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A Simulation Study on AI-Based ANFIS Control of Solar-Powered DC Motors

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Abstract— Solar-powered DC motors are widely used in renewable energy applications because of their high efficiency, simple construction, and environmental benefits. However, achieving accurate speed and performance control under varying solar irradiation and load conditions remains a significant challenge. This paper presents a simulation study of an Artificial Intelligence (AI)-based Adaptive Neuro-Fuzzy Inference System (ANFIS) for the control of solar-powered DC motors. The proposed ANFIS controller is designed to adapt to changing operating conditions and improve the dynamic response of the motor. The performance of the controller is evaluated through simulation under different operating scenarios and is assessed using parameters such as speed tracking accuracy, energy efficiency, response time, and system stability. The simulation results demonstrate that the ANFIS-based control strategy provides improved performance, enhanced reliability, and better adaptability compared with conventional control methods. The proposed approach contributes to the development of intelligent and energy-efficient motor control systems for sustainable renewable energy applications.

Keywords—Adaptive Neuro-Fuzzy Inference System (ANFIS), Artificial Intelligence (AI), Solar Photovoltaic (PV) Array, Solar-Powered DC Motor, Dual Active Bridge (DAB) Converter, Renewable Energy, Energy Management, Energy Efficiency, Solar Irradiance, Fuzzy Logic.

I. INTRODUCTION

The distribution grid's power quality has deteriorated outstanding proliferation and control automated devices occurrence of flexible, unstable, and non-linear loads. Old-style power strategies are commonly employed and improve the overall system. [1-2] Various power devices have been explored in the literature to mitigate controls the quality issues by inserting current and voltage, or Both supply given into grid. D-STATCOM are shunt related power apparatus are applying the current in "POINT OF COMMAN COUPLING".

Then utilization of improve and Spread in D-FACTS controllers within distribution controls to grids have opened up a plethora of applications aimed at safeguarding the stability and reliability of the global network. These controllers offer versatile solutions for enhancing power system stability, regulating voltage profiles, optimizing power flow, and mitigating disturbances. Their integration into distribution grids has facilitated better management of power flow, minimization of losses, and enhancement of overall grid resilience. The diverse functionalities of D-FACTS controllers contribute significantly to ensuring the smooth operation of distribution networks, thereby bolstering the integrity and efficiency of the broader power infrastructure. [4]

Research and proposed by the operation intellectual organized in ANFIS technology in STATCOM scheme to improve active voltage constancy through 3-phase burden situations. To introduced ANFIS technology in control an integrate with ANN and continuously updated by real-time parameters. Simulink outputs are demonstrated with superior effectiveness of this controller compared to other methods such as "ANFIS-GA" and "ANFIS-PSO". And research employed equally particle swarm optimization and genetic algorithm working out the algorithms are modified the parameters in ANFIS system, ensuring its accuracy in reflecting the power system training data under investigation [5].

Custom power devices offer a viable solution for enhancing power quality within distribution systems. Implementing the Instantaneous Reactive Power (IRP) theory to control the DSTATCOM effectively mitigates system unbalance while simultaneously reducing harmonic components. Also control issue of the system is enhanced with consistently continued the harmony. Notably, DSTATCOM exhibits rapid response in compensating sensitive controllers associated to traditional responsive control switch strategies, ensuring efficient operation and improved system performance. [6]

Hence, FACTS controllers like DSTATCOM are preferred due to their technological benefits, notably their swift response to network changes. DSTATCOM, combining a power basis convertor and capacitance in parallel, forms a distribution static compensator [7]. This setup facilitates active and reactive power balancing, unity power factor maintenance, and harmonic elimination from current source [8]. It's mainly communicated to the productivity in DSTATCOM structure is influenced by the chosen control strategy.

simulation discrepancies caused by malfunctioning pistons. Utilizing MATLAB/Simulink and Simpack's co-simulation interface, ANFIS, trained with actual test data, enhances piston performance, significantly reducing errors and improving simulation accuracy [10].

II. PROPOSED METHODOLOGY

A. D-STATCOM Model

Extensive literature review has been conducted to integrate DSTATCOM into distribution systems. DSTATCOM offers the capability to inject both reactive and active power into the system. The flow of dynamic power b/w DSTATCOM in the network is unfair by phase-angle modifications, and magnitude difference between grid and DSTATCOM voltages determines the reactive power flow with active power outputs. In DSTATCOM varies proportionally with system voltage. Positioned and join the DSTATCOM delivers the current. To improve control issue and balance active/reactive power.

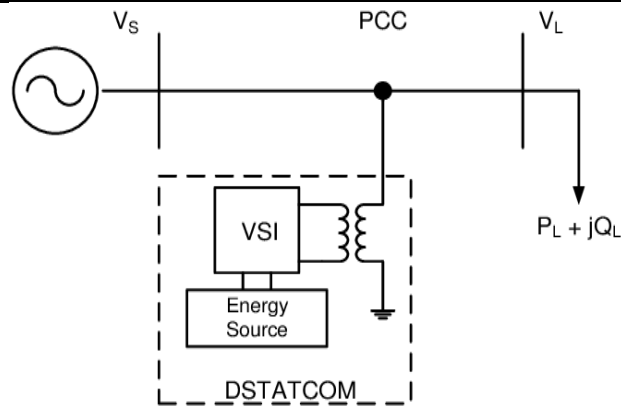


Fig 1. Basic Controller of Executing DSTATCOM

The act of DSTATCOM hinges on the switching system employed and generate VSC change indications. Positioned at the Point of Common Coupling with a link inductor, DSTATCOM consists of a switch element and a pulse generates the elements. These units are responsible for implementing the control strategy and providing gate pulses for the VSC correspondingly. In DSTATCOM controller are devised created on tierce approaches aimed at minimizing Total Harmonic Distortion (THD) as the primary objective. Essential measurements required for algorithm utilization include system voltage and current.

B. Activating The Operation of DSTATCOM Involves the Following Steps

- Obtain the amplitude of the source voltage.
- Calculate reference currents using different algorithms.
- Compare the produced references in real current detected by devices to obtain the fault indication.
- Utilize the derived fault signal to controller and change of IGBT and DSTATCOM.
- Manage bidirectional movement of dynamic controller are in DSTATCOM.

In DSTATCOM modelling was conducted in MATLAB SIMULINK, employing the SIMSCAPE toolbox (Sim power System)

III. CONTROL ALGORITHM

ANFIS is an established by ANN. Then the operate in conjunction with fuzzy inference systems, providing robust artificial intelligence solutions for complex problems. ANFIS is renowned for its exceptional learning capability, making it a preferred choice for various applications.

The ANFIS structure, depicted in Figure 2, includes five deposits. In Layer 1 3-phase load flows are inputted and forwarded into Layer 2. the development of an fuzzification occurs, rendering crisp values fuzzy. Layer 3 matches output and input association purposes. Layer 4 is known as the control level, estimates the firing asset of rules conforming to inputs and outputs. Finally, Layer 5 the defuzzification level, converts hard standards to unsure values and provides the wanted output load existing. In ANFIS structure utilizes 10 neurons for training, employing three-sided input and output association purposes showcased plots, in errors are obtained over 10 epochs.

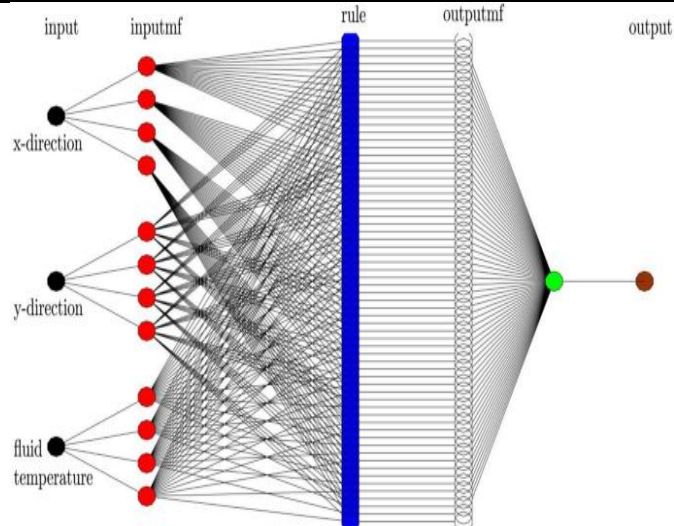


Fig. 2. ANFIS Structure

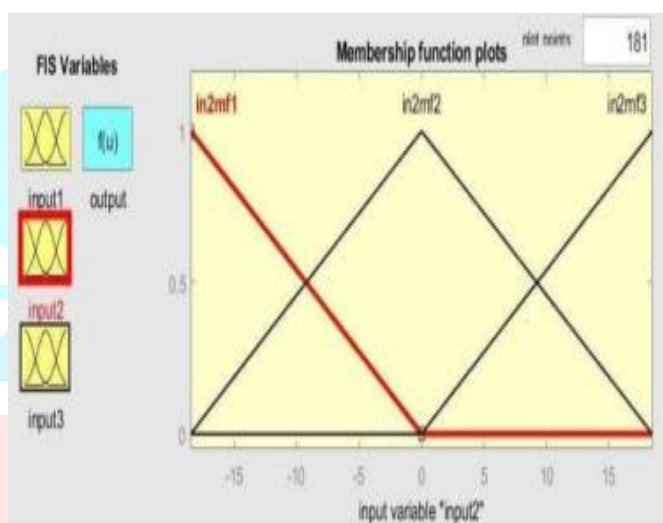


Fig. 3. Membership Purpose Plots for Input1

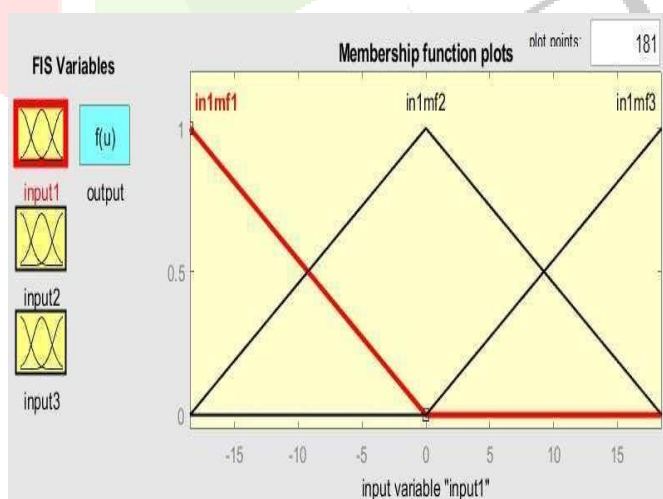


Fig. 4. Membership Purpose Plots for Input2

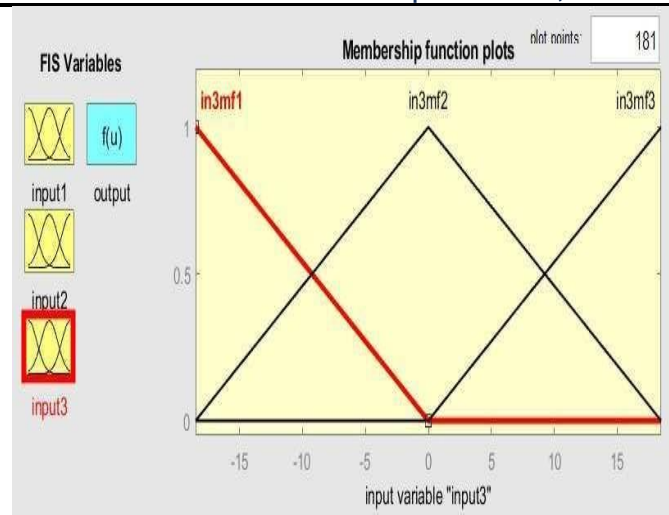


Fig. 5. Membership Purpose Plots for Input3

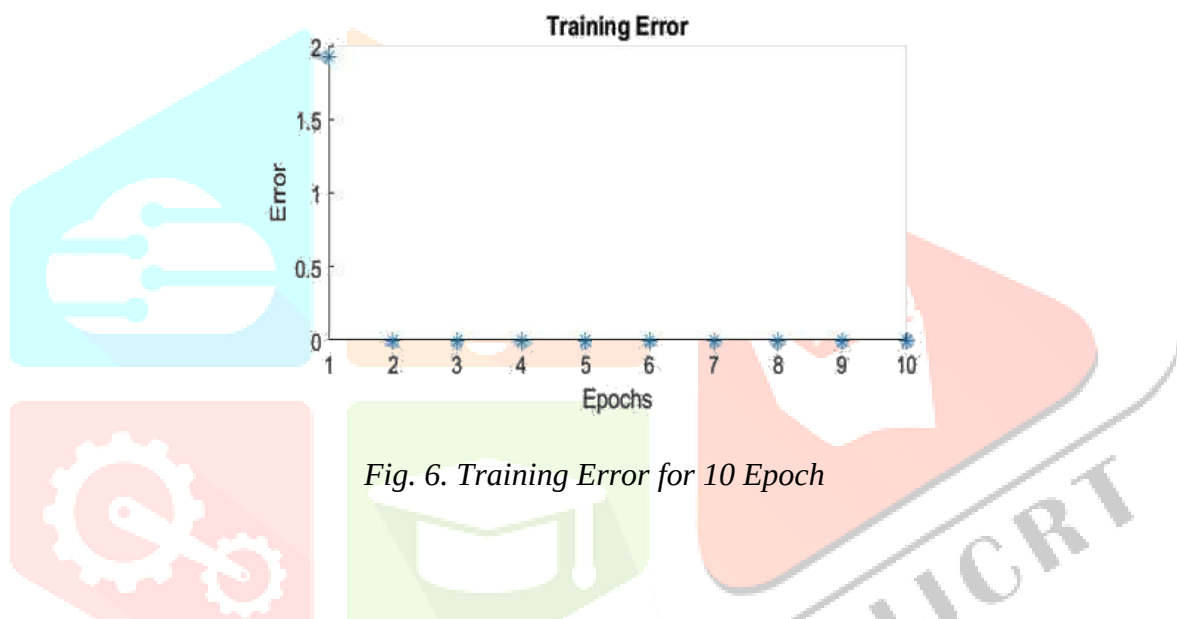


Fig. 6. Training Error for 10 Epoch

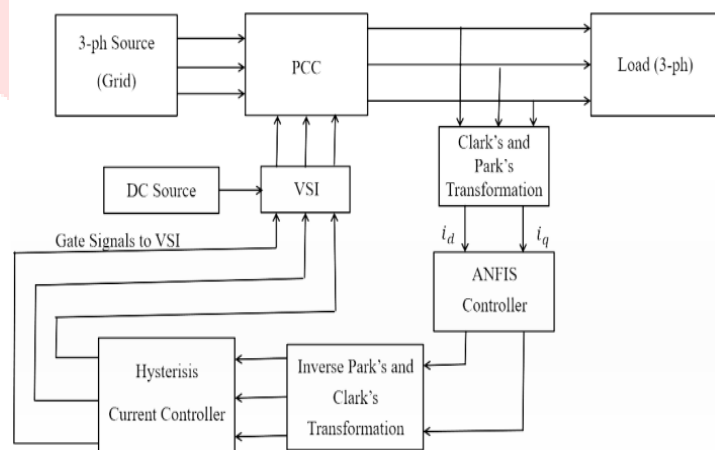


Fig.7.ANFIS Block Diagram

ANFIS construction consists of 5 layers, each playing a crucial role in the system's functionality. In the first layer, three-phase load currents are inputted, and then passed to the second layer where fuzzification occurs, transforming crisp values into fuzzy ones. Subsequently, in the third layer, output membership functions are matched to input membership functions. The fourth layer, known as the normalization layer, calculates the firing strength of rules corresponding to the input-output relationship. Finally, in the fifth layer, called the defuzzification layer, crisp values are converted back to unsure standards, producing the wanted output load current.

The ANFIS structure typically employs 10 neurons for training purposes. Triangular association purposes

are commonly utilized, facilitating the modelling process. These functions help capture the nonlinear relationships present in the system's data.

Training the ANFIS involves adjusting the parameters of the system to minimize the error between predicted and actual outputs. This iterative process is performed over multiple epochs, with the training error monitored to ensure convergence. Overall, the ANFIS structure provides a flexible and adaptable framework for modelling complex systems.

The system comprises a 3-phase 4-wire source (grid) supplying consumer loads. To address harmonics and power quality issues, load currents are converted from three phase to two phase using Park's conversion. PLL facilitates this conversion process. The transformed currents are then directed into ANFIS technology.

ANN and Fuzzy Sense regulator, In ANFIS regulates input currents (i_d and i_q) to produce desired output currents. These currents undergo inverse Park's and Clark's transformations, resulting in 3-phase currents. A Hysteresis Current Controller then receives these 3-phase currents, feeding them to the gate signals of a VSI. The VSI, powered by a DC basis, generates necessary output AC currents, which are injected at the point of common coupling.

Subsequently, these currents traverse the distribution line. If any ripples or harmonics are detected, the process iterates until distortion-free and harmonic-free currents are achieved at the load, ensuring optimal power quality.

IV.ARRANGMENT OF DSTATCOM IN MATLAB

In MATLAB, the arrangement of a Distribution Static Synchronous Compensator (DSTATCOM) involves several key steps to enhance power quality. Firstly, the DSTATCOM structure is defined, typically including a VSI, it is pivotal for generating compensating currents. "Park and Clark" transform and useful to convert into 3-phase grid currents into a 2-phase reference frame, facilitating easier control implementation. This transformation aids in reducing Total Harmonic Distortion (THD) by effectively managing harmonics and improving system stability.

Next, the control algorithm for DSTATCOM operation is developed. This algorithm governs the VSI to produce compensating currents in response to grid voltage and current measurements. Popular control techniques such as PI control or advanced control strategies like Model Predictive Control (MPC) may be implemented to ensure efficient performance.

Simulations are conducted in MATLAB/Simulink to validate the DSTATCOM arrangement. The simulation model incorporates the DSTATCOM structure, control algorithm, and associated power system components. Performance metrics such as THD reduction, voltage parameter, and power issue improvement are analysed to assess the effectiveness of the DSTATCOM arrangement.

Overall, the arrangement of DSTATCOM in MATLAB facilitates comprehensive modelling, simulation, and optimization of power quality improvement strategies, contributing to enhanced grid performance and stability.

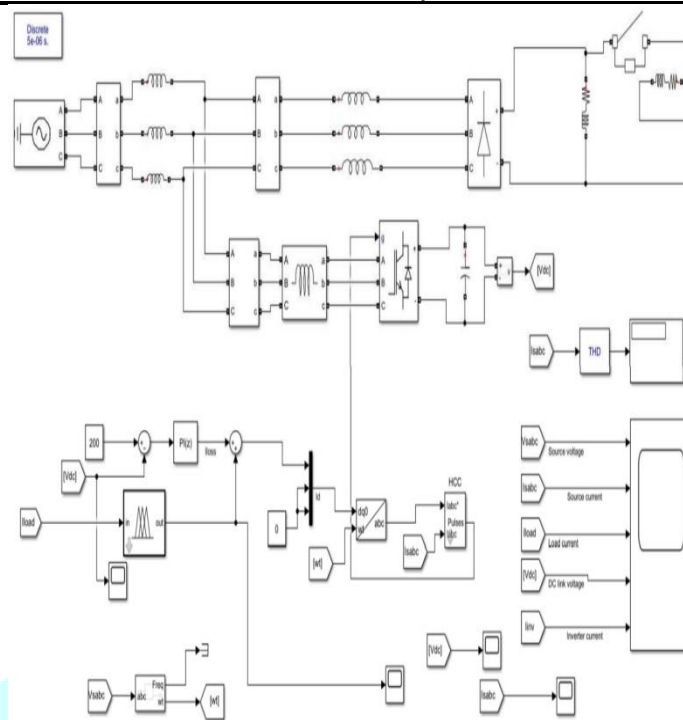


Fig. 8. Control Circuit Diagram of ANFIS Algorithm

V.ARRANGMENT OF ANFIS IN MATLAB

In MATLAB, arranging an ANFIS involves data preparation, defining into FIS, training model, validation, and testing. Firstly, data is pre-processed into training and testing sets. Secondly, the FIS structure, including linguistic variables and membership functions, is established. Thirdly, the ANFIS model is trained using training data, with parameters like epochs and error tolerance adjusted. Next, the model's performance is validated using testing data. Finally, the trained ANFIS model is tested on unseen data, and its effectiveness is evaluated through metrics like Root Mean Squared Error.

VI. RESULTS

A non-linear load, consisting of a resistance (R) of 15Ω and an inductance (L) of $40 \times 10^{-3}H$, was simulated alongside a diode bridge rectifier. To introduce dynamics, a circuit breaker was employed in the R-L load circuit. Initially, a current load of 20 A continued from $t = 0$ to $t = 0.1s$, in stage in the voltage, meeting the load condition. At $t = 0.1s$, the non-linear load increased, causing an increase in grid current to match the heightened demand, while remaining sinusoidal and balanced. Additionally, the DC link capacitor voltage exhibited slight oscillations throughout the process.

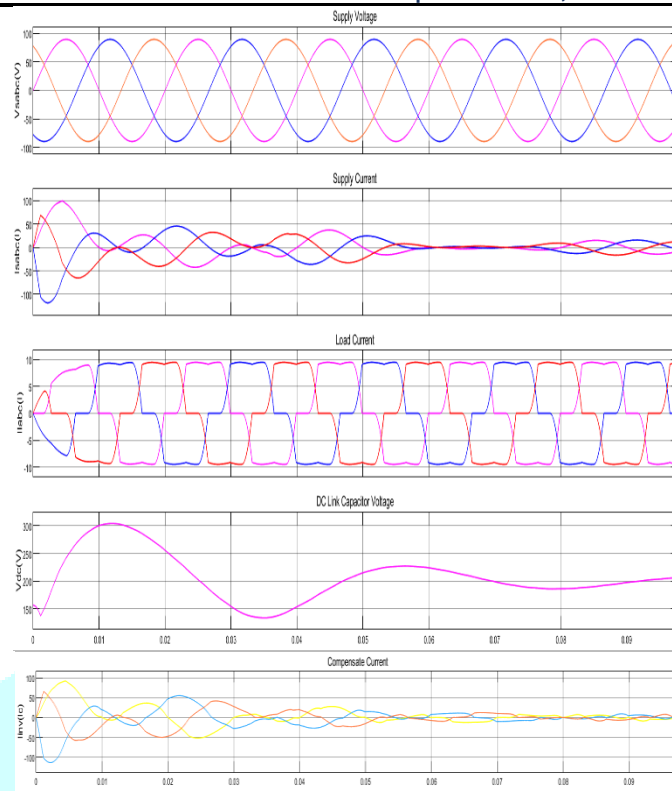


Fig.9. Waveforms Obtained Using ANFIS Controlled Algorithm

VII.CONCLUSION

This study presented an intelligent control strategy for a solar-powered DC motor system by integrating renewable solar energy with an AI-based Adaptive Neuro-Fuzzy Inference System (ANFIS) controller. The proposed approach effectively regulates the power conversion process and enhances the overall performance of the motor under varying operating conditions. When a Dual Active Bridge (DAB) converter is employed, it enables efficient bidirectional power transfer and improves energy management within the system. Simulation results demonstrate that the ANFIS controller provides superior speed regulation, higher energy efficiency, improved dynamic response, and enhanced system reliability compared with conventional control techniques. The proposed methodology offers a promising solution for the development of intelligent, energy-efficient, and sustainable motor drive systems powered by renewable energy sources.

REFERENCES

- [1] Bollen MHJ (1999) Understanding power quality problems: voltage sags and interruptions. IEEE Press, New York
- [2] Hingorani N (1995) Introducing custom power. IEEE Spectr 32(6):41–48
- [3] Gosh A, Ledwich G (2002) Power quality enhancement using custom power devices. Kluwer, Norwell.
- [4] Rahman K.M., Rezwan Khan, M., Choudhury M.A., Rahman M.A. 1997. Variable-band hysteresis current controllers for PWM voltage source inverters. IEEE Trans. Power Electron. 12(6): 964-970.
- [5] Mishra.M.K., Ghosh.A and Joshi.A (2003) .Operation of a DSTATCOM in voltage control mode, IEEE Transactions on Power Delivery.
- [6] S. Shivam, I. Hussain, B. Singh, "Real-time implementation of SPV system with DSTATCOM capabilities in three-phase four wire distribution system", IET Generation, Transmission and Distribution, Vol. 11, No. 2, pp. 495-503, Jan. 2017.
- [7] Anand Kumar, "Application of Custom Power Devices for Improving Power Quality", M.E Project report, Dept. of EE, Indian Institute of Science, Bangalore, July 2005.
- [8] B. Singh and J. Solanki, "Comparison of control algorithms of DSTATCOM, "in IEEE Transactions on Industrial Electronics, vol. 56, no. 7, pages 2738-2745, July 2009.
- [9] A. Singh and B. Singh, "Energy issues related to distribution integration of energy source into utility grids, "2010 Annual IEEE India Conference (INDICON), 2010.

- [10] implementation of Legendre-based neural network controller in grid-connected PV systems. IET Renewable Power Generation. 2019 Nov 18; 13(15):2783-92.
- [11] B. Singh, A. Chandra and K. Al-Haddad, Energy Quality: Problems with Reduction Strategies, John Wiley and Sons, U.K., 2015.
- [12] Akacih Kannazaway and Nabaea. 1983. Generalize theory of the instantaneous reactive power in three phase circuits. In Proc., JIEE IPEC, Tokyo.
- [13] Valdez D., Ortiz V., Cabrera A. and Chairez “Extended Kalman Filter Weights Adjustment For Neonatal Incubator Neurofuzzy Identification”, 0-7803-9489-5/06/\$20.00/©2006 IEEE.

