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ANFIS and PI based performance analysis of three phase three wire distribution system for THD reduction

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ABSTRACT

Due to the rising usage of nonlinear loads and power electronic devices in businesses, one of the key power system concerns today is inadequacy of power quality (PQ). This article presents compensation of current harmonics in distribution system in source side by using adaptive neuro fuzzy inferences system (ANFIS) controller. DSTATCOM optimized proportional integral (PI) controller and ANFIS regulator are utilized for DC link voltage regulation. The ANFIS controller showed better performance compared to PI controller during compensating harmonics time. This paper compared two control schemes results PI and ANFIS. Three-phase three-wire inverter is used for DSTATCOM circuit. In the results compared DC capacitor voltage and total harmonic distortion (THD) values of source current. The THD with PI controller is 7.92% while by using ANFIS controller it is reduced to 2.76%. The concert of proposed method is analyzed with MATLAB/Simulink software.

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1. INTRODUCTION

The adaptive neuro fuzzy inferences system (ANFIS) possesses a high level of generalization capability akin to neural networks and additional machine learning techniques. It can process crisp inputs, representing them in the form of membership functions and fuzzy rules, and subsequently generate crisp outputs for reasoning purposes. This flexibility makes it suitable for applications requiring crisp inputs and outputs. In an ANFIS controller, tunable parameters include membership function restrictions and consequent limitations. This necessitates a competent training mechanism to tune these parameters effectively. The difficulty of parameters directly correlates with computational cost. Hence, a higher number of parameters in the ANFIS controller results in increased training and computational costs. The work in [1]-[6] proposed a power quality improvement using neural networks and ANFIS. The statistical models are used to present the effectiveness of the system. Series and shunt active filters with three-level inverters were presented for power quality improvement and harmonic distortion. To get better power quality implemented ANFIS controller for adaptive control applications. The study in [7] presents transformerless shunt active power filter (SAPF) with ANFIS controller for power quality (PQ) improvement. Soft computing design algorithm is used for reducing total harmonic distortion (THD) from 92.23% to 0.49% and improves the power factor to 0.99 in case of nonlinear loads. The work in [8]-[12] mitigate harmonic current compensation by using a SAPF with implementation of ANFIS controller. The proposed system is realized for effects occurred in artificial neural network (ANN), proportional integral derivative (PID), and ANFIS controller to maintain IEEE 519 standards. The study in [13] implemented a fuzzy model-based controller for power quality improvement by interfacing the system parameters through linguistic rules. The PV-based UPQC is proposed with ANFIS controller for better performance. The study in [14] proposed an artificial intelligence-based controller for PQ in improving grid connected distribution arrangements. The THD value in SRFT is 1.71%, ANN is 1.65% but by implementing ANFIS controller the THD value reduced to 1.51%. The study in [15] implemented an ANFIS controller with DSTATCOM. The reference compensation current is used to reduce the reactive power in nonlinear load. The work in [16]-[19] proposed a power quality improvement with ANFIS optimized proportional integral (PI) controller for distributed generation. The controller supplies power to local loads without affecting the other system parameters.

2. METHOD

Figure 1 represents the IRP theory with ANFIS controller. The ANFIS supervisor having two efforts e1 and e2 and having one production PL [20]-[25]. Three phase voltages Vsa, Vsb, and Vsc are converted to Vα and Vβ by using abc to αβ converter. Three phase shipment currents ILa, ILb, and ILc are converted to Iα and Iβ by using abc to αβ converter. By submitting these values directly, we can calculate active and reactive power. The orientation DC voltage and DC link voltage are connected to the PI controller. The error signal from the PI controller e1 is connected to the ANFIS controller for generating the output PL. The summation of PL and P1 produces the total active power P*. The orientation currents Ia*, Ib*, and Ic* are compared with the foundation currents Isa, Isb, and Isc. The three phase voltages Vsa, Vsb, and Vsc are converted to Vα and Vβ.

$$V_\alpha = \sqrt{\frac{2}{3}}[V_{sa} - \frac{V_{sb}}{2} - \frac{V_{sc}}{2}] \quad (1)$$

$$V_\beta = [\frac{V_{sb}-V_{sc}}{\sqrt{2}}] \quad (2)$$

The current equations are also converted into Iα, Iβ, and I0 exposed in (3)-(5).

$$I_0 = \sqrt{\frac{1}{3}[I_{La} + I_{Lb} + I_{Lc}]} \quad (3)$$

$$I_\alpha = \sqrt{\frac{2}{3}}[I_{La} - \frac{I_{Lb}}{2} - \frac{I_{Lc}}{2} \quad (4)$$

$$I_\beta = [\frac{I_{Lb}-I_{Lc}}{\sqrt{2}}] \quad (5)$$

The (6) and (7) represent the active power P and reactive power Q.

$$P = V_\alpha I_\alpha + V_\beta I_\beta \quad (6)$$

$$Q = V_\beta I_\alpha - V_\alpha I_\beta \quad (7)$$

$$P^* = P_1 + P_L \quad (8)$$

By using inverse Clarke's transformation, the Iα and Iβ currents are converted into Iα* and Iβ*; these equations are presented in (9) and (10).

$$I_\alpha^* = [(\frac{-1}{V_\alpha^2+V_\beta^2})((P^* * V_\alpha) + (Q * V_\beta))] \quad (9)$$

$$I_\beta^* = [(\frac{-1}{V_\alpha^2+V_\beta^2})((P^* * V_\beta) + (Q * V_\alpha))] \quad (10)$$

The reference currents Ia*, Ib*, and Ic* are likened with the source currents Isa, Isb, and Isc; these equations are presented in (11)-(13).

$$I_a^* = \sqrt{\frac{2}{3}}[I_\alpha^* + \frac{I_0}{\sqrt{2}}] \quad (11)$$

$$I_b^* = \sqrt{\frac{2}{3}}[\frac{-I_\alpha^*}{2} + \frac{\sqrt{3}}{2}I_\beta^* + \frac{I_0}{\sqrt{2}}] \quad (12)$$

$$I_c^* = \sqrt{\frac{2}{3}}[\frac{-I_\alpha^*}{2} - \frac{\sqrt{3}}{2}I_\beta^* + \frac{I_0}{\sqrt{2}}] \quad (13)$$

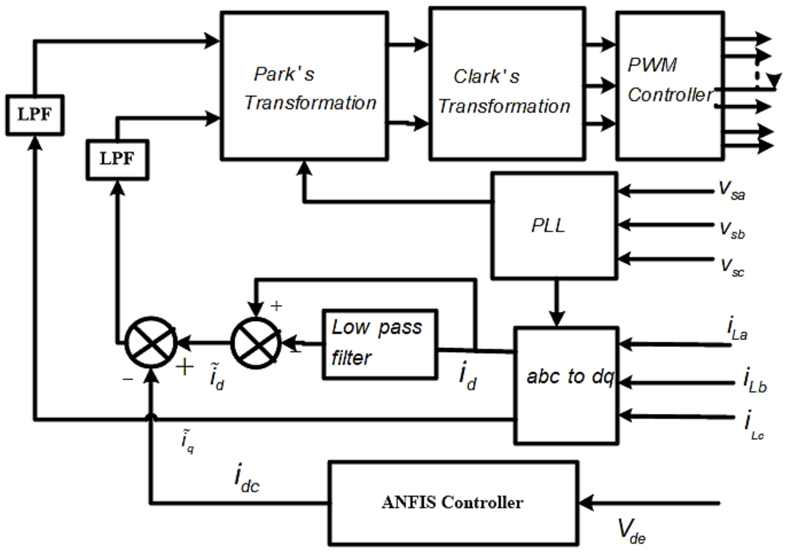

Figure 1. DSTATCOM controller

2.1. ANFIS architecture

Figure 2 illustrates the typical structure of an ANFIS. The ANFIS model comprises five distinct layers, each interconnected through weighted connections. This first layer receives input data and maps it through membership functions to determine the degree of membership for each input value. The second layer applies fuzzy rules to establish relationships between the inputs and outputs. In the third layer, the outputs are normalized, preparing them for the next stage. The fourth layer processes the normalized outputs and applies output membership functions. The fifth layer aggregates the results to produce a single output. Table 1 compares the performance of PI and ANFIS controllers, while Figure 2 depicts the ANFIS flow chart. Figure 3 provides a flow chart detailing the ANFIS training and testing processes in MATLAB.

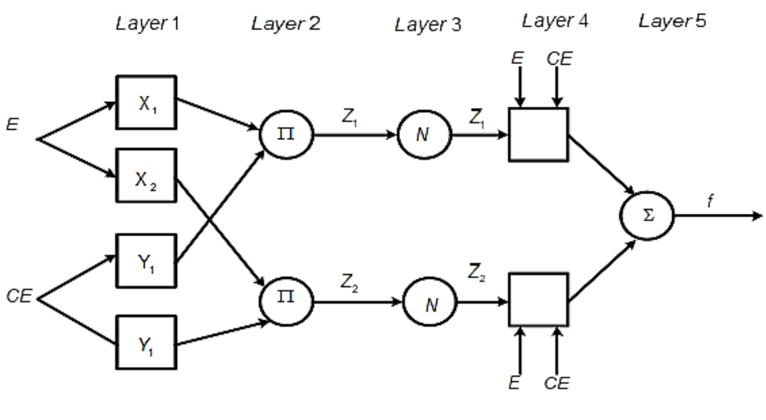

Figure 2. ANFIS architecture

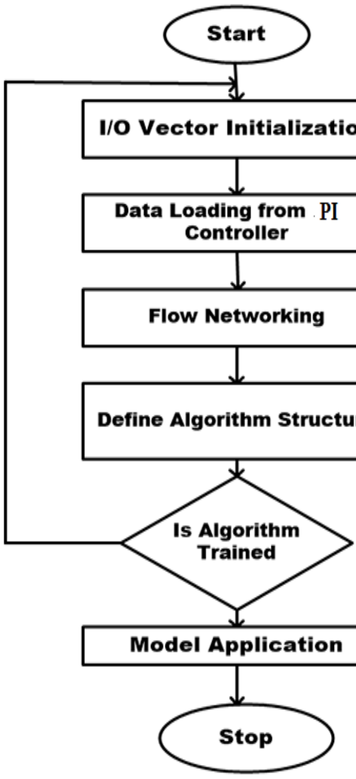

Figure 3. Flow chart of ANFIS training and testing in MATLAB

Table 1. Comparison of PI and ANFIS controller

S. No	PI controller	ANFIS controller
1.	It is a conventional control method	It is an advanced control method
2.	It is well operated only in steady state condition	It is operated in both dynamic and steady state conditions
3.	It is easily implemented	Complex implementation

The neuro fuzzy model had five different adaptive layers in its construction. The Sugeno first order model with double input variables is described briefly below. Layer 1: The name of the fuzzy sets or language variables is defined at the fuzzification layer, where $O^1_{i \text{ or } j}$ are output functions and μ_{Ai} or μ_{Bi} are association functions. In layer 2, the result of layer 1 is represented here. The following layer's weight functions ω_i are defined as (16). Layer 3 standardizes the value from layer 2 before transferring it to layer 4. The standardization in this layer can be formulated as (17). Layer 4 is the defuzzification layer. The linear parameters P_i, q_i, and r_i that consequence from the functions are defined in this layer, as shown in (18). Finally, layer 5 represents the total output layer. The total number of output signals is the output from this layer, as shown in (19).

$$O_i^1 = \mu_{Ai}(x_2), i = 1.2 \quad (14)$$

$$O_j^1 = \mu_{Bi}(x_2), i = 1.2 \quad (15)$$

$$O_i^2 = \omega_i = \mu_{Ai}(x_1)\mu_{Bi}(x_2), i = 1.2 \quad (16)$$

$$O_i^3 = \overline{\omega}_i = \frac{\omega_i}{\sum_i \omega_i}, i = 1.2 \quad (17)$$

$$O_i^4 = \overline{\omega}_i . f_i = \overline{\omega_i}(p_i . x_1 + q_i . x_2 + r_i), i = 1.2 \quad (18)$$

$$Q_i^5 = f(x_1, x_2) = \sum_i \overline{\omega_i} . f_1 = \overline{\omega_i} . f_2 = \frac{\sum_i \omega_i . f_i}{\sum_i \omega_i} \quad (19)$$

3. SIMULATION RESULTS

Figure 4 shows the DSTACOM simulation results with PI controller. The waveform shows the four parameters which are source voltage, load current, source current, and compensating current. The source current it took one cycle for settling current, the source voltage maintained constant entire cycles. Compensating current mainly used for compensation of reactive power. The THD of the source current with PI controller is 7.92%. The evidence of the THD is shown in Figure 5. Table 2 shows the parameters of the simulation file. The MATLAB results for DSTATCOM control with an ANFIS controller are shown in Figure 6. The simulation was conducted using MATLAB/Simulink. ANFIS controller was implemented for DSTATCOM control. ANFIS controller utilized crisp inputs and generated crisp outputs based on fuzzy rules and membership functions. Tunable parameters included membership function parameters and consequent parameters. Evaluation of DSTATCOM performance was based on parameters such as THD, power factor, and dynamic response. The THD of the ANFIS controller is 2.76%. Figure 7 shows the three-phase simulated waveforms with ANFIS controller. The evidence of the THD with ANFIS controller is shown in Figure 8. ANFIS controller demonstrated effective control of DSTATCOM, reducing THD and improving power factor. Comparative analysis with other control schemes, such as PI-based SRF, showcased the efficacy of the ANFIS controller. The computational cost was dependent on the complexity of parameters in the ANFIS controller. Efficient training mechanisms were essential to optimize parameter tuning and minimize computational overhead. MATLAB results indicate that employing an ANFIS controller for DSTATCOM control yields promising outcomes, enhancing system performance and efficiency. Specific numerical results and graphical representations can be provided based on the actual MATLAB simulations conducted. Table 3 shows the comparison table of the THD.

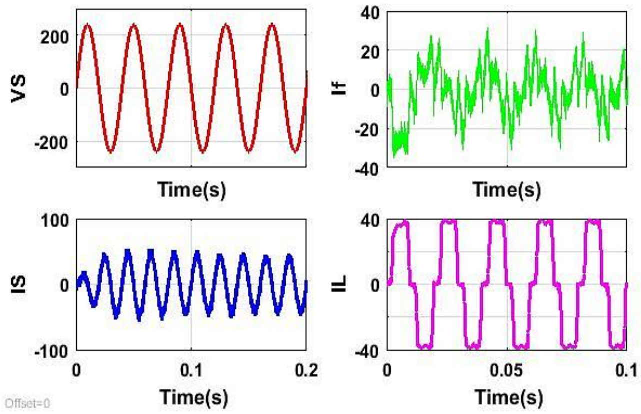

Figure 4. Simulated waveforms with PI controller

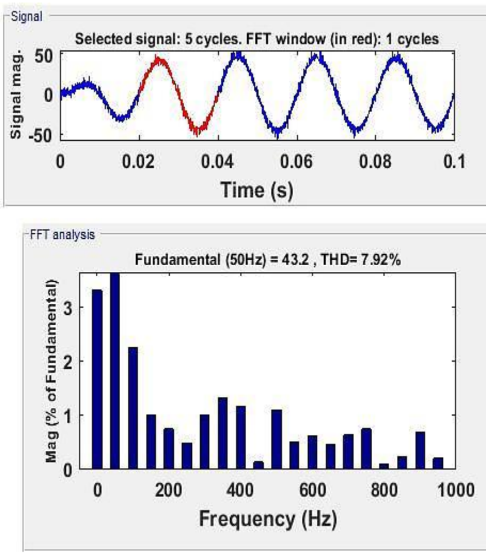

Figure 5. Source current THD without compensation

Table 2. Parameter values

S.No	Parameters	Range
1.	Supply voltage, current	440 V, 40 A
2.	Load current	48 A
3.	DC link capacitor voltage	780 V
4.	Source inductance	0.5 mH
5.	Load inductance, resistance	16 mH, 10 ohms
6.	Capacitance	4700 µF

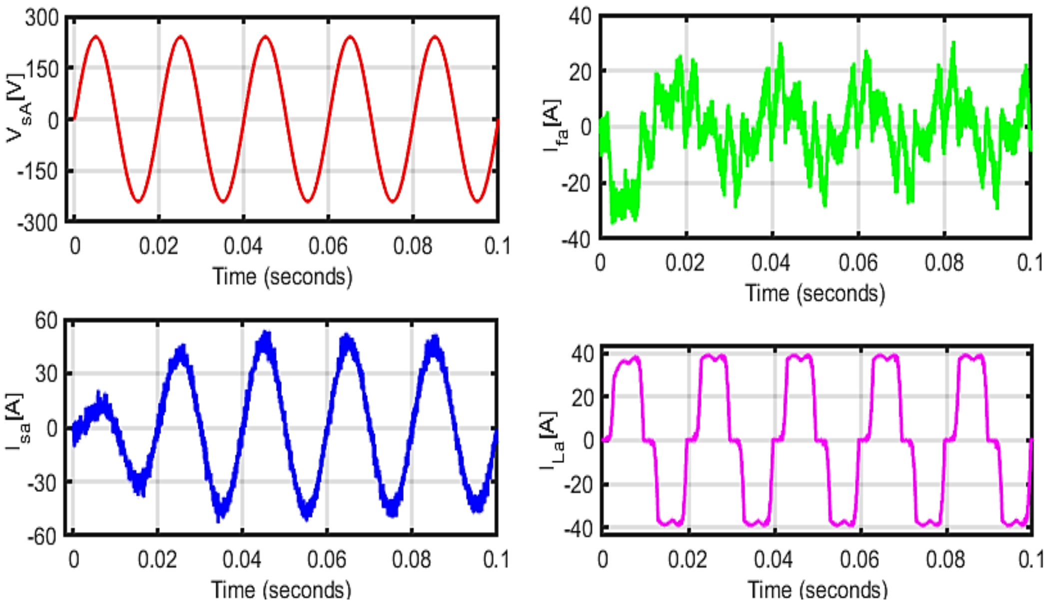

Figure 6. Simulated waveforms with ANFIS controller

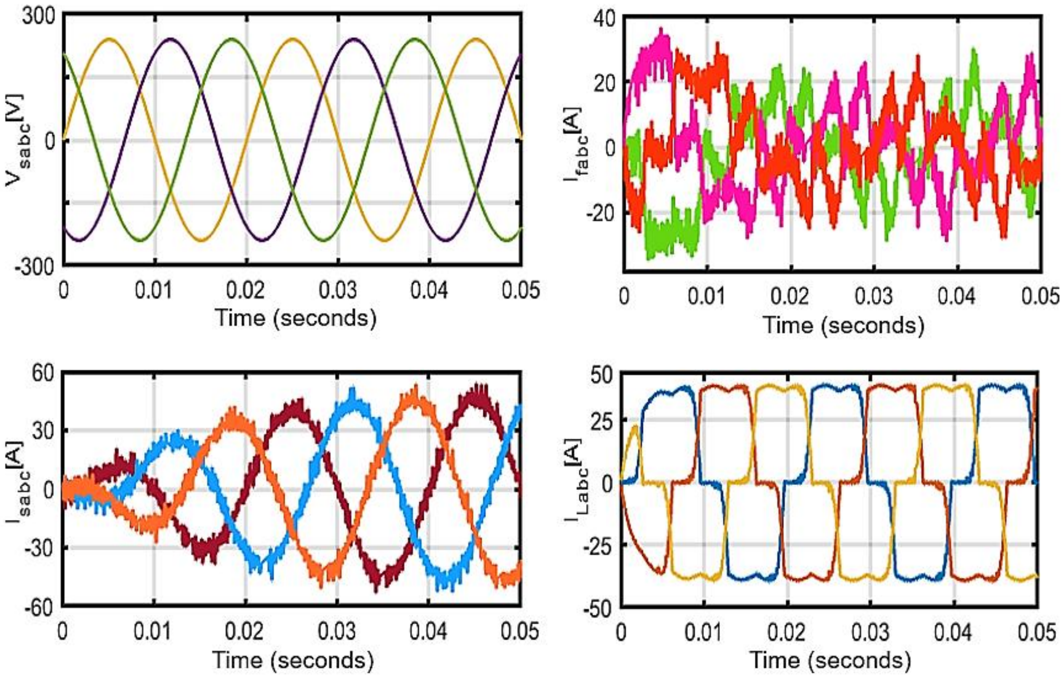

Figure 7. Three-phase simulated waveforms with ANFIS controller

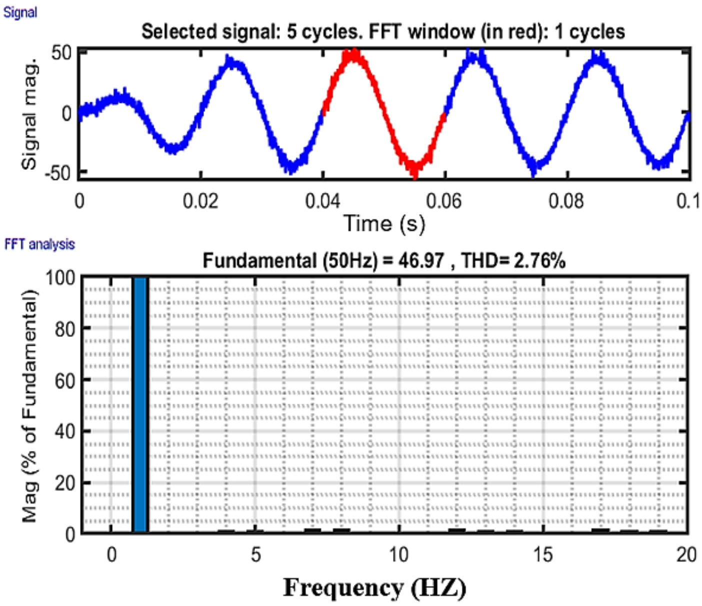

Figure 8. Source current with compensation

Table 3. Comparison of dynamic performance of DSTATCOM

S.No	Control scheme	Percentage THD
1	PI-SRF	7.92%
2	ANFIS-SRF	2.76%

4. CONCLUSION

This paper explores the compensation of harmonic currents in distribution systems at the source side using an ANFIS controller. The performance of the ANFIS controller is compared with that of a PI controller in terms of THD reduction, achieving a reduction from 7.92% to 2.76%. The study involves a three-phase, three-wire system modeled and imitation using MATLAB/Simulink. Simulation results for supply voltage, current, compensating current, DC capacitor voltage, and THD are analyzed and compared between the PI and ANFIS controllers. The results demonstrate that the ANFIS controller offers superior performance in reducing THD compared to the PI controller.

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AUTHOR CONTRIBUTIONS STATEMENT

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Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Khammampati R. Sreejyothi	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
J. Jayakumar		✓				✓		✓	✓	✓	✓	✓	✓	
P. Venkatesh Kumar	✓		✓	✓	✓		✓			✓	✓		✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest to disclose.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] T. Ahmed, A. Waqar, R. M. Elavarasan, J. Imtiaz, M. Premkumar, and U. Subramaniam, "Analysis of fractional order sliding mode control in a D-STATCOM integrated power distribution system," *IEEE Access*, vol. 9, pp. 70337–70352, 2021, doi: 10.1109/ACCESS.2021.3078608.

[2] Y. Peng, X. Huang, S. Xie, and F. Zhong, "Advanced single-phase to three-phase power conversion systems for medium and low voltage single-phase AC systems in remote areas," *IEEE Transactions on Industrial Electronics*, vol. 72, no. 6, pp. 5857–5866, Jun. 2025, doi: 10.1109/TIE.2024.3503601.

[3] K. D. E. Kerrouche, L. Wang, A. Mezouar, L. Boumediene, and A. Van Den Bossche, "Fractional-order sliding mode control for D-STATCOM connected wind farm based DFIG under voltage unbalanced," *Arabian Journal for Science and Engineering*, vol. 44, no. 3, pp. 2265–2280, Mar. 2019, doi: 10.1007/s13369-018-3412-y.

[4] N. Katta, K. Malvekar, T. M. Sunainika, R. Mettu, and K. Chenchireddy, "IoT based UPS battery monitoring system with battery and supply changeover," in *2025 6th International Conference on Inventive Research in Computing Applications (ICIRCA)*, IEEE, Jun. 2025, pp. 723–728, doi: 10.1109/ICIRCA65293.2025.11089703.

[5] S. Charles and P. Venkateshkumar, "Modelling, simulation and implementation of optimisation algorithm based shunt active filter for harmonics mitigation of non-linear loads," *Australian Journal of Electrical and Electronics Engineering*, vol. 9, no. 1, pp. 77–87, Jan. 2012, doi: 10.7158/1448837X.2012.11464312.

[6] V. Padmaja, K. Chenchireddy, N. Praveen, S. A. Sydu, V. Jagan, and L. B. Ganesh, "Smart IoT-based substation control system for enhancing lineman safety," in *2025 6th International Conference on Inventive Research in Computing Applications (ICIRCA)*, IEEE, Jun. 2025, pp. 654–660, doi: 10.1109/ICIRCA65293.2025.11089586.

[7] K. Mahender, S. N. Malvekar, R. Naveen, W. P. Kumar, and K. Chenchireddy, "Smart energy meter with theft detection and voice alert," in *2025 7th International Conference on Inventive Material Science and Applications (ICIMA)*, IEEE, May 2025, pp. 213–217, doi: 10.1109/ICIMA64861.2025.11074139.

[8] F. Yang, X. Shao, S. M. Muyeen, D. Li, S. Lin, and C. Fang, "Disturbance observer based fractional-order integral sliding mode frequency control strategy for interconnected power system," *IEEE Transactions on Power Systems*, vol. 36, no. 6, pp. 5922–5932, Nov. 2021, doi: 10.1109/TPWRS.2021.3081737.

[9] B. Srujana, K. Chenchireddy, R. Achyutha, A. Vandana, and H. M. Lekha, "Comparative study of CHB and RDC multilevel inverter topologies," in *2024 4th International Conference on Soft Computing for Security Applications (ICSCSA)*, IEEE, Sep. 2024, pp. 629–632, doi: 10.1109/ICSCSA64454.2024.00108.

[10] K. R. Sreejyothi, P. V. Kumar, and J. Jayakumar, "SRF theory-based PI controller applied to micro grid interfaced with hybrid sources for power quality improvement," in *2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS)*, IEEE, Mar. 2022, pp. 01–06, doi: 10.1109/ICACCS54159.2022.9785173.

[11] P. Warrier and P. Shah, "Fractional order control of power electronic converters in industrial drives and renewable energy systems: a review," *IEEE Access*, vol. 9, pp. 58982–59009, 2021, doi: 10.1109/ACCESS.2021.3073033.

[12] B. Long *et al.*, "Passivity Fractional-order sliding-mode control of grid-connected converter with LCL filter," *IEEE Transactions on Power Electronics*, vol. 38, no. 6, pp. 6969–6982, Jun. 2023, doi: 10.1109/TPEL.2023.3244754.

[13] M.-F. Guo, H. Lin, J. Lin, and Q. Hong, "Synthetic zero-sequence signal-based intelligent location method for single-phase ground fault in distribution networks," *IEEE Transactions on Instrumentation and Measurement*, vol. 74, pp. 1–13, 2025, doi: 10.1109/TIM.2025.3548224.

[14] K. R. Sree Jyothi, P. Venkatesh Kumar, and J. JayaKumar, "A review of different configurations and control techniques for DSTATCOM in the distribution system," *E3S Web of Conferences*, vol. 309, p. 01119, Oct. 2021, doi: 10.1051/e3sconf/202130901119.

[15] N. Ullah, I. Sami, M. S. Chowdhury, K. Techato, and H. I. Alkhammash, "Artificial Intelligence integrated fractional order control of doubly fed induction generator-based wind energy system," *IEEE Access*, vol. 9, pp. 5734–5748, 2021, doi: 10.1109/ACCESS.2020.3048420.

[16] B. Zhang, L. Zhang, W. Tang, G. Li, and C. Wang, "Optimal planning of hybrid AC/DC low-voltage distribution networks considering DC conversion of three-phase four-wire low-voltage AC systems," *Journal of Modern Power Systems and Clean Energy*, vol. 12, no. 1, pp. 141–153, 2024, doi: 10.35833/MPCE.2022.000404.

[17] G. Tan, Y. Zheng, W. Zhao, L. Qi, and X. Sun, "Droop control of three- and four-leg hybrid parallel inverters based on three-phase generalized coordinate transformation," *IEEE Transactions on Power Electronics*, vol. 39, no. 12, pp. 15831–15844, Dec. 2024, doi: 10.1109/TPEL.2024.3443882.

[18] P. S. Puhan, S. D. Sandeep, E. V. Kumar, G. Shirisha, C. Teja, and M. Imran, "Power quality analysis of a distribution system using a novel shunt hybrid filter," in *2025 International Conference on Sustainable Energy Technologies and Computational Intelligence (SETCOM)*, IEEE, Feb. 2025, pp. 1–6, doi: 10.1109/SETCOM64758.2025.10932335.

[19] R. B. and H. R. Ramesh, "Enhanced power quality in grid-tied PV systems using an optimized ANFIS controller for a 5-level MLI," in *2025 Fifth International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, IEEE, Jan. 2025, pp. 1–7, doi: 10.1109/ICAECT63952.2025.10958922.

[20] N. Xu, L. Dong, L. Hu, W. Feng, Y. Tang, and L. Ye, "Photovoltaic short-term power prediction using LGBM," in *2025 2nd International Conference on Electrical Technology and Automation Engineering (ETAE)*, IEEE, May 2025, pp. 153–159, doi: 10.1109/ETAE65337.2025.11089582.

[21] K. Swetha and V. Sivachidambaranathan, "Second order sliding mode controller interlinked with D-STATCOM for mitigation of total harmonic distortion," *International Journal of Power Electronics*, vol. 16, no. 2, p. 201, 2022, doi: 10.1504/ijpelec.2022.124697.

[22] M. N. Musarrat, A. Fekih, and M. R. Islam, "A robust control scheme to improve the network stability of WECS-based microgrids," in *2022 IEEE IAS Global Conference on Emerging Technologies (GlobConET)*, IEEE, May 2022, pp. 158–163, doi: 10.1109/GlobConET53749.2022.9872344.
[23] K. Chenchireddy and V. Jegathesan, "ANFIS based reduce device count DSTATCOM," *Journal of Applied Science and Engineering*, vol. 26, no. 11, pp. 1657–1666, 2023, doi: 10.6180/jase.202311_26(11).0014.
[24] K. Chenchireddy, V. Kumar, K. R. Sreejyothi, and P. Tejaswi, "A review on D-STATCOM control techniques for power quality improvement in distribution," in *2021 5th International Conference on Electronics, Communication and Aerospace Technology (ICECA)*, IEEE, Dec. 2021, pp. 201–208, doi: 10.1109/ICECA52323.2021.9676019.
[25] R. Kumar, S. K. Mishra, and K. Veer, "Hybrid renewable energy sources integrated shunt active power filter with adaptive fuzzy logic," in *2025 International Conference on Power Electronics Converters for Transportation and Energy Applications (PECTEA)*, IEEE, Jun. 2025, pp. 1–6, doi: 10.1109/PECTEA61788.2025.11076224.

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