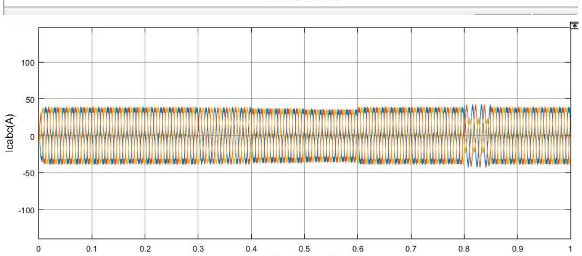
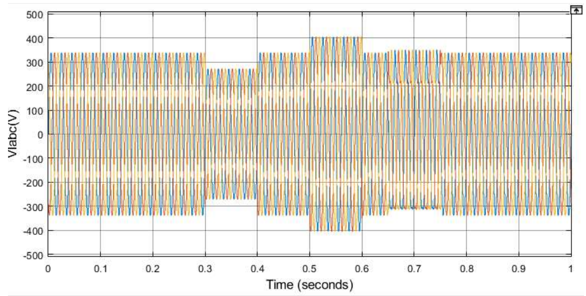


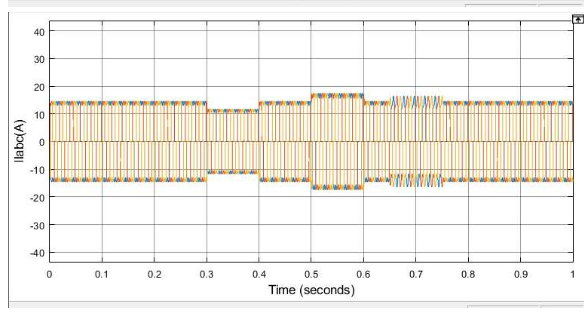
Fig.3 MATLAB schematic of proposed ABC-based PV-SAPF for grid system.

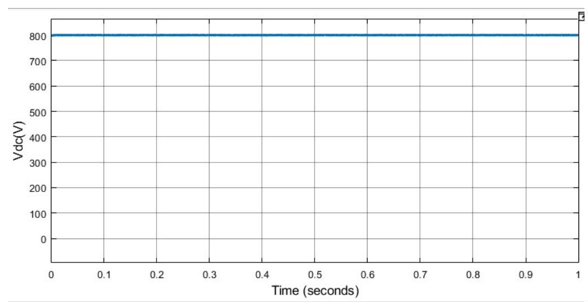












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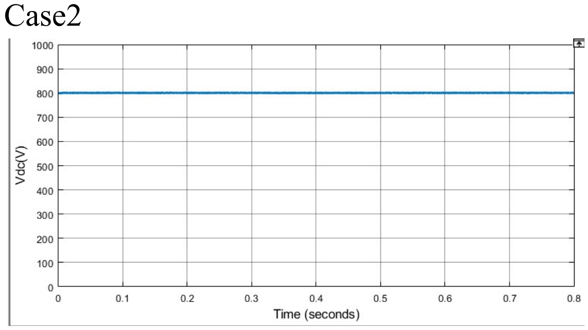

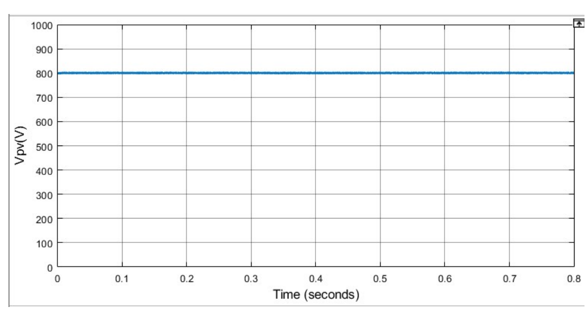

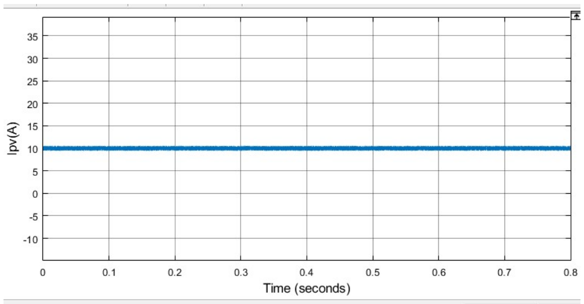

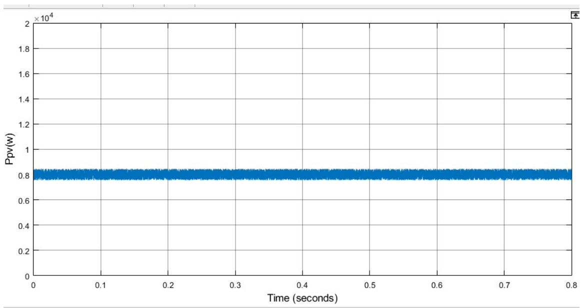

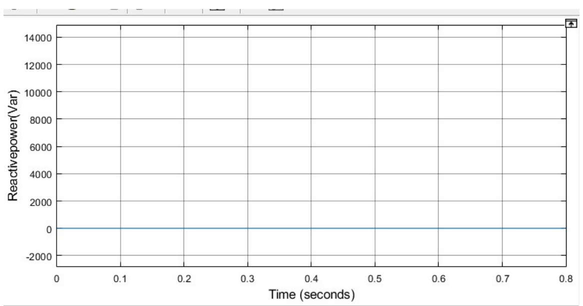

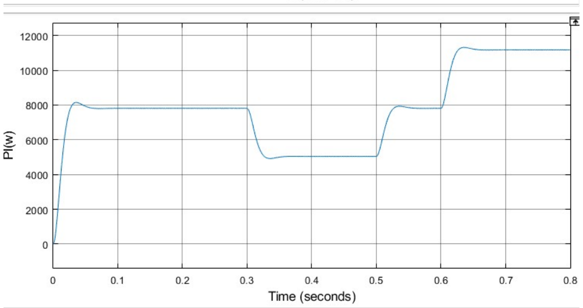

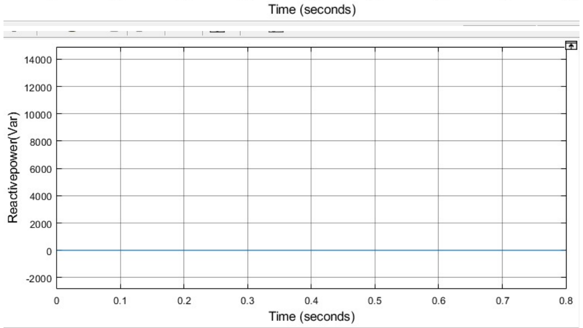

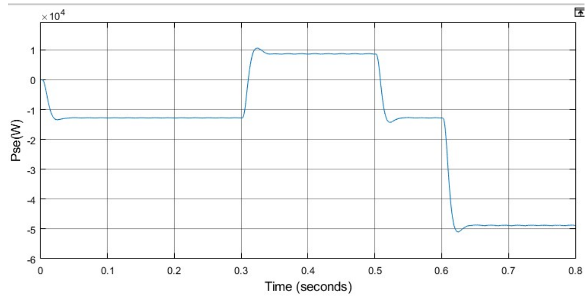

IV.CONCLUSION: In this paper, to improve the performance of the weak-grid, an ABC algorithm-based PV-SAPF is presented. The proposed ABC-based control approach effectively enhances the performance of the grid-tied PV-fed SAPF system by providing efficient harmonic mitigation, improved dc-link voltage regulation, and superior dynamic response. The use of the ABC algorithm significantly provides robustness against weak grid disturbances and ensures stable operation of the PV-integrated SAPF system under varying operating conditions. Instead of using reference-frame transformations and PLL estimations to generate the reference current, the proposed ABC-based control strategy enables accurate reference current generation. The proposed ABC-based SAPF yields better current compensation, reactive power demand, stable grid currents with improved power factor. The simulation results ensured that the proposed ABC-based SAPF well handles harmonic and reactive power compensation for both normal and weak-grid operating conditions.

The proposed method is well-suited for weak grid applications.

REFERENCES: [1] A. C. Moreira, H. K. M. Paredes, W. A. de Souza, F. P. Marafao, and L. C. P. da Silva, "Intelligent expert system for power quality improvement under distorted and unbalanced conditions in three-phase AC microgrids," IEEE Trans. Smart Grid, vol. 9, no. 6, pp. 6951–6960, Nov. 2018.

[2] K.-H. Tan, F.-J. Lin, C.-M. Shih, and C.-N. Kuo, "Intelligent control of microgrid with virtual inertia using recurrent probabilistic wavelet fuzzy neural network," IEEE Trans. Power Electron., vol. 35, no. 7, pp. 7451–7464, Jul. 2020.

[3] K.-H. Tan and T.-Y. Tseng, "Seamless switching and grid reconnection of microgrid using Petri recurrent wavelet fuzzy neural network," IEEE Trans. Power Electron., vol. 36, no. 10, pp. 11847–11861, Oct. 2021.

[4] F.-J. Lin, K.-H. Tan, C.-F. Chang, M.-Y. Li, and T.-Y. Tseng, "Development of intelligent controlled microgrid for power sharing and load shedding," IEEE Trans. Power Electron., vol. 37, no. 7, pp. 7928–7940, Jul. 2022.

[5] M. H. J. Bollen et al., "Power quality concerns in implementing smart distribution-grid applications," IEEE Trans. Smart Grid, vol. 8, no. 1, pp. 391–399, Jan. 2017, doi: 10.1109/TSG.2016.2596788.

[6] A. K. Panda and T. Penthia, "Design and modeling of SMES based SAPF for pulsed power load demands," Int. J. Electr. Power Energy Syst., vol. 92, pp. 114–124, Nov. 2017, doi: 10.1016/j.ijepes.2017.04.011.

[7] J. Monroy-Morales, D. Campos-Gaona, M. Hernández-Ángeles, R. PeñaAlzola, and J. Guardado-Zavala, "An active power filter based on a three-level inverter and 3D-SVPWM for selective harmonic and reactive compensation," Energies, vol. 10, no. 3, Mar. 2017, Art. no. 297, doi: 10.3390/en10030297.

[8] M. H. Rashid, N. Kumar, and A. Kulkarni, "Power Electronics Devices," Circuits Appl., 2014, Art. no. 1027.

[9] S. K. Patel, S. R. Arya, R. Maurya, and B. C. Babu, "Control scheme for DSTATCOM based on frequency-adaptive disturbance observer," IEEE J. Emerg. Sel. Topics Power Electron., vol. 6, no. 3, pp. 1345–1354, Sep. 2018.

[10] K. H. Tan, F. J. Lin, C. Y. Tsai, and Y. R. Chang, "A distribution static compensator using a CFNN-AMF controller for power quality improvement and DC-link voltage regulation," Energies, vol. 11, no. 8, pp. 1–17, 2018.

[11] H. Akagi, E. H. Watanabe, and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning, vol. 62. Hoboken, NJ, USA: Wiley, 2017.

[12] K. B. Rai, A. Singh, and N. Kumar, "Bernoulli polynomial-based control technique for PV-integrated grid system under distorted supply," Int. J. Circuit Theory Appl., vol. 51, pp. 3204–3225, Mar. 2023, doi: 10.1002/cta.3578.