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Study on UPQC Architecture and Control Algorithms with AI Techniques

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Abstract: Power quality is just as significant as power quantity. Poor power quality causes electrical and electronic devices to operate inefficiently and improperly, which could lead to a disruption in the delivery of electrical power. Quality of power is becoming increasingly crucial as a result of the recent growth of electronics and computer-based automated and smart devices in every business, including the medical, banking, and industrial sectors. These devices require the best power quality. Since we cannot completely avoid nonlinear loadings and other problems that lead to poor power quality, power quality mitigation becomes crucial. One of the many compensatory devices, Unified Power Quality Conditioner (UPQC), intends to incorporate voltage differential and series-active power filters into a power distribution network to minimize any kind of voltage and current disturbances and power quality degradation.
Key words: UPQC, Artificial Intelligence, Power Quality, FACTS, Control System

I. INTRODUCTION

Power utility businesses' main goal is to deliver their customers an uninterrupted sinusoidal voltage with constant amplitude. Additionally, adherence to various power quality standards established by various bodies [1] has turned into a point of pride for the power utilities. Unfortunately, this is getting more and more difficult to do as non-linear and low power-factor loads like furnaces, power converters, traction drives, adjustable speed drives, and computer power supplies find use in both domestic and industrial settings. These nonlinear loads draw nonlinear current, which lowers the quality of the electric supply. Low power-factor, low efficiency, transformer overheating, and other problems are caused by quality degradation [2]. Aside from this, it is uncommon to find the overall load on the distribution system to be balanced. Using traditional passive filters, efforts have been undertaken in the past to reduce these recognized power quality issues. However, due to its drawbacks, such as fixed compensation, resonance with source impedance, and the challenge of adjusting time dependence of filter parameters [3], active and hybrid filters have become more necessary [4]–[6]. In response, a novel technology known as custom power was developed [7], [8], which may be applied to distribution systems to improve the quality and dependability of the power supply. The ideal voltage and current waveforms are in phase, the load's power factor is one, and reactive power consumption is zero; this permits the most effective active power transmission and results in the least expensive distribution system.

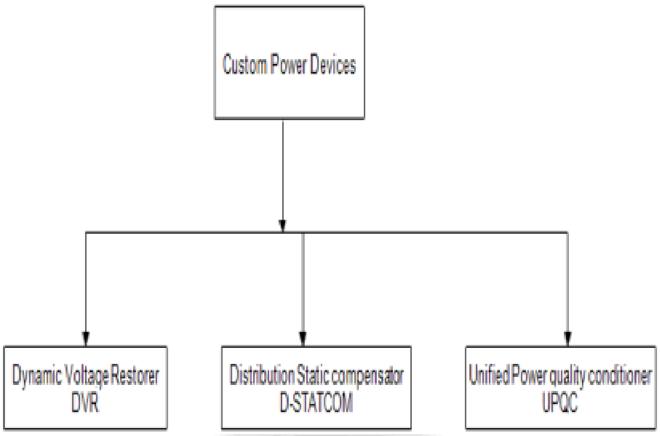

Figure 1 Custom Power Devices major classification

The sensitive load is affected by grid voltage sag. The use of bespoke power devices is taken into consideration to protect such delicate loads. The quality and dependability of the power that is given to the clients are improved by custom power. Low harmonic distortion, a reduction in supply voltage flutter, and a decrease in voltage sag and swell are all effects of improved power quality. The unique power devices are displayed in Figure 1 of the flowchart above.

1. Dynamic voltage restorer (DVR)
2. Distribution static compensator (D-STATCOM)
3. Unified power quality conditioner (UPQC)

The main function of DVR is to increase the quality of power. Whereas the D-STATCOM compensates the harmonic and unbalance in current of loads which are nonlinear. The UPQC is the combination of DVR and D-STATCOM.

II. UPQC ARCHITECTURE

Shunt active power filter and series active power filter are used to create the Unified Power Quality Conditioner (UPQC). Figure 2 depicts the UPQC's fundamental circuit. The series component serves as a harmonic blocking filter, corrects for supply voltage harmonics and voltage imbalances, and dampens oscillations in the power system. Harmonic load currents, reactive power, and load current imbalances are compensated by the shunt component. Additionally, it controls the voltage of the DC link capacitor. Power needed by the series compensator and power needed to make up for losses is supplied or absorbed by the shunt section. a Unified Power Quality Conditioner that can manage current and voltage simultaneously. Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Restorer (DVR) actions are combined in UPQC. If the source voltage or load current are unbalanced, harmonic, or flickering, the voltage control mode can be used to make the bus voltage at the load terminal sinusoidal. Regardless of imbalance and harmonics in the source voltage or load current, it pulls a balanced sinusoidal current from the utility bus while in the current control mode.

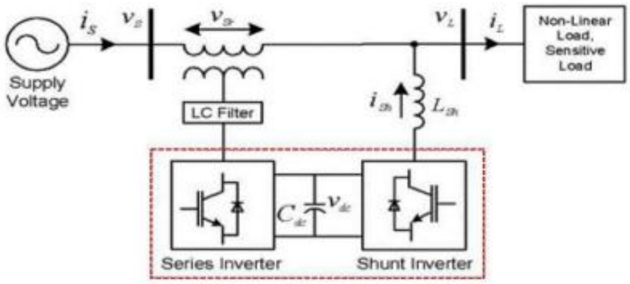

Figure 2: Basic Architecture of UPQC

The various components used in UPQC are as follows:

1. Series inverter - The inverters connected in series to the supply known as the series active filter. This inverter behaves as a voltage source line which eliminates a voltage interruption.
2. Shunt inverter - The inverter connected in shunt to the supply line is known as shunt active filter. It eliminates the current related harmonics also minimize the reactive current in the load circuit.
3. DC link - The capacitor or inductor can be used as common DC link. As shown in fig. 4 the capacitor is used as DC link, which supplies the DC voltage.
4. LC filter - The output of the series active filter produces high switching ripples. The LC filter minimizes the ripples in a system. The LC filter acts as the low-pass filter.
5. Lsh Filter - The Lsh filter act as a high-pass filter. The ripples during switching mode are minimized by Lsh filter.
6. Injection transformer - The series injection transformer

PQ issues, like harmonics, flicker, and imbalance, have evolved into serious issues, like transients, voltage sag/swell, harmonics, flickers, and interruption, as a result of the growing use of nonlinear and electronically exchanged devices in dispersion frameworks and businesses. Using a STATCOM, D-STATCOM, DVR, series dynamic channel, UPQC, and other tools, the PQ concerns can be successfully compensated. These tools were developed to handle specific PQ challenges. The DVR is used for voltage list pay and functions as a series compensator. The shunt compensator STATCOM is used to compensate for voltage sag and responsive power. For compensating a particular kind of PQ fault, the STATCOM and DVR are useful tools. In this way, UPQC has included the opinions of energy designers to produce adaptable and dynamic solutions to PQ problems. UPQC is a combination of arrangement and shunt APFs, and each APF has unique capabilities. This led to the development of novel topologies and better control mechanisms for UPQC.

III. RELATED WORK

J. Lin et.al [9] Power system operation, analysis, scheduling, and energy management are the areas of the power system where these optimization techniques are required. These issues necessitate various approaches to the examination of the objective function and restrictions. The overview of various optimization techniques and how they apply to these kinds of issues is the main goal of this chapter. The most important issues that are now emerging in this field are also covered.

Z. A. Saafin et.al [10] This paper introduced a novel hybrid particle swarm optimization and artificial neural network (PSO-ANN) based controller gain tuning approach for DSTATCOM. The simulation's findings demonstrate the superiority and dependability of DSTATCOM's suggested approach for enhancing voltage profile in the distribution power system.

J. SRIKAKOLAPU et. al [11] In this work, a fundamental extractor with adaptive observer assistance is created to estimate the load current's basic components for a three-phase distribution static compensator (DSTATCOM) under nonlinear load. The fundamental pulling out from the distorted load current and the computation of PI controller gains are the main variations in the proposed study. The salp swarm optimization method (SSOA) is employed with this observer to estimate the gains of the DC PI controller and the AC PI controller. Both the DC bus voltage and the AC terminal voltage errors are minimized using the anticipated gains. This optimization technique does an admirable job of moving the initial random solutions forward and achieving the best result. With astounding convergence and coverage, SSOA approximates Pareto optimum solutions. The SSOA can look for solutions in uncharted territory and to challenges that arise in the actual world. The suggested control strategy with the optimum gain settings has managed power quality issues like reducing the load on the grid's reactive power generated by a nonlinear load and increasing grid current's total harmonic distortion (THD). For implementation work, the laboratory performance of the system under consideration with an adaptive observer using d-SPACE-1104 has been presented.

S. Balan and K. Selvi [12] In this paper, the performance of the rectifier load linked system is examined using a traditional proportional-integral (PI) controller, and the Artificial Neural Network (ANN) driven DVR is built. The Voltage Source Inverter (VSI) control algorithm uses the Levenberg-Marquardt (LV) Back propagation method. Offline training of the ANN is done with PI controller data. The DVR is employed not only to compensate for voltage sag and harmonics, but also to safeguard a linear load from diverse source voltage disturbances. The analysis of three different fault types with two levels of voltage sag is done, and MATLAB/SIMULINK is used to estimate how well the DVR performs under these disturbances. Also shown is the comprehensive output of the PI and ANN controllers.

S. Arulkumar and P. Madhavasarma [13 In order to balance out and enhance the load side power in this study, solar-based additional power is supplied with a maximum power point tracking algorithm controlled by a particle swarm optimization technique tuned fuzzy based PI control technique utilizing MATLAB software. Total harmonic distortion has decreased from an average of 2.77% to 1.16% for voltage and from an average of 4.48% to 2.02% for current.

F. M. F. Flaih et.al [14] In order to control the line voltage and enhance power quality, the authors of this study offer a design of fuzzy logic-based controllers with two-input and single-output TISO FLC subsystems for a DSTATCOM. The scale factors of the created TISO FLC are tuned using Particle Swarm Optimization (PSO). The proposed controllers are used to improve the grid voltage's response to conditions with significant load changes and source voltage variation (sag and swell). Experimental results and the effectiveness of the suggested controllers are contrasted with those of traditional PI controllers. The outcomes of the simulation demonstrate that the proposed controller enhances the distribution system's dynamic performance and voltage profile.

E.Ramakrishna et.al [15] This study employs a hybrid convergence method to assess how PQ has evolved in a distribution device. A D-STATCOM-based Modular Multilevel Converter device is being examined for PQ analysis. The Adaptive Recurrent Neural Network with a Crow Search Optimization Algorithm (ARNN-CSOA), which is utilized for Modular Multilevel Converter (MMC) optimization based on the device D-STATCOM, is the name of this proposed hybrid adapter. The quick watt controller with invisible power will now be provided via the advanced D-STATCOM approach to account for loads, contemporary imbalances, flicker power reductions, and voltage regulation. By using an RNN technique, the suggested hybrid control strategy aims to maximize the power of participation. The PI controller obstacles are detected in advance to deliver suitable MMC-based DSTATCOM action utilizing the suggested hybrid adapter mechanism. The suggested method teaches various varieties of switches for mechanical issues, including DC power, real power, and active power. The proper MM-based D-STATCOM cones are created using the suggested method, and the desired results are obtained. The suggested solution works with the MATLAB / Simulink platform and is connected to many PWM techniques including the SVM and ANN process.

P. Kumar et.al [16] The primary goal of this study is to create a hybrid predictor for dynamic voltage restorers (DVR) to estimate the reference load voltage and self-tuned voltage regulation to improve voltage power quality issues. The potential benefits of metaheuristic algorithms combined with Antlion Optimization (ALO) and Genetic Algorithm (GA) are used to find the best-fit predictor model. In order to generate the subsequent switching signal with lower error rates for load voltage estimation, the study suggests an ALO optimized multilayer perceptron (MLP) neural network (NN) control method. To automatically tune fuzzy rules with fewer membership functions (MFs) and produce the ideal ANFIS (Takagi-Sugeno) prediction models for efficient DC and AC link voltage regulation, the ANFIS-GA control algorithm is designed. The early convergence, slow learning mechanism, lower likelihood of local entrapment, and challenges in achieving the estimated target under parametric uncertainties, specifically sag, swell, unbalance, and distortion, are disadvantages of classic ANN that are addressed by the suggested hybrid controller.

P. Kumar et.al [17] In order to address voltage aggravations in the power distribution network (DN), a hybrid approach is used in this study, namely neural network training (NNT) based machine learning (ML) estimator inspired by artificial neural network (ANN) and self-adaptive neuro-fuzzy inference system (ANFIS). In this study, the particle swarm optimization (PSO) swarm intelligence technique's potential is examined in order to create the best possible prediction model by modifying the training algorithm's parameters. In reality, when systems are regularly subjected to parametric changes or external disruptions, enough time is devoted to fine-tuning the system in order to restore its steady functioning. It is suggested to use intelligence-based solutions to address the limitations of traditional controllers in order to enhance the dynamic performance of the system. Therefore, gain tuning based on intelligence system is a preferable option. The effectiveness of the controllers is declared using statistical tools. In the training phase, the resulting MSE, RMSE, ME, SD, and R were assessed as 0.0015959, 0.039949, 0.00089838, 0.039941, and 1; in the testing phase, they were evaluated as 0.0015372, 0.039207, 0.0005657, 0.039203, and 1 accordingly. The findings showed that, when compared to the standard PI network model, the ANFIS-PSO network model could achieve a better DC voltage control performance.

IV. CONTROL TECHNIQUES FOR UPQC BASED ON ARTIFICIAL INTELLIGENCE (AI)

The recent sharp increase in load demand prompts power system planners to concentrate on creating innovative methods for power system control and optimization. These considerations extend beyond network-wide use of smart devices and place a high priority on optimization strategies. On the other hand, improving optimization techniques also aids in the growth of artificial intelligence (AI). Therefore, in order to automate the operation of the distribution system, researchers are concentrating on conventional controllers. These are the leading AI-based power system developers who prioritize real-time control above offline control [20]. Traditional controllers and research on them are mostly focused on hybrid controllers that use AI-based optimized controllers to increase power quality. A block diagram in Figure 3 shows how information is flowed and decisions are made using a hybrid AI-based optimal controller when power quality disturbances of any kind occur. When a disturbance is detected, the system sends feedback input—current, voltage, or both—to the controller portion. The gains of the controller are optimized based on the inputs, and the AI system is run using optimal values to create the necessary outputs for producing the VSI gate pulses.

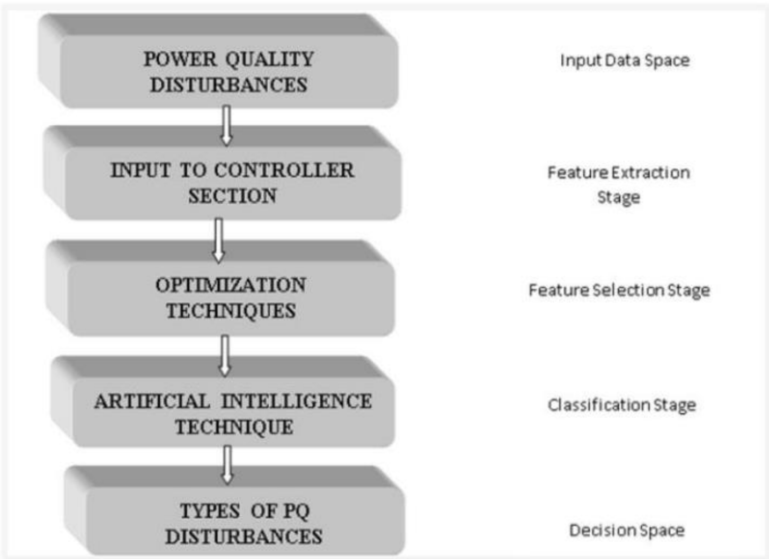

Figure 3: Work flow of control for UPQC using AI methods

The technology intelligently resolves issues in accordance with the type of disturbance. The majority of the research publications in this field focus on various hybrid AI-based optimal controllers for power quality improvement. Artificial intelligence approaches fall under a number of categories.In order to find solutions for industrial and commercial problems, AI researchers and partitioners have been developing and experimenting with a wide range of methodologies.
Artificial Neural Networks (ANN), Fuzzy Logic Systems, Genetic Algorithm, Particle Swarm Optimization, Colony Optimization, and Simulated Annealing are the key artificial intelligence approaches used in power systems. To increase the quality of the power, a variety of optimization approaches are used with AI algorithms.

Here, several research publications have been examined, and it has been discovered that engineering applications frequently use meta heuristic optimization problems. In order to address complex issues that are otherwise challenging to solve using conventional techniques, metaheuristic optimization problems have gained popularity. In addition to employing one metaheuristic approach, the optimization problem is also solved by combining any two metaheuristic methods. As shown in table 1, metaheuristic optimization issues can be categorized. In the controller part of the FACTS devices, a lot of research has been done and is currently being done, and the conventional controllers have been replaced by AI-based optimized controllers. The majority of publications discuss hybrids of two or more approaches, which show to perform well in cases where power quality is improved. For FACTS devices to increase power quality, numerous research articles use the contemporary AI-based optimized controllers. Table 1 lists the method and instrument for various AI-based optimized controllers used in conjunction with DFACTS devices and taken into consideration to address the power quality challenges.

Table 1: Quality issues and their mitigation techniques based on AI controllers for FACTS

Power quality problems considered	DFACTS device chosen	AI based optimized Controller used	Results and Conclusions	THD%
Voltage sag Voltage swell	DSTATCOM	• PSO-ANN based PI controller	• With combined techniques with optimization topology give more accuracy to power system and solves PQ problems with more reliability	9.23%(sag) 3.26%(swell)
Total Harmonic Distortion Reactive power variation	DSTATCOM	• Salp Swarm Optimization Algorithm (SSOA) in PI controller	• THD reduced • Decreasing burden of the reactive power on the grid due to non-linear load	3.23%
Voltage sag Harmonics	DVR	• ANN based PI controller	• Fast compensation of voltage sag • THD reduced	2.01%
Total Harmonic Distortion Variation of load side voltage	UPQC	• PSO-Fuzzy tunned PI controller	• THD is reduced	1.16%
Voltage profile System stability	DSTATCOM	• PSO- Two Input Single Output (TISO) Fuzzy Controller	• Improvement in voltage profile • Dynamic stability of the system is achieved	Not calculated
Voltage imbalances Flicker Voltage regulation	DSTATCOM	• RNN-CSOA based PI controller	• Mitigation of voltage sag, swell and flicker	4.32%(swell) 7.16%(sag)
Sag, Swell, Unbalance Distortion	DVR	• ALO-MLP NN based controller	• Effectively compensates for all PQ events	2.65%
Voltage aggravations	DVR	• ANFIS-PSO based controller	• Compensates the voltage related PQ issues	3.27%
Total harmonic Distortion	UPQC	• PSO-ANN based controller	• Minimizes THD • Compensates all types of power quality disturbances	0.81%
Harmonics	UPQC	• PSO-GA based PI controller	• Compensates harmonics and unbalance • Neutral current magnitude gets reduced	0.93%

V. ARTIFICIAL INTELLIGENCE TECHNIQUES

There is still a sizable class of issues that are impossible to fully solve in a traditional environment, despite the triumphs of the algorithmic approaches outlined in the preceding section. Use of knowledge bases to store human knowledge is necessary for solving these issues.
• Operator judgment, especially when it comes to workable solutions. • Experience accumulated over time.
• Characterization based on changes in load and network uncertainty, etc.
The overview of AI methods (ES, ANN, fuzzy systems, EC, ant colony search, tabu search, etc.) for power system issues is presented in this part.

A. Expert System

Feigenbaum et al. conducted the first extensive investigation on ES in the early 1970s [50, 51]. ES is a knowledge-based or rule-based system that employs knowledge and interface techniques to address issues that are complex enough to call for human expertise. The following are the main benefits of ES [52]: (i) It is permanent and consistent; (ii) It is transferable or reproducible; and (iii) It is easily documented. The primary drawback of ES is that it cannot learn new skills or adapt to novel situations as a result of a knowledge bottleneck. Applications range in maturity from software prototypes to real-world systems being used in the power industry. Beginning with basic rule-based procedures, knowledge engineering techniques have progressed to include more sophisticated methods including object-oriented design, qualitative reasoning, verification and validation techniques, natural language processing, and multi-agent systems.

B Artificial Neural Network

The training technique Hebb devised in 1949, which showed how a network of neurons might exhibit learning behavior, served as the foundation for ANN [20]. ANN are primarily categorized by their topology (connectivity pattern, feed forward or recurrent, etc.), architecture (number of layers), and learning regime. Multi-layer feed forward networks are used in the majority of ANN applications in power systems. ANN's primary benefits are as follows [21–24]:
(i) It is fast;
(ii) Possesses learning ability;
(iii) Adapts to the data;
(iv) Robust;
(v) Appropriate for non-linear modelling.
These benefits point to the usage of ANN for monitoring and managing voltage security. Even though the computational cost of neural network training is typically high, once the network has been trained, evaluating voltage stability only requires a little amount of time. Despite its benefits, the ANN has certain drawbacks, including:

(i) Large dimensionality;
(ii) Selection of the optimum configuration;
(iii) The choice of training methodology;
(iv) The 'black-box' representation of ANN – they lack explanation capabilities and so decisions are not audible;
(v) The fact that results are always generated even if the input data are unreasonable.

C Fuzzy Logic

Zadeh created fuzzy logic in 1964 to deal with the uncertainty and imprecision that frequently arise in engineering difficulties. It was first used in 1979 to address issues with the power system. It is possible to think of fuzzy set theory as a generalization of classical set theory. According to traditional set theory, a universe element either belongs to or does not belong to the set. As a result, an element's degree of relationship is clear. The association of an element can continually change in a fuzzy set theory. A fuzzy set is a mathematical mapping from the realm of discourse to the closed interval [0,1] known as a membership function. Incorporating knowledge, heuristics, or theory into controllers and decision-makers can be accomplished using fuzzy logic as a generic methodology. Fuzzy theory has two benefits: (i) it more properly depicts the operational limitations of power systems; and (ii) its fuzzy constraints are softer than conventional restrictions [24]. [25] provides a thorough introduction to fuzzy logic and its uses in electrical power systems. The overview and literature review of fuzzy set theory's use in power systems have been provided by Momoh et al. in their study [26]. According to a recent study [27], fuzzy set theory has mostly been used in the following areas: voltage and reactive power control, load forecasting, fault diagnosis, power system protection/relaying, stability, and power system control, among others.

D Evolutionary Computation

Darwin's "survival of the fittest" idea forms the foundation of EC. Initializing a population of potential solutions to a problem is the first step of an evolutionary algorithm [28]. Then, by randomly altering those of the initial population, new solutions are produced. Every solution is evaluated based on how well it completes the job. Finally, a selection criterion is used to eliminate any subpar answers. The process is repeated using the chosen set of solutions up until a certain requirement is satisfied. Although EC has the potential to adapt to change and produce adequate solutions, it must be understood in relation to computing needs and convergence features. GA, evolution strategies, evolutionary programming (EP),genetic programming, classified systems and simulated annealing (SA).

E Ant Colony Search

The ACS system was first introduced by Dorigo in 1992 [29]. In order to tackle function or combinational issues, ACS approaches draw their inspiration from the behavior of actual ant colonies. In some ways, ACS algorithms resemble the actions of actual ants. The key features of ACS are distributed computation, which prevents premature convergence, positive feedback for recovering good solutions, and the use of a constructive greedy heuristic to locate workable solutions early in the search process. The fundamental weakness of this method is the poor computing performance of the ACS. The shortest path for a transmission network has often been determined using the ACS approach [30, 31].

F Tabu Search

Similar to a "greatest descent neighborhood" search technique, TS is an iterative improvement procedure that starts with an existing answer and seeks to improve upon it. Moves, a tabu list, and aspiration levels make up the fundamental elements of TS. TS is a metahuristic search that uses multi-level memory management and response exploration to address global optimization problems. Transmission scheduling [32], optimal capacitor placement [33], unit commitment, hydrothermal scheduling, fault diagnosis/alarm processing, reactive power planning, etc. are just a few of the power system applications where TS has been applied.

VI.CONCLUSION

For the generation of reference current and voltage signals in accordance with the specifications for the series active power filter and shunt active power filter of the power quality conditioner, various control techniques are employed. Shunt APF is typically used to handle the current quality of a power system, while series APF is typically used to handle voltage quality. The distribution system's UPQC is a custom power device that addresses issues with power quality such as voltage sag and swell, current harmonics, etc. The review paper has offered a thorough investigation of AI-based control methods used to Unified Power Quality Conditioners (UPQC), emphasizing its revolutionary effects on grid stability and power quality improvement. It is clear from a thorough study of the most recent research and innovations that AI-driven control strategies have become a viable option for addressing complicated power quality issues in contemporary electrical systems.

REFERENCES

[1]. IEEE recommended Practices and Recommendations for harmonics Control in Electric Power Systems,IEEE std.519,1992.
[2]. E.W.Gunther and H.Mehta, "A survey of distribution system power quality",IEEE Trans. on Power Delivery, vol.10, No.1, pp.322-329, Jan.1995.

[3]. J. C. Das, “Passive filters - potentialities and limitations,” IEEE Trans. Ind. Applicat., vol.40, pp.232-241,Feb.2004
[4]. B. Singh, AL.K. Haddad and A. Chandra, “A review of active filters for power quality improvement,” IEEE Trans. on Ind. Electron, vol.46, pp. 960– 971, 1999.
[5]. H Akagi, “New trends in active Filters for power conditioning”, IEEE Trans.on Ind. Appl., 1996, 32, pp. 1312–1322
[6]. B.Singh,V. Verma,A. Chandra and K. Al-Haddad, “ Hybrid filters for power quality improvement,”Proc. IEE on Generation, Transmission and Distribution, vol.152,pp.365-378,May2005.
[7]. Arindam Ghosh, Gerard Ledwich,“ Power Quality Enhancement Using Custom Power Devices” Kulwer International Series in Engineering and Computer Science, 2002.
[8]. N. G. Hingorani,” Introducing custom power,”Proc. IEEE Spectrum, vol.32, pp.41-48, June1995.
[9]. J. Lin, F. MagnagoJuan and . M. Alemany, "Optimization Methods Applied to Power Systems: Current Practices and Challenges," in Classical and recent aspects of power system optimization, Academic press, 2018, pp. 1-18.
[10].Z. A. Saafin, F. Zaro and M. Jawadeh, "Voltage Profile Improvement Using DSTATCOM based on Artificial intelligence techniques," in IEEE Jordan International Joint Conference on Electrical Engineering and Information Technology, Jordan, 2019.
[11]. J. SRIKAKOLAPU, S. Raj ARYA and . R. MAURYA, "Distribution Static Compensator Using an Adaptive Observer based control algorithm with salp swarm optimization algorithm," CPSS TRANSACTIONS ON POWER ELECTRONICS AND APPLICATIONS, vol. 6, no. 1, pp. 52-62, 2021.
[12]. S. Balan and K. Selvi, "Power Quality Enhancement in Power Distribution system using Artificial intelligence based Dynamic Voltage Restorer," International Journal on Electrical Engineering and Informatics, vol. 5, no. 4, pp. 433- 446, 2013.
[13]. S. Arulkumar and P. Madhavasarma, "Particle Swarm Optimization Technique Tuned Fuzzy Based PI Controller of Unified Power Quality Conditioner," Journal of Computational and Theoretical Nanoscience, vol. 14, no. 7, pp. 3433-3441, 2017.
[14]. F. M. F. Flaih, L. Xiangning, Q. k. Mohsin and S. M. Dawoud, "Improving Voltage Profile in Distribution system using PSO-TISO fuzzy in Dstatcom control," IEEE, pp. 424- 429, 2016.
[15]. E.Ramakrishna, P. Bharath Kumar, Krishna and P. Sujathad, "Adaptive RNN with CSOA controlled based MMCDSTATCOM for PQ enhancement in Distribution System," Turkish Journal of Computer and Mathematics Education, vol. 12, no. 2, pp. 876-888, 2021.
[16]. P. Kumar, . S. . R. Arya and K. D. Mistry, "Hybrid selflearning controller for restoration of voltage power quality using optimized multilayer neural network," WILEY, pp. 1- 26, 2021.
[17]. P. Kumar, S. . R. Arya and K. D. Mistry, Optimized neural network and adaptive neuro-fuzzy controlled dynamic voltage restorer for power quality performance Int. J. Emerg. Electr. Power Syst., pp. 1-17, 2021.
[18]. K. Saeed and . K. Sheikhyounis, "Power quality improvement of distribution systems asymmetry caused by power disturbances based on particle swarm optimizationartificial neural network," Indonesian Journal of Electrical Engineering and Computer Science, vol. 25, no. 2, pp. 666- 679, 2022.
[19]. T.Gunasekar and R. Anita, "Design of UPQC by Optimizing PI Controller using GA and PSO for Improvement of Power Quality," International Journal of Engineering and Technical Research (IJETR), vol. 2, no. 4, pp. 196-200, 2014.
[20]. P.D. Wasserman. Neural Computing: Theory and Practice. Van Nostrand Reinhold, New York, 1989. [61] D. Niebur and T.S. Dillon, Neural Network Applications in Power Systems, CRL Publishing Ltd. U.K. 1996.
[21]. R. Aggarwal and Y.H. Song. Artificial Neural Networks in Power Systems: Part 1 General Introduction to Neural Computing. IEE Power Engineering Journal, 11(3): 129-134, 1997.
[22]. R. Aggarwal and Y.H. Song. Artificial Neural Networks in Power Systems: Part 2 Types of Artificial Neural Networks. IEE Power Engineering Journal, 12(1):41-47, 1998.
[23]. R. Aggarwal and Y.H. Song. Artificial Neural Networks in Power Systems: Part 3 Examples of Applications in Power Systems. IEE Power Engineering Journal, 12(6):279-287, 1998
[24]. S.K. Pal and D.P. Mandal. Fuzzy Logic and Approximate Reasoning: An Overview. Journal of Institution of Electronics and Telecommunication Engineers, Paper No. 186-C, 548-559, 1991.
[25]. Y.H. Song and A.T. Johns. Applications of Fuzzy Logic in Power Systems. I. General Introduction to Fuzzy Logic. IEE Power Engineering Journal, 11(5): 219-222, 1997.
[26]. J.A. Momoh, X.W. Ma, and K. Tomsovic. Overview and Literature Survey of Fuzzy Set Theory in Power Systems. IEEE Trans. Power Systems, 10(3): 1676-1690, 1995.
[27]. R.C. Bansal. Bibliography on the Fuzzy Set Theory Applications to Power Systems (1994-2001). IEEE Trans. Power Systems, 18(4):1291-1299, 2003.
[28]. D. B. Fogel. What is Evolutionary Computation? IEEE Spectrum, 37(2):26- 32, 2000.

[29]. Y.H. Song and M.R. Irving. Optimization Methods for Electric Power Systems, Part 2, Heuristic Optimization Methods. IEE Power Engineering Journal, 15(3): 151-160, 2001.

[30]. M. Dorigo, V. Maniezzo, and A. Colorni. The Ant System: Optimization by a Colony of Co-Operating Agents. IEEE Trans. Systems, Man and Cybernetics, 26(1): 29-41, 1996.

[31]. Y.H. Song and C.S. Chou. Application of Ant Colony Search Algorithms in Power System Optimization. IEEE Power Engineering Review, 18(12): 63- 64, 1998.

[32]. F. Wen and C.S. Chang. Transmission Network Optimal Planning using Tabu Search Method. Electric Power System Research, 42(2): 153-163, 1997.

[33]. Y.C. Huang, H.T. Yang, and C.L. Haung. Solving the Capacitor Placement Problem in a Radial Distribution System using Tabu Search Approach. IEEE Trans. Power Systems, 11(4): 1868-1873, 1996.