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# Research on STATCOM and Application for Power Quality in Electrical Grid with Hybrid Renewable Energy Sources Using Soft Computing Techniques: A Comprehensive Review

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**Abstract:** In the review paper, FACTS device like STATic COMpensator (STATCOM) and applications for power quality, efficient use of HRES are exhibited, for example, wind and photovoltaic (PV). Here, the rule point of utilizing STATCOM is a reactive power control for guideline and decrease of unbalance cases which occur in the electrical grid. A novel highlight of this review paper is to categorize power quality enhancement approaches into two main groups depending upon the various optimization strategies. A comparison between these methodologies in terms of benefits, issue alleviation and its control are likewise analyzed in this dissertation. This review could be utilized as a manual for designers, application engineers and researchers to provide data source and selection guide in STATCOM linked grid connected HRES system.

**Keywords:** *Hybrid renewable energy system, STATCOM, grid connected HRES, wind and photovoltaic (PV)*

## 1. INTRODUCTION

Nowadays, Flexible AC Transmission System (FACTS) method is utilized at productive utilization of energy, required control, voltage stability, improvement of power quality (PQ), power factor correction, harmonics mitigation [1, 2]. The addendum applications are power flow control, voltage, guidelines, reactive power compensation, transient upgrade with steady state voltage stability, reduction of power loss, improvement of power condition along PQ [3, 4]. The growing use of renewable and distributed generation (DG) contains precipitated and also enlarged the work of electronic appliances in the electrical grid's effective use, improved security and reliability [5]. New applications for standalone micro-grids for renewable energy use have likewise developed utilizing photovoltaic systems, micro-hydroelectric, wind, biomass, waste of energy including hybrid AC-DC sources along battery energy storage for remote villages [6]. Utilizing power electronic converters, renewable energy sources (RESs) are used in rapid rate then associated with transmission, distribution/use systems. This prompts expanded harmonics and a deterioration of the PQ in the point of common coupling (PCC). PQ mitigation problems have risen as real difficulties and difficulties confronting electrical applications, industrial, commercial and residential users [7-10].

Different Flexible AC Transmission System devices with control methods can aid mitigate issues with PQ. The Flexible AC Transmission System conception was unveiled at late 1980s to make proficient use of power system resources [11-13]. The fundamental conception of Flexible AC Transmission System devices is depend on use of higher-voltage power electronics to regulate the transmission system's active with reactive power flow as well as voltage [14]. The comprehensive investigation has focus in innovative topologies including voltage source inverters (VSCs) framework to enhance the efficiency of Flexible AC Transmission System devices in power systems and thereby develop the security of the power system [15, 16]. Flexible AC Transmission System devices along smart control methodologies have recently become very salient in renewable energy generation, like solar, wind, waves [17]. Major investigation concentrated in increasing extraction of energy from RESs. Implementation outcomes of FACTS devices at renewable smart grids are inspiriting [18-20]. The purpose of this dissertation is to review with debate about STATCOM applications at renewable energy sources like wind and PV. This dissertation deals with the following topics: Overview of PQ problems and FACTS devices in grid connected RES is presented in Section 2; Section 3 depicts the grid connected photovoltaic generation system along various methods; Section 4 portrays the grid connected wind generation system along various methods; Section 5 portrays the grid connected photovoltaic-wind generation system along various methods. Section 6 concludes the paper.

## 2. OVERVIEW OF PQ PROBLEMS AND FACTS DEVICES IN GRID CONNECTED RES

Certain difficulties are adopted at the consolidation of wind and solar systems with grid. We use grid integration grid tie inverter to interface RESs to the grid. The inverter utilization is to extracted energy from the grid when RES is deficient also when high power is created it can supply the energy.

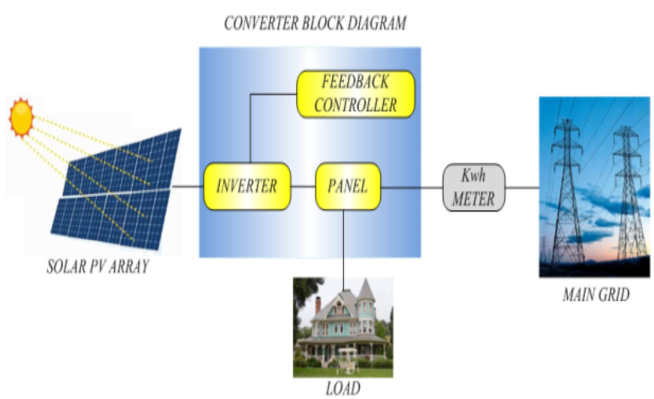


**Figure 1(a):** Grid connected PV array

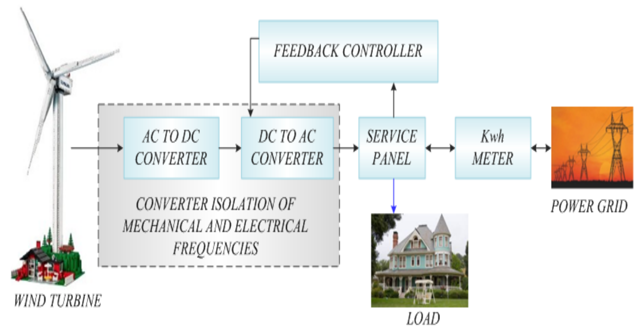


**Figure 1(b):** Grid connected system of wind energy

The major converters function at photovoltaic array connected grid system by taking feedback from utility grid to address the magnitude and phase of PV system output. Due to the grid system connected to the wind turbine it is filled with mechanical and electrical frequency isolation. Harmonics and fluctuations in voltage and frequency are the PQ issues. Figure 1(a) portrays the grid connected photovoltaic array block diagram; the grid connected wind energy system is appeared in Figure 1(b).

### 2.1. Harmonics

Harmonics signifies current or voltage with different integer frequencies of essential power frequency. Harmonics cause interference in large volumes and create all electrical appliances and generators. Because of their distribution on the network even at high levels of penetration it cause harmonic issues which display low levels of harmonic current for the greater part of the grid connected inverters with DG applications.

### 2.2. Variations in Frequency and Voltage

Reclassified frequency and voltage fluctuation are shown in Figure 2. In the section below, each fluctuation is explained.

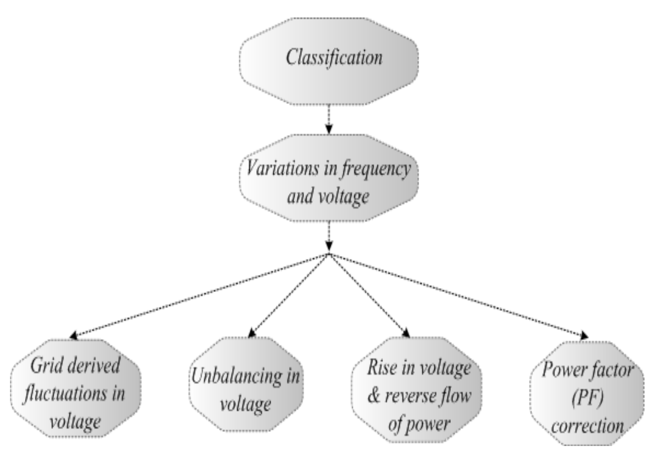


**Figure 2:** Classification of frequency and voltage fluctuation

*2.2.1. Grid Derived Fluctuations in Voltage*

Inverters have been typically arranged to work at grid voltage and also to separate distributed generations while the grid voltage moves outside set parameters. Owing to the out of range grid voltage their automatic disconnection can be tricky as different generators on the network should supply additional power abruptly where there are high count of distributed generation systems or huge distributed generation systems in the specific feeder [9, 10].

*2.2.2. Unbalancing in Voltage*

In a three-phase system voltage unbalance happens with every phase voltage's amplitude, so the phase variation is not actually 120$^o$. Single phase systems introduced excessively can cause extreme unbalanced networks those distributed generator's wreckage controls, transformers, motors, electronic power devices.

*2.2.3. Rise in Voltage and Reverse Flow of Power*

Power flow in one direction is chiefly engaged with the traditional centralized power networks. As per rule, supply loss of line voltage is greater than the nominal end-use voltage. To keep up the voltage along the line inside the predefined range and to balance the voltage drop, voltage regulators are utilized.

*2.2.4. Power Factor (PF) Correction*

Due to dismal power factor line loss, increment of losses with voltage controlling becomes more complex. To direct voltage, dismal grid power factor builds the line loss and creates it progressively complex. Inverters on voltage controlling mode furnish power out of phase along grid voltage though inverters designed to imitate the voltage have unity power factor and at this manner give optimal power factor correction [8, 9].

**2.3. Role of FACTS Devices in Grid Connected RESs**

In order to provide solutions of PQ, FACTS devices are considered as the community of electronic power devices or tool box that can be utilized by distribution systems.

***2.3.1. STATCOM: STATIC SYNCHRONOUS COMPENSATOR***

STATCOM is defined as shunt connected reactive power compensation device that is depicted in Figure 3. It can produce reactive power [12] and regulate the particular parameters of an electrical power system where output can be differed. When encouraged at its input terminals from source of energy or energy storage device for creating or retaining freely controllable active with reactive power in their output terminals is termed as solid state switching converter fit. Specifically, STATCOM refers to VSC, which delivers 3 phase AC output voltages from a given DC voltage input.

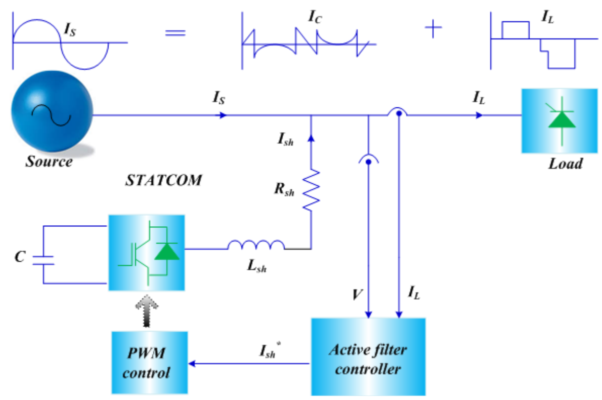


**Figure 3:** System configuration of STATCOM

The application is constrained to reactive power support since as it operates in traditional STATCOM leading and lagging mode. Because of wind variety dynamic power control utilizing a STATCOM can't smooth the fluctuating power, because it does not contain active power control capacity. The BESS was integrated to STATCOM which demonstrates active with reactive power control capacities to conquer this issue [13]. Section 3 delineates the grid connected wind generation system along different strategies.

**3. GRID CONNECTED WIND GENERATION SYSTEM (GCWGS) BY OPTIMIZATION TECHNIQUES**

In this section, GCWGS with different techniques is examined at [21-28]. The optimization technique to the GCWGS is delineated at references [21-28].

A hybrid particle swarm optimization and firefly algorithm is applied [21] to dissect the distribution static synchronous compensator for relief of voltage sag, harmonic distortion and improvement of power factor. To three-phase VSC the DC bus voltage can be characterized by,

$$U_{DC1} = 2\sqrt{2}\,\frac{U_{ll}}{\sqrt{3}s} \tag{1}$$

here, AC line to line output voltage of DSTATCOM can be expressed as $U_{ll}$, modulation index can be specified as $s$. In [22] the shuffled frog leaping algorithm (SFLA) for optimum design multi-proportional integral controllers of STATCOM system along the aim of enhancing grid-connected wind farm transient stability is presented. Whale optimization algorithm (WOA), is used to designing the control rules including Gaussian memberships of eight Sugeno FLCs, concurrently, by reducing higher dimensional multiple-objective fitness function [23]. The WOA-FLCs and the grid-connected gearless permanent magnet synchronous generator driven by a variable-speed wind turbine (VSWT-PMSG) is modelled utilizing PSCAD/EMTDC environment. Figure 4 shows the pitch angle controller.

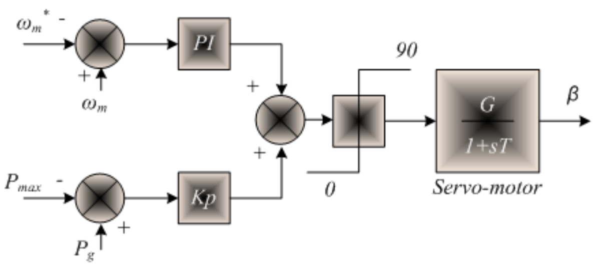


**Figure 4:** Pitch angle controller [23]

In [24], STATCOM operates as LVRT for 9 MW wind farm coupled with the grid by 120 kV transmission system. To improve the dynamic performance of STATCOM, there are two different types of optimization methods are used: ant Colony optimization (ACO) as well as particle swarm optimization (PSO) are proposed to better modify the proportional integral controller coefficients to optimize STATCOM dynamics. The integral time absolute error operation is represented as,

$$ITAE = \sum_{i=1}^{n} t(i) * abs(error(i)) \quad (2)$$

The grey wolf optimization with Fuzzified error (GWFE) model is an innovative methodology for simulating the optimized control system is defined in [25]. Three artificial intelligence-based methods is utilized to controlling the STATCOM-fuzzy logic, PSO, fuzzy logic combination are explained in [26]. The impact of STATCOM Compensator on the power systems stability connected to the wind energy conversion systems (WECS) was investigated at [27]. To improve the STATCOM performance on wind energy grid connected system stability, the STATCOM controller's parameter tuning which can be significant issue in stabilization is optimal. In [28], PQ development of wind energy grid-connected systems occurs using shunt connected STATCOM as the wind farm creates PQ issues. The proportional integral controller of STATCOM applied in this dissertation is tuned by genetic algorithm and particle swarm optimization. Table 1 shows the technical comparison based on grid connected wind energy system along various optimization techniques.

**Table 1:** Technical comparison based on grid connected wind energy system along various optimization techniques [21-28]

| Ref | Main advantages | Problem Mitigation/Control | Drawbacks |
|---|---|---|---|
| [21] | Power quality of GCWES is maintained | Mitigating the issues in PQ | The system is not fully compensating the fluctuation generated by wind turbine |
| [22] | Reduce low frequency harmonics | Good harmonic mitigation | Necessity of high performance controller to mitigate harmonics |
| [23] | Nonlinear unbalanced load compensation for PQ development | Mitigate the issues in the power quality like flicker, interruption of harmonics | Shunt Active filter is more benefits than Series Active filter because many industrial applications need current harmonics compensation. |
| [24] | Control the speed variation of active power and provide the needed reactive power compensation during torque change | Find stable gain matrix for the system stability | The wind speed variation contains rapid impact on the grid, leading to a deterioration at PQ, a destabilization of grid including grid-connected systems |
| [25] | Optimal supply of reactive power to enhance power quality | Mitigate the integration issues of wind power | It has fault ride through capability |
| [26] | High dynamic performance of CHB STATCOM | Optimal redundancy | It is limited to less prediction horizons owing to online computational cost. |
| [27] | Regulation of voltage at the PCC | Mitigate power quality issues | It gives more complexity to the system |
| [28] | Faster convergence because of hybrid algorithm | Harmonics reduction reached to less percentage as1.216 | It has capability to find the proper control signals.<br>But it leads to high complexity |

## 4. GRID CONNECTED PHOTOVOLTAIC GENERATION SYSTEM WITH VARIOUS METHODS

At this section, grid connected photovoltaic generation system along different strategies are talked about in [29-34]. To guarantee the optimal end-user energy cost performance together with energy supplying dependability for the micro-grid with hybrid micro-sources, a dynamic proportional integral-controller in terms of fuzzy logic and also seeker optimization approach (SOA) was developed [29]. The photovoltaic solar farm as STATCOM was defined to analyze day and night use for satisfying the load requirement without PQ interruptions [30]. During day time photovoltaic solar farm generate power but during night time it become totally inactive. The inverter is utilized to active power production during day time, and the inverter is utilized to satisfy the load requirement during night time along with improved performance by voltage control, current, active with reactive power including damping controls. The proposed hybrid methodology is used to the efficiency of PV-STATCOM analysis, which including the tenets of chicken swarm optimization with particle swarm optimization. The chicken swarm optimization algorithm is applied to reach the control of above parameters whereas particle swarm optimization algorithm is applied to optimize the rooster's position of chicken swarm optimization algorithm. In [31], a reconfiguration method in terms of multi-objective modified flower pollination algorithm (MO-MFPA) the purpose is to reach the minimization of power losses, minimal load balancing indices, maximal voltage profile at radial distribution networks, photovoltaic arrays, distribution static compensator (D-STATCOM). After establishing the photovoltaic unit, active with reactive power flow system is following,

$$P_{PV}=\left[\frac{v_i^2}{r_i}P_{loss}^{PV}-\left(P_i^2+Q_i^2\right)-\left(Q_{PV}^2-2P_iP_{PV}-2Q_mQ_{PV}\left(\frac{G}{L}\right)\right]^{1/2} \quad (3)$$

$$Q_{PV}=\left[\frac{v_i^2}{r_i}P_{loss}^{PV}-\left(P_i^2+Q_i^2\right)-\left(P_{PV}^2-2P_iP_{PV}-2Q_mQ_{PV}\left(\frac{G}{L}\right)\right]^{1/2} \quad (4)$$

here, active power supplied by photovoltaic as $P_{PV}$, reactive power supplied by photovoltaic as $Q_{PV}$, distance from source to photovoltaic location as $G$, overall feeder length from source to bus i as $L$ ,voltage at bus i as $v_i$, line section resistance among buses i with i + 1 as $r_i$. The tuning parameter technique of proportional integral controller to photovoltaic grid-connected system with STATCOM is considered. The chaotic orthogonal particle swarm optimization algorithm is applied to optimize the optimum total efficiency of the direct current capacitor voltage including the photovoltaic inverters point of common coupling point voltage to improve the proportional integral controller parameters of the system. [32]. In [33], a smart inverter photovoltaic-STATCOM control removes the required physical STATCOM, storing immense cost for utilities that deal with TOV issues, voltage rise, grid connected photovoltaic systems. In [34], an approach for optimum PV-STATCOM placement with size is proposed utilizing experiential data. In order to the aim of power loss, cost reduction, voltage enhancement, the two sub-problems of placement and size, respectively, are determined by the power loss indices including adaptive particle optimization (APSO). Table 2 shows the technical comparison based on grid connected photovoltaic system along various optimization approaches.

**Table 2:** Technical comparison based on grid connected photovoltaic system along various optimization approaches [29-34]

| Ref | Main advantages | Problem Mitigation/Control | Drawbacks |
|---|---|---|---|
| [29] | STATCOM gain parameters evaluation to enhance the performance of CWF stability | ANN enhances active with reactive power, CWF voltage during fault condition | It can't give the proficient response |
| [30] | Compensate reactive power | Reduce total harmonic distortion (THD) | Higher complexity |
| [31] | System parameters were controlled by synchronous reference frame theory | Voltage fluctuations are eliminated | Low convergence rate and its low response |
| [32] | Compensate reactive power, balances load | Elimination of harmonics | No losses considered |
| [33] | Enhance the performance of WFMPS under different abnormal conditions | Better damping oscillation under fault conditions | Poor flexibility in control |
| [34] | Increases the less-voltage ride through (LVRT)capability | Regulate the flow of VAR between STATCOM and grid | can't guarantee favorable efficiency at the event of disturbances in the power system |

## 5. GRID CONNECTED PV-WIND GENERATION SYSTEM WITH VARIOUS METHODS

On this section, grid connected photovoltaic-wind generation system along different techniques are talked about in [35-50].

In nearness of high probabilistic uncertainty to assess gain parameters of STATCOM controller STATCOM efficiency for voltage reactive power controller is researched with the input of wind power including reactive power load requirement in [35]. By STATCOM voltage instability responding at minimal time, reactive power requirement was overseen. Propelled controllers, for example, genetic algorithm, artificial neural network (ANN), adaptive neuro fuzzy inference system (ANFIS) were needed. For de-centralized hybrid power system, reactive power balance equation is determined utilizing with equation,

$$\Delta U(S) = \frac{1}{d_v + s\frac{U}{\omega X_m}}\left[\Delta Q_{SG}(S) + \Delta Q_{ST}(S) - \Delta Q_{IG}(S) - \Delta Q_L(S)\right] \quad (5)$$

here, $Q_{SG}$ represents reactive power of synchronous generator, $Q_{ST}$ could be specified as reactive power of STATCOM, $Q_{IG}$ represents reactive power of induction generator, $Q_L$ could be indicated as reactive power of load. By utilizing the STATCOM compensation the reactive power balance diagram is portrayed in Figure 5.

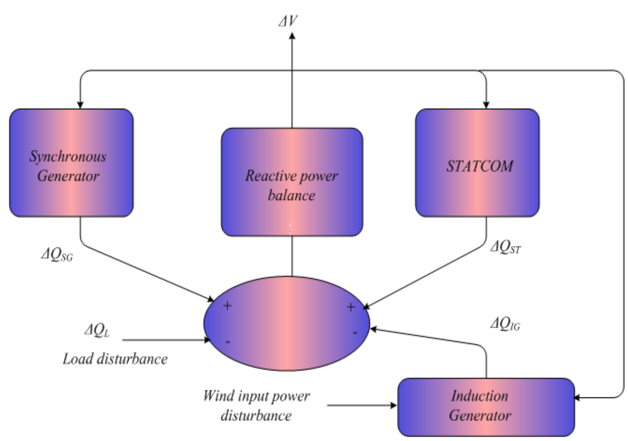


**Figure 5:** Reactive power balance diagram [35]

In DSTATCOM associated N-level inverter system to PQ relief a hybrid control scheme is shown in [36]. The hybrid control system is the integration of random forest search algorithm (RFSA) together with lightning search algorithm (LSA) called as (RFLSA). By using the proposed scheme, proportional integral controller gain parameters are anticipated to give the DSTATCOM optimum control signal. By utilizing LSA, the learning procedure of RFSA was upgraded dependent on the minimal error objective function. The network equation is determined by barring the generators and DSTATCOM which are as per the following,

$$C_b = Y_b \times U_b \quad (6)$$

here, infusing current can be expressed as $C_b$, node voltage of the power system can be specified as $U_b$, and the admittance matrix can be specified as $Y_b$.D-STATCOM device is utilized for compensating power from PV and wind ranch. To control the power flow efficient control techniques are exercised. Recurrent Neural Network (RNN) with Tree Seed Algorithm (TSA) was employed in [37]. The power quality issue was formulated as an optimization problem [38]. An Extended Search Algorithm (ESA) is proposed to solve the optimization issue. The objective function is formulated based on the voltage, power loss and harmonic distortion.

Solar photovoltaic-Wind Hybrid Micro-grid model with increasing constant operating limitation of the system integration of STATCOM is analyzed in [39]. The main objective of this dissertation is the gain parameters optimization of four proportional integral controllers at STATCOM controlling circuits depending upon GA, Bacterial Foraging (BF) algorithm, thus acquiring the best responses and voltage stability based on linear nature of solar-wind hybrid micro-grid. Particle swarm optimization is proposed to acquire the optimum number of D-STATCOM appliances, the size and location for reducing overall power loss, bus voltage deviations, overloading lines at the radial distribution system with distributed generations [40]. The injected reactive power by D-STATCOM can be written as:

$$Q_{D-STATCOM} = \mathrm{Im}\,aginary\left(V_{j,new} I_{D-STATCOM}\right) \quad (7)$$

here, injected reactive power with current by D-STATCOM as $Q_{D-STATCOM}$ and $I_{D-STATCOM}$. Designing of a Hybrid solar/wind system as well as integrating it with the grid system in MATLAB /SIMULINK environment was performed in [41]. And Designing of a compensating device and compare it with the basic STATCOM compensator for active power output enhancement in the system. GSA was proposed to improve the implementation of D-STATCOM and remunerating the PQ [42]. Figure 6 represents the gain tuning of PI controller involving presented system.

A self-tuning proportional integral controller that the controller gains are modified utilizing particle swarm optimization approach was proposed to STATCOM [43]. An advanced control method is formulated for damping the minimal frequency oscillations and voltage deviations of a multi-machine power system using ACO-based STATCOM [44]. Figure 6 depicts the ACO-based STATCOM controller.

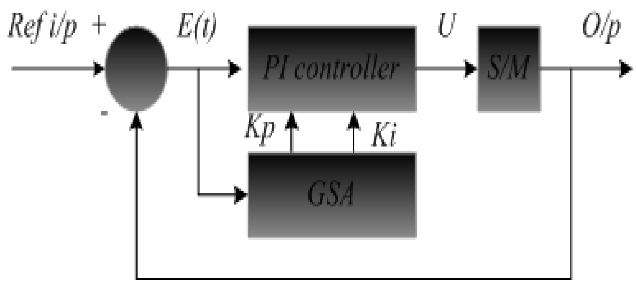


**Figure 6:** Gain tuning of the PI controller involving presented system [42]

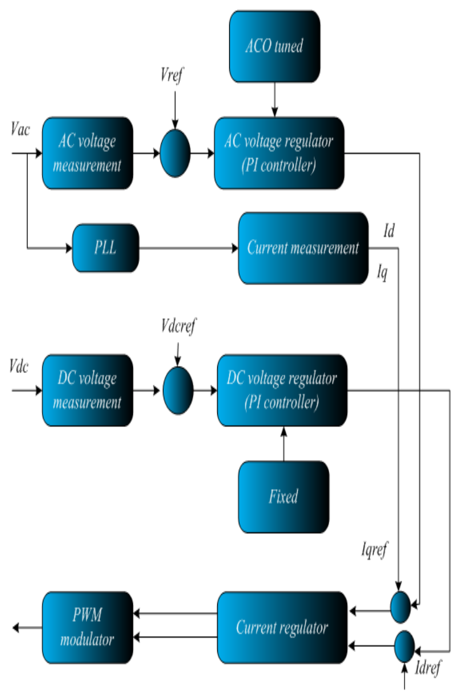


**Figure 6:** ACO-based STATCOM controller [44]

The proficient involvement of PSO with their variants like constrained factor-PSO (CF-PSO), Cauchy mutation-CFPSO (CM-CFPSO), Gaussian mutation-CFPSO (GM-CFPSO) algorithm to select appropriate location and STATCOM rate depend on new index known as unification index (UI) [45]. In [46], there are three Flexible AC Transmission System controllers effects, they are static synchronous series compensator (SSSC), thyristor controlled series compensator (TCSC), static synchronous compensator (STATCOM), in the multiple-machine power system transient stability in the presence of two 200MW wind farms in terms of doubly fed induction generator with 120MW photovoltaic solar plant are studied. The design issues of PSS, Flexible AC Transmission System, proportional integral controllers are designed as an optimization issue, the adaptive velocity update relaxation particle swarm optimization algorithm, gravitational search algorithm, genetic algorithm are applied to search the optimum control parameters [47]. The index of dv/dq is preferred to find the location of compensatory device allocation. Objective function is the mathematical expression of objectives. FACTS devices are taken in use because of their multi-functionality. These devices are able to achieve more than single objective as:

$$F.O = \sum_{k=1}^{N} g_k \left[V_i^2 + V_j^2 - 2V_iV_j \cos(\delta_i - \delta_j)\right] \quad (8)$$

$$S.O = \sum_{j \in I_L} \left|V_j - V_{jref}\right|^2 \quad (9)$$

$$F.O.F = Min(F) = w1 * \min(F.O) + w2 * \min(S.O) \quad (10)$$

here, weight factors as $w1$ and $w2$.Whale optimization algorithm (WOA) of PI controllers for controlling STATCOM is investigated in [48]. This WOA-PI controller of STATCOM is applied for a renewable hybrid system to improve the efficiency of the entire system. A multi-objective methodology for ideally keep the D-STATCOM at distribution system using the multi-objective genetic algorithm is described in [49]. In the proposed approach, average current THD, the functions of installation as well as operation cost are determined into the objective functions, here input harmonic limits for individual buses are selected as the optimization limitations. The GA utilization for optimum size and STATCOM allocation at power system is investigated in [50]. STATCOM devices are utilized to increasing the transmission system ability and improve the voltage stability by controlling the voltages at their terminal and regulating the number of reactive power injected into or absorbed from the power system. Table 3 shows the technical comparison based on grid connected hybrid system with various optimization techniques.

**Table 3:** Technical comparison based on grid connected hybrid system with various optimization techniques [35-50]

| Ref | Main advantages | Problem Mitigation/Control | Drawbacks |
|---|---|---|---|
| [35] | Magnify the utilization factor of the present proposed grid integrated system | Mitigation of power quality related problems | Voltage imbalance |
| [36] | Improvement in performance, system responding time, settling time, robustness, transient | Better transient including sub-transient respond | Restricted number of usage of input variables |

| | | | |
|---|---|---|---|
| | including sub transient stability, total system reliability | | |
| [37] | Efficiencies of the controllers are higher | Eliminate reactive power on micro-grid loads | Owing to integral time however ,the process must have relative slowly changes in load to prevent oscillations induced by the integral overshoot |
| [38] | High proficient PQ management system for grid interfaced wind energy generation system | Active power, reactive power, voltage variation, filcher, harmonics and electrical behaviors of switch function and these are optimally measured | Complicates the circuit design when external devices are needed |
| [39] | It maintains the voltage source, current in-phase, support the reactive power requirement to the load of PCC at grid system, thus it provides a chance to improve utilization factor of transmission line. | Mitigate the power quality issues like interruptions. | Reduces the flexibility and resilience of the electricity grid |
| [40] | Un-stabilized and unbalanced power supply is being improved | Voltage Sag, load changes, Distortion were mitigated | Central control is required it is complicated |
| [41] | Power management of the system is controlled | THD obtained in the presence of STATCOM is less than 5 % | It requires tuning of membership functions |
| [42] | Able to correcting the power factor close to unity | Mitigate harmonics, electrical switching behavior, variation of voltage, and flicker | Additional device are required to compensate the interruption |
| [43] | Maintain voltage stability, enlargement of critical clearing time | Removes the harmonics from the system in presence of fault | Need more accurate technique |
| [44] | Able to preserve optimum efficiency over wide range of disturbances using Integral of Square of Errors criterion | Control the reactive power at the de-centralized hybrid power system | Number of permutations of functions including variables |
| [45] | The fuzzy control theory with hysteresis loss current control algorithm based D-STATCOM has the ability for good characteristics of compensation. | By using fuzzy controller compensation strategy the THD (Total Harmonics Distortion) is reduced up to 1.89%. | It requires lots of data |
| [46] | Settling time decreases and also the peak over shoot decreases | Optimal control of reactive power | It is not useful for programs much smaller or greater than historical data |
| [47] | Optimally manage the energy from the HRES | Voltage regulation and harmonics mitigation | The user has to define a priori the number of linguist terms to be considered for the variables |
| [48] | Improve output voltage, closed loop hysteresis current control is reached | Reduce Total Harmonic Distortion (THD) | The main disadvantages of cascaded multilevel inverter are the voltage |

| | | | |
|---|---|---|---|
| | | | unbalance |
| [49] | Dynamic response, high efficiency | Diminished harmonics | The main disadvantages of random forests are their complexity. They are much harder and time consuming |
| [50] | Good accuracy by the optimization process. | Transient stability limit of multi machine power systems are enhanced | Perform poorly on complex problems |

### 6. CONCLUSION

This review paper reviewed the state-of the-art power quality enhancement approaches, which are still an active research area for STATCOM linked grid connected HRES system. Firstly, the overview of PQ problems and the role of FACTS device like STATCOM in grid connected HRES system were discussed. Next all the reviewed strategies were investigated based on the optimization techniques. The performances, main advantages, problem mitigations of various strategies were also discussed. The objective of the proposed analysis was proficient energy utilization, less minimization, voltage stability, power factor, PQ, harmonic mitigation in PCC with nonlinear loads. Moreover, various problems involve interfacing wind/photovoltaic systems along weak ac electric utility systems were regarded. Furthermore, STATCOM was found to be very efficient at incorporating solar as well as wind energy into electrical grid. Most of the works in this review were provided to focus of power quality issues and the presented works do not provide effective results for detecting swelling / sagging / harmonic issue at system voltages to create system performance. As a result, additional researches have been anticipated to enhance the system performance and mitigate the PQ issues at HRES system using an upgraded approach.

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