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A Review Article of Statcom Design and Inhancement Controlling of Power Quality

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Abstract- This paper deals with A New design of D-STATCOM (Distribution Static Compensator) is Used for Mitigation of Power Quality Problems under unbalance caused by various loads in distribution system. This paper addresses the modeling and analysis of custom power controllers, power electronic-based equipment aimed at enhancing the reliability and quality of power flows in low voltage distribution networks using DSTATCOM. A new PWM- based control scheme has been proposed that only requires voltage measurements the operation of the proposed control method is presented for D-STATCOM. Simulations and analysis are carried out in MATLAB/SIMULINK with this control method for two proposed systems.

Keywords - D-STATCOM, VSC, FACTS Devices, PQ, PCC.

I. INTRODUCTION

From the past few decades, the increase in electrical energy demand for industries and domestic use resulted in the higher production of electrical energy which has consequently resulted in higher tariff rates, for industrial and domestically usage A.C Power is essential, In A.C the power factor is described as the ratio of real power to the apparent power (real power+ reactive power). Reactive power is produced when the current and voltage waveforms are out of phase with each other, in a capacitive load current leads voltage whereas in inductive load current lags voltage, reactive power is denoted as var. Reactive power compensation is essential to increase the power factor quality, which obviously results in the decrease of power consumption and tariffs; finally the aim is to decrease the reactive power.

Reactive power can be decreased by placing a shunt capacitor in line but it does not fulfill the problem because it gets in resonance when it gets tuned with reactance of the system. In order to overcome the disadvantages caused by placing a shunt capacitor in line, facts devices have been developed to solve the problem effectively examples of FACTS devices are SC, TSC...etc. Though the power electronic devices known as Facts devices are developed for transmission part of the system its model have been changed from past few years to serve better power quality at low and medium voltages.

DSTATCOM is a distribution static compensator network which is placed at the distribution part of the system which works with the FACTS devices which react faster than the shunt capacitors actually. In recent years, the custom power technology, the low voltage counterpart of the more widely known flexible ac transmission system (FACTS) technology, aimed at high voltage power transmission applications, has emerged as a credible solution to solve many of the problems relating to continuity of supply at the end-user level. Both the FACTS and custom power concepts are directly credited to EPRI [1], [2]. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications.

Among these, the distribution static compensator (DSTATCOM) based on the VSC principle [3]- [5] has been used to perform the Modelling and analysis of such controllers for a wide range of operating conditions based PWM control reported in this seminar for the DSTATCOM. It relies only on voltage measurements for its operation, i.e., it does not require reactive power measurements [6]. A sensitivity analysis is carried out to determine the impact of the dc capacitor size on DSTATCOM performance.

II. RESEARCH MOTIVATION

An improved power quality has always been a primary requirement and also a major challenge in any electric distribution system [1]. Due to the growing use of power electronics, power quality problems have become an important concern nowadays since these problems not only result in degradation of the power factor but also lead to failures of sensitive devices, equipment overheating etc. [2]–[5]. The increased penetrations of the distributed energy resources to the power grid have also given rise to many challenges related to power quality.

The work reported in [6] presents a comprehensive discussion of power quality issues, basic standards, power quality monitoring techniques as well as techniques to mitigate power quality problems etc., especially in distributed generation systems. The non-linear loads

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connected at the point of common coupling (PCC) draw the harmonic and reactive currents in addition to the active current from the source, thereby degrading electric power quality [3], [7]. Earlier, only passive filters were used to mitigate power quality problems [3]. Nevertheless, fixed compensation capability and time-dependent adjustment of the filter parameters were present as some of the limitations of the passive filters [8], [9].

Nowadays, the inverter-based power quality conditioners have received much attention from researchers in mitigating power quality problems because of their small size and fast dynamic response with lower losses [10]. The shunt active power filters are used today not only to enhance reliability but also to mitigate the power quality problems due to the non-linear loads connected at the PCC [3], [8]. The performance of active power filters at different conditions along with involved control algorithms have been investigated in literature [11]–[15]. Further, different sorts of control algorithms employed for the shunt active power filters have been reviewed thoroughly in [2].

III. LITERATURE REVIEW

Nitin Kumar Saxena, Firefly Algorithm based LCL filtered grid-tied STATCOM design for reactive power compensation in SCIG based Micro-grid: Microgrids are facing several operational and control issues while integrating with the grid. To deal with it, STATCOM, as one of the emerging power converter circuits, is connected with such microgrids. STATCOM with microgrid introduces current harmonic, inherent resonance, and active power losses related to high switching frequency.

Filter design can help attenuate these effects and maintain the predefined standards as in IEEE 519-1992 and IEEE P1547.2-2003. There are also some more points of concern about filter design. Inappropriate filter types and parameters may cause worse filtering, reactive power surplus production, and low power factor. Therefore, this paper suggests that the reactive power compensation capability, as a local area problem, must be attended through the proper designing of LCL filtered grid-tied STATCOM.

The parameters are estimated through transient analysis, power quality, and power balance studies for proposed Micro-grid and the results obtained are compared using nature-inspired algorithms such as GA, PSO, and FA over conventional mathematical formulation. The main contributions of this work are; (i) study of system with the inclusion of voltage and frequency-dependent load, (ii) modified STATCOM model clubbing reactive power control feedback and LCL filter with damping resistance, (iii) real and reactive power tracking system using dynamic compensator capabilities, and (iv) suppression of total harmonic distortions along with real and reactive power tracking using advanced tuning for filter parameters with GA, PSO, and FA based algorithms.

Javad Ansari, Simultaneous design of fuzzy PSS and fuzzy STATCOM controllers for power system stability enhancement: The low frequency oscillations have always been the main problem of power system and can lead to power angle instability, limiting the maximum power to be transmitted on tie-lines and system separation. For boosting power system stability limits, the most effectiveness way is to install supplementary excitation control, power system stabilizer (PSS) to add a supplementary feedback stabilizing signal into the automatic voltage regulator (AVR). This article investigates the coordination and optimization of fuzzy controllers for designing PSS and STATCOM controllers for more attenuation of power system fluctuations.

The designed fuzzy controller replaces the STATCOM AC voltage regulator. Moreover, for more damping a fuzzy power system stabilizer (FPSS) is placed on all machines. Coordination between Fuzzy Based STATCOM (FSTATCOM) and FPSS is achieved by Self-Adaptive Learning Bat Algorithm (SALBA) in two stages. At first, scaling factors and then fuzzy sets of membership functions (MFs) will be tuned based on a performance index. To indicate the effectiveness of the proposed scheme, the coordinated optimized FPSS andFSTATCOM are compared with conventional design approaches like conventional PSS (CPSS) and proportional-integral controller based STATCOM (PISTATCOM). The simulations clearly demonstrate the effectiveness of the coordinated fuzzy controllers in terms of transient and dynamic stability.

Akhil Gupta, Power quality evaluation of photovoltaic grid interfaced cascaded H-bridge nine-level multilevel inverter systems using D-STATCOM and UPQC: The enhancement in Power Quality (PQ) becomes essential to increase the overall performance of equipment in utility-grid tied systems. To enhance PQ, this paper enumerates operational impact of Distribution Static Compensator (D-STATCOM) and Unified Power Quality Conditioner (UPQC) into a cascaded H-bridge Nine-Level Multi-Level Inverter (NL:MLI). The effectiveness of proposed topology is evaluated at a constant 200 V DC voltage and two SPV arrays of 100 kW each.

A PQ comparative analysis is presented under faulted conditions at linear load. In order that the proposed system operates effectively under changing environment conditions, the implementation of competent control techniques is dominant. Consequently, the control approach for D-STATCOM and UPQC compensates reactive power requirement of load and utility-grid. Total Harmonic Distortion (THD) and DC offset current are estimated, with distortion-less current-voltage waveforms obtained at coupling points. THD levels are validated in

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agreement with IEEE-519 standard. Indeed, the effectiveness of UPQC is demonstrated by feeding excess power through SPV arrays into variable DC link. Overall, the operation of UPQC interfaced with NLMLI is effective over D-STATCOM in alleviatin g harmonics, DC-offsets, and voltage-current imbalances during faulted conditions. The accurateness of simulation results and their comparative analysis is found to be satisfactory.

P. Devachandra Singh, Clean and sustainable micro hydro power generation using parallel variable asynchronous generators controlled by AC-DC-AC converter and fuzzy PSO/PI D-STATCOM for remote areas: This paper presents a new parallel operated micro hydro-power generation scheme for supplying power to energy deficient remote areas. Effort has been made to develop a simple and cheap micro-hydro power scheme with new converter architecture for application in a microgrid operation. Standalone microgrid systems usually consist of solar PV systems, wind energy systems, etc. However, small scale hydro-power system based microgrids are least addressed though these energy sources are clean and sustainable energy. Hence, a scheme that requires minimum civil work and generates electricity from free-flowing water is presented. A low cost variable operation capacitor excited asynchronous generator is considered.

The paper also presents a fully controlled 2-level PWM based AC-DC-AC converter adapted for a micro-hydro power applications to control the generated power. Furthermore, novel converter architecture is implemented for parallel operation of asynchronous generators. This facilitates easy synchronization of the asynchronous generators where the traditional synchronization method fails. The performance analysis of the proposed model under steady-state and dynamic operations with different types of loads has been presented. Additionally, the analysis of a fuzzy PSO PI-controlled D-STATCOM has been incorporated for efficient operation during unbalanced and non-linear loads. The MATLAB simulation results are presented and discussed.

R.R.Hete, Analysis of DFIG-STATCOM P2P control action using simulated annealing techniques: This paper discusses the performance of Double Fed Induction Generator (DFIG) and static synchronous compensator (STATCOM) in a transmission system using simulated annealing techniques. The rotor speed of DFIG is always changing with respect to wind speed in a nonlinear manner, which makes the system to be more unstable. Under such a condition the performance of the system is disturbed. To improve voltage stability throughout the line, an integration of STATCOM is essential at proper location of the transmission system. The STATCOM integrated DFIG system can enhance the system voltage profile and flexible flow of power in a transmission system. In case of a large disturbance or during the shunt fault condition, the performance study is very important which can be assessed using simulated annealing techniques. The proposed model present in this research work is a multi-objective optimization problem. The parameters for the objective function were identified as voltage at the point of common coupling of wind turbine and low frequency oscillation present in the post restored active power.

Therefore a stochastic algorithm based on normalized simulated annealing has been applied where the performance of the system can be tested. Coordinated reactive power control combining with DFIG and STATCOM has been analysed together during various shunt fault condition. To achieve better performance of the system Low voltage rides through the capability of the wind farm and FRT (Fault Ride Through) have been tested under the presence of STATCOM including mutual coordinated control action.

Helmy M.El Zoghby, Isolated microgrid stability reinforcement using optimally controlled STATCOM: This paper presents optimal control of static synchronous compensator (STATCOM) intended for the application in isolated microgrids using genetic optimizers. The main objectives are to enhance the microgrid stability and reduce the oscillations in voltage, power, and frequency at different operating conditions. The proposed microgrid is a hybrid power system consisting of a diesel generator and a wind turbine each rated at 500 kW. The microgrid is supplying standalone static/dynamic loads rated at 500 kW. The wind turbine unit is controlled to operate at maximum power point tracking (MPPT). The diesel unit is used for ensuring the generation-demand equilibrium is maintained particularly under low wind speeds. The paper mainly discusses the voltage and frequency regulation of the isolated microgrid at different conditions such as: sudden changes in wind speed and/or load variations. Moreover, the proposed microgrid operation is examined under abnormal three-phase short circuit condition at the point of common coupling (PCC).

To guarantee the microgrid voltage and frequency regulation at these diverse operating conditions, an optimally controlled STATCOM is considered as a reactive power source. The multi-objective genetic algorithm (GA) is used to obtain the optimal scheduling of the STATCOM controller's gains without any delay in the control signal. From the simulation results, using Matlab™, the performance of the microgrid is improved and the oscillations in voltage, frequency, and power are reduced. The microgrid stability is enhanced using STATCOM device.

D.Sarathkumar, Power system stability enhancement in two machine system by using fuel cell as STATCOM (static synchronous compensator): In this paper describes fuel cell functioning is a STATCOM to enhance the power

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system stability during various symmetrical and asymmetrical fault conditions. Nowadays our power utility confronting plenty of issues in retaining the stability of the system. Install the flexible alternating current transmission system (FACTS) compensator gives to be better results for this. But the expenses of compensating system extra payload to the consumers. For this reason a novel approach using fuel cell (FC) is a supply of compensation system was presented in this paper. Fuel cell (FC) was designed as a STATCOM – as a FACTS device. The potentiality of the FC STATCOM to improving transient stability of two machine system after a fault occurrence. In this paper fuzzy logic controller is a main controller was modeled to enhance the power system stability of two machine systems.

Fuzzy logic controllers give the trigger pulse to improve the stability after the various fault occurrences. Proposed compensators are carried out in MATLAB simulink tool boxes. The design of with and without compensators was integrated in two machine power system and compared the results with traditional FCSTATCOM device. Various types of asymmetrical and symmetrical faults created in the proposed transmission line system. During the fault more oscillations occurred. After connecting the FC STATCOM oscillation level was reduced. Finally concluded that the results are found to be satisfactory in this proposed fuzzy logic based FC STATCOM compared with conventional FCSTATCOM.

Abdelnasser A.Nafeh, Intelligent fuzzy-based controllers for voltage stability enhancement of AC-DC micro-grid with D-STATCOM: Voltage stability and power quality play very effective issues in power systems. This paper aims to improve the voltage stability and enhance system power quality in the AC-DC micro-grid system based on intelligent fuzzy controllers. These controllers are fuzzy-PI (FPI) and fuzzy-PID (FPID) current-controller with the existence of distribution static synchronous compensator (D-STATCOM). The capability of proposed system has been applied in two case studies that emulate abrupt fault and dynamic load changes on AC-DC hybrid micro-grid that collects different types of renewable energy sources. In addition to, the proposed fuzzy-based controllers produce the optimum dynamic response and resolve the power quality issues.

Numerical simulations associated with detailed comparisons between different controllers are provided. It was found that when the studied system is subjected to a 3-phase fault, the voltage fluctuation at the D-STATCOM is reduced by 7.86% and 4.62% and the dynamic system performance is improved by 12.9% and 8.8% with using Fuzzy-PID and fuzzy-PI, respectively. Also with the dynamic load changes, the fluctuation of system voltages at the D-STATCOM is reduced by 0.982% and 0.577 % and the dynamic system performance is improved with 6.67%, 5.71% when comparing Fuzzy-PID controller and Fuzzy-PI to the uncontrolled system. The Fuzzy-PID provides a capability to enhance dynamic performance and system power quality because achieve less fluctuation and more smoothing for signals makes it is superior for voltage control for AC-DC micro-grid.

R.O.de Sousa, Wear-out failure analysis of modular multilevel converter-based STATCOM: The role of the modulation strategy and IGBT blocking voltage: The modular multilevel converter (MMC) is an attractive option for medium- and high-voltage static synchronous compensator (STATCOM) application. For this application, three aspects are relevant. Firstly, reliability and efficiency are directly related to the operation costs of this converter. Secondly, either high IGBT blocking voltage capability, featuring little number of submodules (SMs), or low-voltage IGBT modules, with a larger number of SMs, can be employed in an MMC-STATCOM.

Lastly, either modulation strategies with fixed or variable switching frequency can be employed. Nevertheless, the literature does not present works evaluating these three aspects of an MMC-STATCOM at the same time. Therefore, this paper analyzes the impact of modulation strategies and number of SMs on wear-out failure and efficiency of an MMC-STATCOM. The effect of all SM components is considered. Two distinct modulation strategies are selected: phase-shifted pulse-width modulation (PS-PWM), with fixed switching frequency, and nearest-level control with cell tolerance band algorithm (NLC-CTB), with variable switching frequency. Four commercially available semiconductor blocking voltages are considered to evaluate the converter with different number of SMs. The results demonstrate that the number of SMs and the modulation strategy affect the MMC-STATCOM performance. Indeed, the converter presents different reliability at system-level and energy losses per year, depending on the IGBT blocking voltage and modulation strategy. The design with higher IGBT blocking voltage is the most affected.

Parul Gaur, An effective PSO based cascaded H-bridge multilevel inverter STATCOM with reduced number of materials count: Medium voltage and high power multilevel inverters are nowadays widely used for reactive power compensation applications. Multilevel inverters based Static Synchronous Compensator (STATCOM) devices makes the power system more feasible due to the benefits offered by the multilevel inverters such as output voltage with lower harmonics, high modularity, and high-power quality in the output. This paper presented an effective Particle Swarm Optimization (PSO) algorithm based cascaded H-bridge multilevel inverter STATCOM with reduced number of materials count. The materials used for the semiconductor devices are the Insulated Gate Bipolar Transistors (IGBTs). These IGBTs are fired using the optimized switching angles, which further leads

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to minimum total harmonic distortion. PSO technique is being used for the calculation of optimized switching angles. Further, the performance of PSO based multilevel inverter with STATCOM is investigated by calculating the harmonics reduction and total harmonic distortion.

Kamel Sayahi, Implementation of a D-STATCOM control strategy based on direct power control method for grid connected wind turbine: Distributed generation (DG) is getting increasing relevancy on the electric energy production. In Tunisia, the increase of the installed wind power has an impact on the grid transmission due to the intermittence of production. Grid operators have now enough field experience to adapt the existing grid codes to the new energy mix. DG systems have proved that they can contribute to grid stability using power converters and control algorithms. Therefore, the installation of the FACT devices is necessary to guarantee the high energy quality and electrical grid stability.

STATCOMs present the FACTs which are currently used. This paper presents the main effects of the DG connection to a grid and the role of STATCOM to reduce undesirable effects, making the DG fully operable. Thus, a STATCOM control strategy based on DPC is proposed to show the impact of this device on the quality of electrical power system. The advantage of the proposed technique is to enhance the voltage profile in steady state operation and under different working conditions and sags voltage. Moreover, STATCOM improves the transient voltage stability and therefore helps the wind turbine generator system to remain in service during grid faults. The proficiency and functionality of the proposed controller are demonstrated through detailed theoretical analysis. Computer simulation using the Matlab/Simulink software is performed. Accordingly, a hardware prototype employing a dSpace 1104 board -based system is built for final verification test. Experimental results show that the proposed control method is very effective.

Muhammad Humayun, Analysis of hybrid switches symmetric flying capacitor multilevel inverter based STATCOM: Static compensator (STATCOM) based on cascaded H-bridge (CHB) multilevel inverter (MLI) uses a lower number of switches compared to the other topologies. Therefore, it is preferred due to lower switch losses. However, it is possible to reduce further the number of switches and its losses in cascaded STATCOM. In this context, a STATCOM based on a cascaded symmetric flying capacitor (SFC) constituted by IGBT and IGCT is presented in this paper. Furthermore, the common issue of imbalance due to asymmetric switch losses has been resolved by proposing and implementing multistage feedback voltage control with a combination of level-shifted and phase-shifted LS-PS PWM switching techniques. Moreover, the switching and conduction power losses calculations and efficiencies of SFC-MLI based on these semiconductors are also presented. Finally, the experimental results show the effectiveness of the proposed topology and the control strategy.

Meenakshi Rastogi, Performance investigation of two-level reduced-switch D-STATCOM in grid-tied solar-PV array with stepped P&O MPPT algorithm and modified SRF strategy: In this paper, a Two-Level, Three-Phase, Reduced-Switch (2L3PRS) Voltage Source Converter (VSC) based Distribution Static Synchronous Compensator (D-STATCOM) integrated with a grid-tied solar photo-voltaic (PV) array has been discussed and its performance investigation has been carried out. A versatile control strategy is proposed which gives the system maximum power point tracking capability with stepped perturbation and observation (P&O) algorithm and the grid current is maintained at unity power factor. The layout in addition to the control technique helps in supplying active power to the power grid and feeding active and reactive power demand of the 3-phase reactive unbalanced load. Modified Synchronous Reference Frame (MSRF) theory-based current control methodology is implemented to sustain the DC-link voltage and to maintain the voltage balancing across split capacitors under all loading conditions.

This modified algorithm generates switching pulses for three-phase VSI with only four IGBT switches for fulfilling the desired objectives like maintaining a constant DC-link voltage, balancing split-capacitors' voltages, balancing the power-sharing between the power grid and the solar-PV energy system, balancing the grid currents and voltages in case of unbalanced loading conditions and maintaining unity power factor operation of the grid by making the D-STATCOM compensate for load reactive power.

The proposed system is replicated in MATLAB/Simulink using SimPowerSystems software-based environment. The experimental outcomes have been obtained with a digital real-time simulator to vindicate the simulation results. The experimental, as well as simulation results of the proposed real-time based model, are demonstrated for three unbalanced single-phase inductive linear loads and with a load on one phase kept open in Power Factor Correction (PFC) mode of operation of D-STATCOM.

Yang Zhang, Switching transient analysis of the cascade STATCOM by the equivalent model with redundant H-bridge submodules: Cascade Static Synchronous Compensator (STATCOM) is a multilevel power electronic device, and its safety, reliability, and operation life are directly affected by switching transient processes. The work presented a switching transient analysis of the redundancy fault-tolerant control for the Cascaded STATCOM by the proposed contactor equivalent model. It was more accurate, ignoring fast dynamic changes and replacing the instantaneous speed with the average speed. Redundancy fault-tolerant control of submodules was

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crucial to the reliability of Cascade STATCOM. The closing and opening process of the AC contactor generally lasted for several milliseconds. When failure occurred in H-bridge, many factors such as the change of excitation circuit, the resistance, and the capacitance affected the electromagnetic transient process during the closing of the AC contactor. Arc discharge occurred when the H-bridge submodule was re-entered, and the AC contactor was turned off.

Based on this, an equivalent model of ac contactor suitable for h-bridge was proposed, considering the influences of excitation circuit, arc discharge, and distribution parameters on switching transient. Simulation and experiments were used to analyze the electromagnetic transient waveform of a single H-bridge sub-module in the contactor closure and disconnection process, and the electromagnetic transient waveform of cascade STATCOM in the redundant sub-module contactor closure and disconnection process. The results showed that the transient change of the proposed model during sub module's bypass and re-entry process was closer to the physical process. The equivalent model obtained in the work provides the theoretical and numerical basis for the design and operation of high-power power electronic equipment.

Sudhanshu Ranjan, Voltage stability assessment of isolated hybrid dish-stirling solar thermal-diesel microgrid with STATCOM using mine blast algorithm: This paper presents the voltage control of an isolated hybrid diesel-dish-Stirling solar thermal system (DSP) based power system. As DSP is employed with an induction generator (IG), it needs reactive power for magnetic field. Though synchronous generator (SG) is coupled with the diesel generator, SG alone unable to supply sufficient reactive power to cater the reactive power requirement of the consumers load and the IG. Under such circumstances, static synchronous compensator (STATCOM) is used to meet the reactive power demand. The parameters of the controllers employed with the STATCOM as well as automatic voltage regulator (AVR) of the SG are tuned simultaneously applying recently developed mine blast algorithm (MBA).

Performance of the MBA based controllers are compared with that of the cuckoo search algorithm (CS), and particle swarm optimization (PSO) based counterpart on the proposed model. Application of STATCOM and MBA based control strategy in diesel-dish-Stirling solar thermal system-based hybrid system for reactive power regulation is a maiden attempt. Extensive simulations of the model for dynamic responses of voltage deviations and reactive deviations under several uncertain conditions, such as step disturbance in reactive power load of the consumers and IG without/ with STATCOM, realistic variations of power output of DSP and reactive load have been carried out. Results analyses indicate that MBA based control strategy is the best amongst all the control strategies attempted here in the terms of maximum overshoot and the settling time. Further, meager values of the maximum overshoot and the settling time under several uncertain conditions justify the coordinated control of AVR and STATCOM to maintain the voltage stability of the isolated hybrid system.

IV. CONCLUSION

Rotor angle stability, voltage stability, and resonance stability are among the critical and widely occurring stability issues in the presence of wind and PV penetration. The effectiveness of STATCOMs with respect to addressing these issues has already been confirmed. In this respect, this paper presented a comprehensive review of several methods proposed for STATCOM control to enhance the stability of wind- and/or PV-interfaced power systems. Conventional, adaptive, nonlinear, robust, model predictive, and coordinated control along with soft computing techniques were discussed. In addition, the performance of multi-functional converters such as GSC and PV inverters to work as STATCOMs was also assessed.

Among the different control techniques, conventional control is frequently applied; however, these approaches do not consider dynamic operating states in the absence of any adaptive mechanism. Machine learning- and heuristic-based control is one of the evolving trends. But, in most cases, the designed control structure is uncoordinated. In this regard, coordinated schemes based on centralized, decentralized, and distributed control have provided enhanced performance through appropriate coordination of STATCOMs and wind/PV plants. Therefore, a wide scope of future research is anticipated for these control schemes, particularly for the coordination of STATCOMs with multiple large-scale wind farms and PV clusters to provide enhanced stability. Moreover, other future aspects including the design of new STATCOM control structures for SSO mitigation and the functionality to work as PV-STATCOMs provide researchers with numerous opportunities for future investigations.

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