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Augmentation of Power Quality Through PV Static Synchronous Compensator using Shunt Active Power Filter

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Abstract: The burgeoning energy demand has prompted all the developing nations to search for the most dependable sources. Solar energy source has emerged as the main prominent green energy source. However, the integration of these energy sources using the traditional alignments of electrical power systems resulted in reliability concerns. Moreover, the rapidly increasing utilization of power electronic based loads is leading to power quality concerns in the distribution system. At present-day, the major power quality issues in the distribution networks are poor power factor, islanding of renewables caused extreme voltage deviations, harmonics and reactive power demand. These power quality concerns may affect the end user equipment, which may result in the complete spoilage of products. The various traditional techniques (capacitor bank, passive filters, UPS etc.) are unable to attenuate the power quality issues completely. The FACTS devices are being used vigorously to annul the power quality deviations that originate in the distribution networks. Among the various power filters, the Shunt Active Filters are playing a determinant role to mitigate power quality concerns in the distribution systems. This research work proposes to develop a system that can eliminate the power quality concerns to a considerable level using SAF configured from solar photovoltaic Inverter control. This work proposes to employ the P-Q Control theory and Unit Vector Template Method to start the PV STATCOM's operation. The voltage source converter (VSC) based PV-STATCOM injects and or absorbs the required reactive and active powers at PCC in the distribution systems for attenuation of the power quality concerns. This study primarily exhibits the effectiveness of PV-STATCOM in improving power quality in grid-tied systems and demonstrating the possibility of Low Voltage Ride Through (LVRT). The LVRT requirement implies that active and reactive power injections are necessary to maintain grid voltages during grid disturbances. The MATLAB / Simulink results with designed settings show that PV-based STATCOM for enhancing power quality in distribution systems performs better.

Keywords: *Voltage Source Converter (VSC), Low Power Quality Improvement, PV-STATCOM, Voltage Ride Through, Power Quality Enhancement.*

1. Introduction

In the current electricity environment, electrical power consumption outstrips electrical power output. The demand for electrical energy has been steadily increasing because, over the last few decades, critical activities such as domestic, municipal, commercial, transportation, agricultural, and industrial activities in the society have become increasingly interconnected with electrical energy. As a result, demand has increased significantly.

Different energy sources such as wind, geothermal, tidal, and solar energy are being investigated as grid-integrated system options in order to alleviate the capital-intensive nature of the system. The use of modern power converters in solar & wind energy systems is becoming more common because they have the capability of absorbing or injecting true power (real power) and reactive power (VAR power) into grid-integrated systems, hence improving the overall power quality. At the moment, an electrical power distribution system is comprised of almost all reactive and nonlinear load components (Power Electronic based loads). In order to accommodate the progressive growth in the use of non-linear loads, the reactive power demand or burden in electrical power distribution systems would increase, causing the feeder losses to increase and the actual power flow efficiency of electrical distribution networks to decrease.

When non-linear loads like electric arc furnaces, electronic equipment's (computers, TV, monitors, and so on) and street lights generate significant asymmetric disturbances in the alternating current mains, it causes Power Quality (PQ) issues in the power system like voltage fluctuations, harmonics distortion, increased reactive power demand, low power factor, transients, voltage flickering, and so on. It's a duty for power engineers in order to ensure the efficient and beneficial functioning of an electric power system in the modern day.

Unusual swings in alternating current power may exacerbate a number of problems in term of power quality (PQ) caused due to non-linear loads. Pure energy transmission is

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becoming an increasingly important task for power engineers as they strive to keep a power system working efficiently and effectively. [1]

Overheating, overloading, increased power losses, transformer saturation, failures of equipment's, data errors, are just a few of the consequences of poor power quality. [2].

The poor quality of power causes overheating, overloading, transformer saturation, malfunctions of equipment's, data errors and poor quality of services etc. and a negative impact on the profits of individual organisations. It may also shorten the life of the system and reduce its performance. The passive filters, which are composed of inductors, capacitors, and resistors, which act as an important function in decreasing the power quality in distribution networks during the early stages but due to a number of notable drawbacks of passive filters such as their large size and weight, resonance, poor performance, and the need for compensation, the researchers sought to develop quick and dynamic solutions to improve power quality. As a result, "Active power filter" (APF) have been explored, and a significance quantity of research has been available as a result of this [3, 4]. Active power filters are used to reduce the amount of energy of device. As a result, active power filters will soon take the place of passive power filters in the marketplace. Typical electrical systems [4] are shown in Figure 1 in line with industry standards, which is a traditional representation of the system.

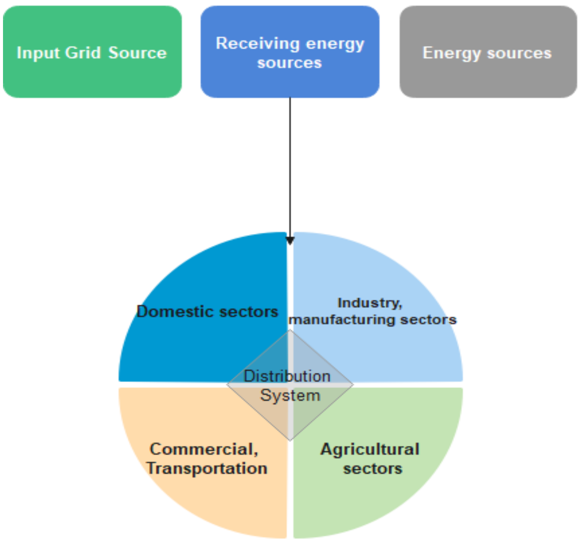


Fig. 1 Electrical system-sector wise

The "shunt Active Power Filter" (APF) is one of the many types of power filters available, which is especially helpful for the power quality of transmission and distribution system. Shunt APF results show that almost all end users have to deal with energy quality issues on a highly irregular basis, based on the findings of the Shunt APF study. A PV-based STATCOM is being investigated as a power injector and active energy compensator for power gains in a network system, according to the findings of this study. This investigation's findings will be published in a peer-reviewed journal. A consequence of this collaboration, a PV solar farm has given the shunt integrated device recognized as the "Static Synchronous Compensator" for use in this proposed study, which is referred to as PV-STATCOM for short. At night and throughout the evenings and nights, the solar photovoltaic farm is absolutely inactive, since it creates no actual electricity during the day. The demand on electrical feeders is much lower throughout the night than it is during the daily hours of operation. Increased wind speeds allow for higher wind farm power production, and reverse current flows from the power conversion centre to the main grid source are feasible [5], resulting in voltage fluctuations of up to 5% in the grid-tie system [6]. In a grid-integrated test model, an active and reactive power balancer (APF) at the PCC is employed to retain the system voltage within the acceptable boundaries to increase power quality [6]. In this paper, it is projected that the operative performance of a PV based shunt Active Power filter be demonstrated by employing the "Hysteresis Current Controller", "Proportional Integral and P-Q control theory" to release current harmonics, compensate reactive power, improve the PF, reduce the total harmonic distortion and reduce voltage required for LVRT with critical phase and magnitude be demonstrated.

Shunt active power filters (APFs) are one of the power filters that are used to lessen power quality difficulties in distribution and transmission networks. Shunt APFs have shown to be effective and efficient solutions for practically all end-user power quality challenges that are caused by load variations in the electrical grid.

It is vital to create critical and adaptable solutions to power quality problems. As a result of this, the creation of specialised power devices has taken place as well. Shunt Active Filter, a cutting-edge and cost-effective bespoke power device that tackles the issue of poor power quality, is now available for purchase. In order to demonstrate their improved performance when compared to standard linear and nonlinear loads, a number of experiments have been conducted in a range of power quality issues Many control strategies for increasing distribution network power quality should be investigated in more detail in the future due to their shown performance as recognised equipment. It will be necessary to design and build active shunt filters as well as power quality monitoring systems in order for the intended grid-tie system to be designed and built. PV-STATCOM controllers are used in order to grow the distribution capacity of existing distribution lines. According to solar energy experts, a new research plan in which electricity transmissions and distribution lines will be employed act as shunt Active power filters to boost performance factors in photovoltaic solar farms is being considered. During this project, an active shunt filter is incorporated into a photovoltaic solar farm converter that is connected to the electrical grid. PV-STATCOM is a technology for using solar photovoltaics as shunt offsetting devices in telecommunications networks that was developed by the University of California at Berkeley. According to IEEE standards, a reactive force whose output may be effectively accomplished in order to increase the power quality in network systems is employed to do this. The design of shunt compensators that make use of PV technology might result in either the absorption or the generation of reactive power.

Now power quality is very important research problems among all power sectors, as well as for all who belong in commercial activity. In response to a growth in the need for dependable electric power of high quality, as well as an increase in the usage of non-linear loads, utilities and end customers may become more conscious of the importance of good quality of power. Because distortion or power electronic-based loads draw non-sinusoidal currents, Pollution from power plants has been a major cause of concern in the distribution and transmission networks. The dirty electricity will have an impact not only on the system's operational, but also on the efficiency of the workforce.

Power researchers are concerned with the transmission of power quality from generating stations to end users, which is most essential key challenge for power researchers due to the existence of reactive and distorting loads in the distribution network.

Accordingly, power researchers are heavily engaged in their study effort for the creation of Power Electronics-based active filters for the attenuation of power quality problems in the distribution network. which is intended to regulate these issues. The active power filters (APFs) are now explored and an immense amount of work has been issued on shunt APFs for the attenuation of current-related power quality difficulties in distribution systems as a result of the developments in the area of Power Electronics

2. Literature Survey

At the time of its discovery, active power filters were not fully understood to their profitable potential due to the lack of availability of high rated solid state power electronic switches; however, this has since changed. Solid state technology has evolved in the realm of power semiconductors as a result of the introduction of the start. Approximately five hundred and fifty Active Power Filters (shunt APF), and they are being used in commercial applications because of their small size and low cost. For the lowering of current distortion factor, we now have Shunt APFs with extremely high-power ratings that are readily accessible. Various filters design such as shunt, series and shunt-series have been modified and marketed for the purpose of mitigating the effects of power quality issues. In the beginning, single- phase active power filters were developed focus on the Voltage Source Converter (VSC) with capacitive energy storage conception and the Current Source Inverter (CSI) with inductive energy storage conception. Later, three-phase, three-wire active power filters were developed, and hybrid power filters (shunt-series combination) were combined with passive filters for the purpose of improving power quality. Various technologies, such as Static Var Generators (SVG) and others, have been published in scientific journals and books. Thyristors, MOSFETs, and Bipolar Junction Transistors were used in the early stages of the development of active power filters, and subsequently SITS's (Static Induction Thyristors) were used in the creation of shunt APF.

With the introduction of IGBTs, the shunt APF have seen a significant increase in performance. Insulated Gate Bipolar Transistors, hall-effect sensors, and sophisticated sensor technologies, for example, are readily available at a reasonable price, providing the necessary rating for a device. Shunt active filters have seen an improvement in performance. The microelectronics revolution resulted in the subsequent major innovation in the shunt active power filters technology, which is described in detail below.

In recent years, with the fast development of power electronics, bespoke power devices (FACTS devices) have been introduced into electric power systems.

Apart from that, there is no differentiation between the input and the output.

It is never appropriate to provide something in exchange for anything else (power gain and voltage gain).

• The inductor causes the circuit to become clunky as a consequence of its presence.

• Enforcement of a compensation mechanism that has been predetermined.

This poses an issue with resonance since it makes it possible to load the source code from the disc.

A great number of researchers have developed active filters that are based on power electronics in order to address the disadvantages of passive filters. Active filters [7] were used to reduce current or voltage distortion, and a flexible and adaptable approach was developed in 1970 to alleviate the drawbacks of active filters. Various studies have been supported for power quality issues that are related with active power filter technology. The usage of static synchronous compensators may be used to compensate for higher-order harmonics in a system. [8] The synchronous compensator is used in the distribution stage to compensate for the effects of the sources, therefore upgrading the overall power quality of the system. It is possible to employ Active Power Filters in a number of different applications, some of which are described below. Because of the consistent current flow in the 3-phase system, active power filters are employed in combination with four-wire systems in a variety of applications. Comparing active filters to passive filters, active filters have a higher power factor because passive filters have less reactive power correction and are thus less efficient.

In conjunction with the increasing use of non-linear loads, rising demand for high-quality, dependable electricity has the potential to raise the level of power quality awareness among utilities and end users, resulting in increased cost-effectiveness and production for power generation, the facility industry, and the favourable application of Power Electronic technology. Power quality [9], often known as customised power, is very important and rapidly developing applications today. Customized power is used in electric distribution system to provide the reliability and power quality that end-users and utilities need in order to operate electronic controllers [10]. To be sure, Custom Power (CP) is a technology that is supposed to protect end-users from power quality [11]. UPQC (United Power Quality Condition) and Active Filters are used to process bespoke power devices or controllers, which may aid in reducing power quality concerns like voltage and current interruption, as well as voltage changes on distribution system. When using a customised power system, the activation of end users is performed via the use of bespoke power devices or controllers, which deliver defined and certified electricity. Power interruptions are reduced to an absolute minimum, voltage swings and swells are maintained within acceptable limits, and the unit functions stably throughout the low phase, to mention a few benefits of custom-built power generators.

When it comes to energy transmission, FACTS controllers have the ability to expand the capability of existing transmission lines for transfer of power. [12] The methods of ac transmission are quite versatile. It has been suggested by a number of solar PV farm specialists that recent research on shunting APFs may be able to improve overall performance of the energy distribution line. As part of this dissertation, the grid-integrated “PV solar farm” inverse is utilised of active filter in combination with another active filter, and it is also employed as a shunt active filter. Using solar photovoltaics as a shunt compensator is referred to as PV-STATCOM, which is the word used to characterise the technology. The reactive power (VAR power) adjustment is carried out in the case of PV-based shunt compensation. A range of outputs and controls are available to regulate and modulate the unique properties of the electrical distribution network, allowing reactive energy to be either absorbed or created. The Solar Farm makes use of shunting active filters to decrease power quality issues, which are a common occurrence. More attention must be paid to the challenges associated with harmonics in a distribution system when more scattered sources, like as solar and wind, are integrated into the system [13]. The solar photovoltaic system that has been presented is completely inactive at night and does not generate any real energy. However, the controller has the capacity to alter the voltage at the power conversion centre (PCC) at any time of day or night, regardless of the time of day. It is entirely operational even when the “photovoltaic solar farm” is not generating active energy since the solar photovoltaic farm's reactive power potential is entirely utilised. In the proposed grid system, a little amount of active power is withdrawn, and as a consequence, the DC bus capacitor voltage will maintain a consistent level throughout. Additionally, as a consequence of this extraction, the PCC voltage will stay constant.

3. Design Characteristics of PV-STATCOM in Grid System

Use either SI (MKS) or CGS as primary units. The projected study is focused of possible power increase that could be acquired from solar systems by resolving power quality concerns in solar systems. We may explain the PV system's circuit model that is equal to the proposed Current Controlled source using the suggested Current Controlled source (CCS). A PV-based compensator's design parameters are examined in order to have a better thoughtful of the improving power factor seen in the proposed PV grid model using solar energy. The active, reactive, and absorption power injection and absorption are discussed in detail with the use of supporting phasor diagrams in order to alleviate power quality difficulties in the power system. Aim of the proposed research is to determine how much more energy can be generated in a solar system by lowering the quantity of power quality issues that arise in the system. The proposed Current Controlled source defines the circuit architecture of the PV system, which is equivalent to that of the conventional power source (CCS). In order to demonstrate how the power factors are enhanced in the proposed PV grid model, the design parameters of a PV-based compensator are provided. When phasor diagrams are used to depict the active, reactive, power injection and absorption, it is

possible to decrease power quality problems in the power system.

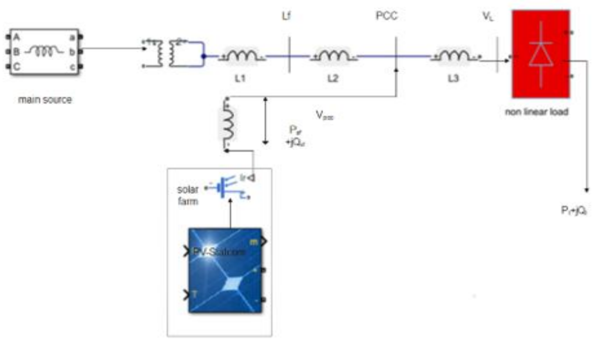


Fig. 2 Power Quality Improving System

The "PV-STATCOM" device shown in Fig. 3 with a "shunt active filter" added to the device for demonstration purposes. It is a three-phase device unit made of a number of alternating current/direct current converters. The PV Shunt Active Filter is a three-phase device unit.

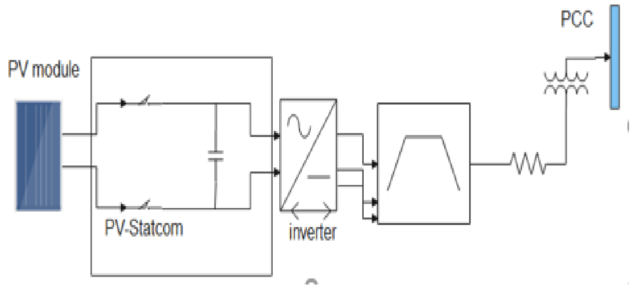


Fig. 3 Shunt Active Power Filter with "Solar farm"

Shunt APFs, such as the solar PV farm, enhance power quality in distribution networks by balancing reactive power at PCCs and, as a result, reduce the costs of running the distribution network. In this suggested system, the shunt APF is driven by a "photovoltaic solar system" that generates electricity.

3.1. PV-STATCOM with Voltage Source Converter

A typical active compensator of this kind, as seen in Fig. 4, is made of a DC-side condenser and a small AC side reactor that filters the high frequency segment associated with IGBTs. This device, known as a PV-STATCOM, is a "voltage source converter" that converts "photovoltaic solar farms" into a sequence of o/p alternating current voltages & connects them to an associated alternating current system by the use of a small reaction capacitor (leakage produced by the coupling transformer or interfaces).

Important factors to consider are both the voltage difference between the inverter and the intended Grid system, as well as the voltage differential between the grid systems and the inverter. By using the suggested control system to its maximum extent, the VSC-based PV-STATCOM may be able to decrease power quality difficulties in the future. Actual and reactive power may be adjusted to a sufficient level by using PV-based APF shunting. An APF, as seen in the following diagram, supplies real and reactive power to the distribution system in order to improve power quality [14]. According to the constant state balances listed below.

$$P_s = \frac{|V_{s1}||V_m|}{y_s} \sin(\delta) \tag{1}$$

$$Q_s = \frac{|V_{s1}|V_m|}{y_s} \cos(\delta) - \frac{|V_{s1}^2|}{y_s} \tag{2}$$

Regarding the system voltage unit, Vs1 represents the system voltage unit in PV-STATCOM, V m represents the inverter voltage in PV-STATCOM, and with respect to the reactance, the phase difference among the system and inverter voltage is represented by the symbol. Modes of operation for PV-active STATCOM and reactive power injection/absorption are described in further depth in the following sections.

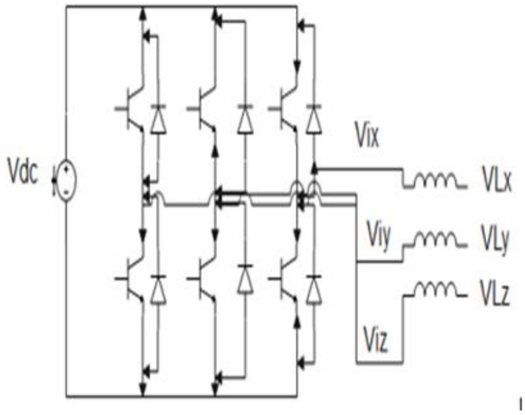
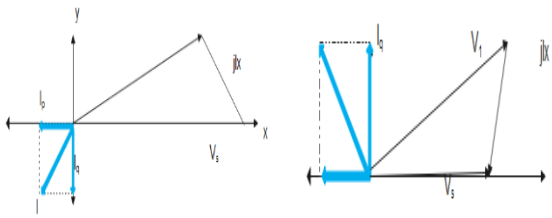


Fig. 4 PV-STATCOM based with Proposed Voltage Source Converter

Because of this, the inverter's voltage is higher than the system voltage (which is phased in), and the micro grid receives only VAR (Q) Reactive power from the inverter while it is operating in capacitive mode [15]. In the inductive mode of operation, the inverter voltage is lower than the system voltage (despite the fact that they are in phase), as a result, to operate, the inverter draws reactive power from the main system.



(a) (b)

Fig. 5 Inductive & Capacitive mode of Injections - (Active and Reactive)

Fig. 5 (a) illustrates how the PV-STATCOM is intended to supply of actual power (P) while also absorbing (VAR) Reactive Power energy. This is because the system voltage is greater than the inverter voltage, as illustrated in Figure 5a. The voltage in the system has been turned off (Q). Also shown in Fig. 5 (b) is that the system voltage is lower than the system voltage delays of the inverter voltage and the system voltage, showing that PV-STATCOM inserts enough reactive and actual power into the system (P).

3.2. PV STATCOM: Projected Design Features

For the purpose of removing power quality issues, the PV shunt Active Power Filter with the VSC feature is utilised in the grid test model to deliver the necessary actual and reactive power. The PV-STATCOM is comprised of a DC bus capacitor, an interconnecting inducting unit, and other components that serve as the foundation. The APF unit with the following characteristics is to be installed in the PV-STATCOM as part of the planned work at the facility.

The DC bus voltage is explained from the equation-

$$V_{dc} = \frac{2 \cdot \sqrt{2} \cdot V_I}{\sqrt{3} \cdot m1} \quad (3)$$

in where V1 =o/p voltage in the system's line of communication and m1 = modulation index of the shunt unit. shunt APF bus voltage is denoted via symbol V dc.

By fixing the modulation index to 1 and the line voltage to 416 V, the bus voltage is estimated to 679.32 V, which is fixed at a rate of 750 V. The line voltage is computed to be 679.32 V, which is fixed at a rate of 750V. According to the results, the bus voltage in the VSC circuit should be higher than the main voltage in order to better modulation control in the circuit. The DC bus capacitor is based on the concept of boosting DC bus voltage by eliminating loads and dejection units from the voltage distribution system, as shown in Fig. 1. In this case, it is due to the principle of conservation of energy [16]. The voltage across the DC bus capacitor is described by the equation.

$$\frac{1}{2} C_{dc}\{(V_{dc}^2 - V_1^2)\} = C\{3V_{pv}(FI_{pv})t\} \quad (4)$$

The DC bus capacitor calculation is denoted by C dc, and the voltage of DC is denoted by Vdc. The min. voltage through the dc bus, phase voltage and current are denoted by Vpv and Ipv, respectively, and the constant is denoted by C. The overloading aspect of the Shunt circuit is denoted by the letter F, which is denoted by the letter C. The DC bus capacitor calculation is denoted by C. The interface inductor (Li) on the alternating current side of the PV-STATCOM is the primary focus of the proposed research and development. According to the proposed PV-STATCOM, the neutralisation is done by the use of harmonics, which are square waves created by the VSC. The switching frequency and ripple current, which are represented by the symbols f s and i crp, are responsible for handling the interface inductor. As a result, the equation may be written as

$$L_i = \frac{\sqrt{3} \cdot m1 \cdot V_{dc}}{[12.F \cdot f_s i_{crp}\}} \quad (5)$$

The process of a "PV-based shunt APF" for the purpose of alleviating a lowered power quality hitch in the power system must be accomplished via the use of a voltage source converter-based shunt APF operation. When it comes to the production of gate signals for the stimulation of the photovoltaic system-based shunt APF in the proposed test system, several control techniques play an important role. As a result, the "photovoltaic solar farm's" power circuit and operation process must be defined. When executing the shunt active power filter to mitigate the harmonics problem in order to complete the project. The PV-STATCOM is able to maintain a constant voltage through the DC bus capacitor because of the compensatory mechanism used. The figure that follows in Fig. 6 illustrates this. the grid connected model might be used to examine the improvement of the power quality and issues related to control listed above, including true and variable amplitude regulation (VAR).

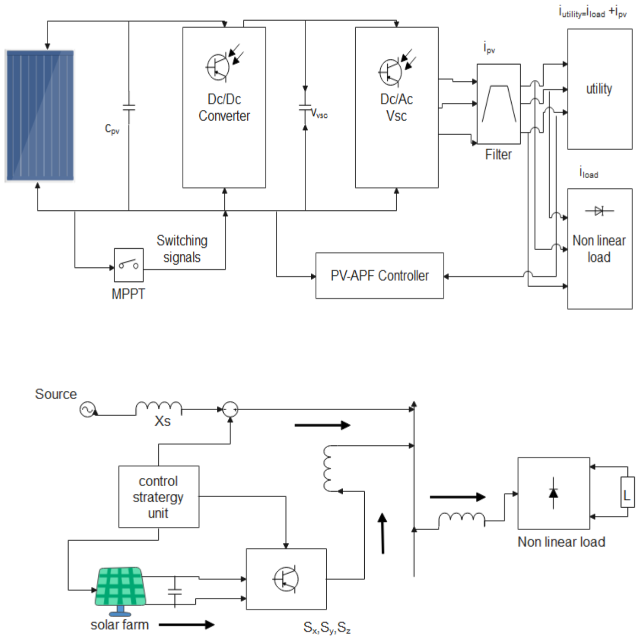


Fig. 6 Projected work to increase Power Quality

As projected project, a "photovoltaic solar farm" is being employed as a shunt APF. in order to reduce difficulties in the power quality system as much as possible. Using reactive power compensation, the PV-STATCOM not only injects real energy into the distribution network but also controls reactive power in the distribution system. Problems with power quality connected with solar power system integration and nonlinear features are improved by the use of PV-STATCOM in this innovation, which is a breakthrough in the field. The 3-phase R-L type full wave rectification is linked to the alternating current side of the PV shunt active filter that is coupled to a shunt. On sunny days, "photovoltaic solar farm" serves as a shunt -

compensator, supplying actual power (P), while on cloudy days, it serves as a low-power generator and compensator, delivering power (P). According to the "1EEE 1547 standard", the VAR (Reactive Power) injection into the micro grid was not permitted. The VAR (Reactive Power) injection into the micro-grid is required for the loads (wind farm, solar farm, DG). The old 1EEE 1547 Standard has been changed with IEEE P1547.8 to reflect the VAR power injection in the grid system in order to improve standards of power quality [17]. This is due to the fast advancement of technological advancement. The proposed controller makes use of hysteresis current control technology in order to keep system variables within the hysteresis region is the limitations of the system. The sensor must be used by the controller to quantify a number of parameters, including three-phased sources, inverters, and DC bus tensions [18]. Both actual and the reference currents are eliminated from the Voltage Source Converter base PV in order to activate the converter's base PV. Fig. 7 depicts the STATCOM unit.

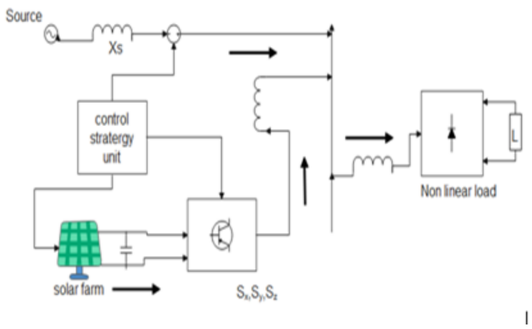


Fig. 7 Operative System for on grid PV-STATCOM

Following the same procedure as previously described, the template of unit vector and the generation of pulse approach, are used to investigate how the reference current changes with the I/P voltage at the PCC unit. In performance analysis, the root- mean- square, which is determined by the square of two vectors, is a critical parameter to understand and calculate. By splitting the source voltage, which is used to initiate the separate phase unit vector, the sample peak voltage may be calculated.

3.3. Grid Synchronization to avoid Harmonic Defects

The projected work comprises of 3- phases which are denoted by (V_{sx}, V_{sy}, V_{sz}). The unit vector is based on the sample peak voltage and represent as

$$V_{sn} = \left\{\frac{2}{3}\left(V_{sx}^2 + V_{sy}^2 + V_{sz}^2\right)\right\}^{\frac{1}{2}} \tag{6}$$

The PV system's input source voltage is expressed as

$$V_{sx} = V_1 \text{Sin}\,(\omega t) \tag{7}$$

$$V_{sy} = V_1 \text{Sin}\,\left(\omega t - \frac{2\pi}{3}\right) \tag{8}$$

$$V_{sz} = V_1 \text{Sin}\,\left(\omega t - \frac{4\pi}{3}\right) \tag{9}$$

The sampled peak voltage is used to calculate the unit vector template u_{sx}, u_{sy}, u_{sz} of 3- phases, as shown in eqn.10.

$$u_{sx} = \frac{V_{sx}}{V_{sn}} \tag{10}$$

$$u_{sy} = \frac{V_{sy}}{V_{sn}} \tag{11}$$

$$u_{sz} = \frac{V_{sz}}{V_{sn}} \tag{12}$$

The reference currents $\left(i_{sx}^*, i_{sy}^*, i_{sz}^*\right)$ and active current component calculate the error voltage in the DC link. Equation 13 is used to compute the error component.

$$\begin{gathered} V_{\text{err}\,(F)} = V_{\text{ddof}\,(F)} - V_{dc(F)} \\ I_{m(F)} = I_{m(F-1)} + K_P V_{dc(F)}\left(V_{\text{er}\,(F)} - V_{\text{er}\,(F-1)}\right) + K_I V_{dc(F)} V_{\text{err}\,(F)} \end{gathered} \tag{13}$$

In the case of the Hysteresis-based controller, this error is created by subtracting the output currents from the actual and reference currents. PI control is used to generate reference currents, which are then utilised to reduce power quality concerns by using the proportional integral (PI) control technique. The voltage that is measured is compared to the voltage that is used as a reference. in this control approach, the error voltage is created as a result of the comparison. Gate signals are generated from each sample point for the PI controller's Shunt Active Filter, which is implemented as a Shunt Active Filter. The PV system works because it is an inductive system. Otherwise, the highest amount of reactive power sent into the grid is used to sustain PCC voltage [19].

The inverter voltage is controlled using the current hysteresis control method. In the hysteresis control technique [20-24]. The hysteresis levels are matched to the measured current, and the switching sequence is controlled by the comparison output. Figure 9 illustrates the hysteresis current controller. can handle gate pulse switching signals and may be included in MATLAB/SIMULINK.

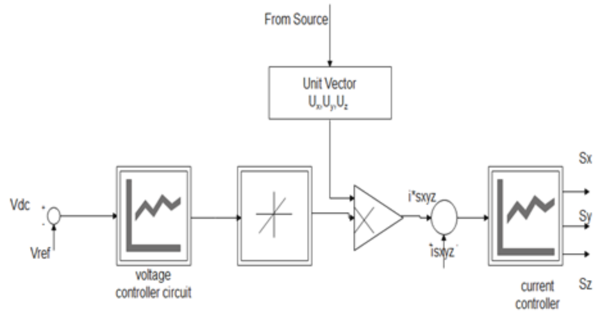


Fig. 8 Proposed PV-STATCOM's Control Strategy

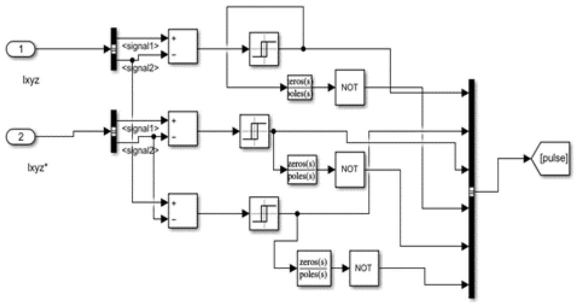


Fig. 9 Current Controller of Hysteresis Unit

The modulation signal is important in hysteresis control because of the random movement of positive and negative switches coupled in the shunt filter. The switching process is depicted as Sx and Sy, Sz for 3- phases respectively. The switching and error factors for the 3- phases are shown in Table 1.

Table 1. Input Condition of Proposed structure

Switching Status for phase – X	
1	$i_{sx} > (i_{sx}^{*} - HB) \rightarrow S_y$
0	$i_{sx} < (i_{sx}^{*} - HB) \rightarrow S_y$
S_y Status for phase – Y	
1	$i_{sy} > \left(i_{sy}^{*} - HB\right) \rightarrow S_y$
0	$i_{sy} < \left(i_{sy}^{*} - HB\right) \rightarrow S_y$
$S_z\, Status\ for\ phase - Z$	
1	$i_{sz} > (i_{sz}^{*} - HB) \rightarrow S_z$
0	$i_{\text{se}} < (i_{sz}^{*} - HB) \rightarrow S_z$

The suggested PV-STATCOM stability with the Hysteresis Band is determined by this switching condition. i_{sx}, i_{sy}, i_{sz} represents the actual source current, $i_{sx}^{*}, i_{sy}^{*}, i_{sz}^{*}$ represents the reference currents. To meet the Low Voltage Ride Through (LVRT) criteria, voltage source converter-based shunt active power filter system must insert the necessary real and reactive power into the grid-based integral test model to reduce current distortion, voltage dip & harmonics. To improve distribution system power quality, to supply gate currents for launching a photovoltaic STATCOM operation, an instantaneous reactive power theory is used [25-27].

In the scenario of LVRT $k_d$represents the Power derating factor, v_{gn}represents the reference values of Grid voltage and I_N indicates the rated grid current values. As a result, the average power quality can be determined as follows:

$$P = k_d P_N = \left(\frac{k_d}{2}\right) v_{gn} I_N \tag{14}$$

The "PV-STATCOM" injects reactive power for improving quality of power in the suggested grid connection model, that is investigated and evidenced by the results of the experiments.

4. Pv- Statcom -Experimentation -with APF

The MATLAB / Simulink platform is used in order to validate the proposed test model and control strategy. In the presence of a PV-STATCOM connected through a shunt, the test model's operational behaviour is recreated. One-phase circuit breakers connect the PV-based active filter to the PCC, and three single-phase perfect sinusoidal alternating current voltage sources and an induction generator provide power to the non-linear RL load, which is driven by an induction generator. The DC capacitor is linked to the PV-DC STATCOM's side, whereas the inductor is connected to the STATCOM's AC side. The reference current signals produced by the control algorithm proposed in this paper activate the electronic valves in the PV-STATCOM IGBTs.

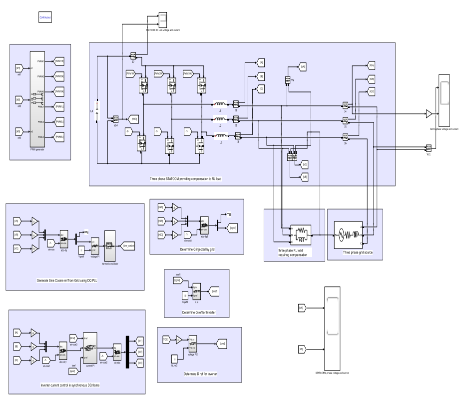


Fig. 10 Simulation of STATCOM Unit

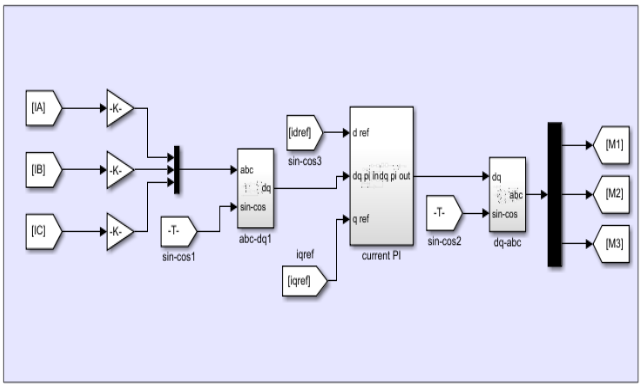


Fig. 11 Simulation Block of proposed controller

Fig. 11 Illustrates the reference current generator's MATLAB/ Simulink design-voltage source converter based static compensation (Shunt APF) in the planned distribution network to address power quality concerns.

Table 2 lists the input settings for tuning the projected PV-STATCOM device with a fixed voltage level.

Table 2. Proposed work parameters

S. No	Parameters	Ratings
1	Input Source	3-phase, 416 V, 50 Hz
2	Single line Inductance	0.15 mH
3	Active Shunt Inductance	0.75 mH
4	Load distortion	Three-phase rectifier load supplying 9 Ω , 11 mH
5	Parameters of Inverting circuit	C = 4 mF, DC link Voltage = 760V f= 2 kHz.
6	Input Solar Panel	19.5 kVA
7	Switching Parameters	Gate Voltage = 15.5V, I =40A, Collector Voltage =1550V

The dynamics of a solar farm are studied using the findings of a MATLAB simulation which act as a shunt active filter, this is the subject of the projected test model and approach to control. As a consequence of the MATLAB simulation, it was shown that PV-based shunt compensators may do double duty as a real-world injector of energy and a reactive power offset to improve power quality in both day and nighttime conditions. It is more effective to utilise the numbers 2.5 and 1.25 for gate current generation and signal to switch for the electronic valves used in the switching shunt active power filter for this investigation since they are more accurate. While running in the MATLAB simulation, the PV-based STATCOM with a shunt coupling may function between 0.1 and 0.2 seconds every cycle (0.25 sec). Current harmonics (current distortions) induced by diode rectifier load distortion were reduced by the PV-based STATCOM by injecting current in the phase and magnitude illustrated in Fig. 12.

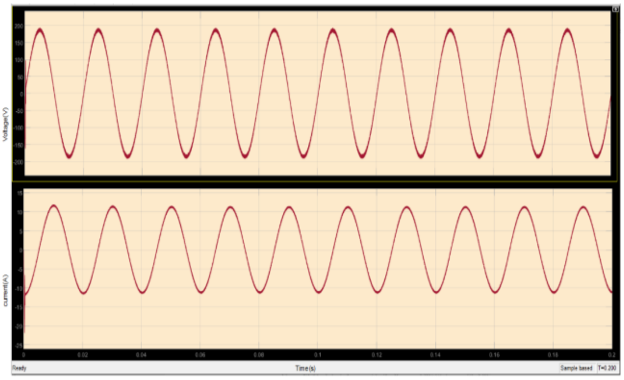


Fig. 12 Proposed System Current

The switches determine the performance of the projected PV STATCOM. When you flip on the switch for 0.1 to 0.2 seconds, the harmonic condition is achieved without changing the load value. The source current is polluted by harmonic circumstances when the switch is switched off after 0.2 seconds. Fig. 13 depicts the projected PV-STATCOM based APF's overall active and reactive power adjustment.

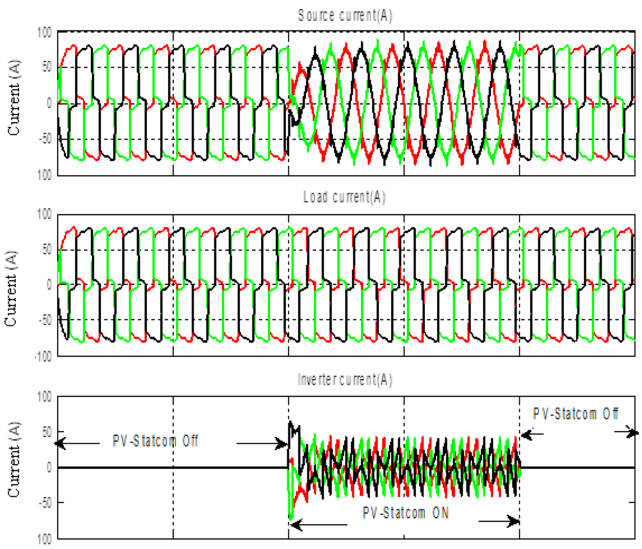


Fig. 13 Variations in input unit of STATCOM

The power management of the PV STATCOM is presented in Fig. 14 with injected mode. VAR power factor does not completely compensate with the input source.

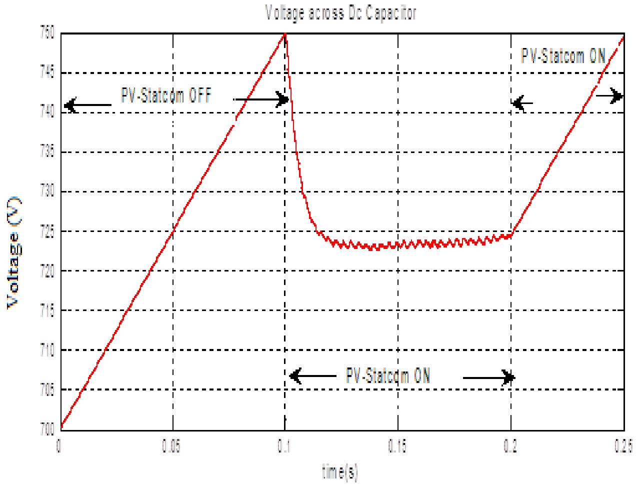


Fig. 14 Input Power Unit of PV-STATCOM

Fig. 15 In grid-connected systems, indicates a stable DC-Bus voltage to reduce power quality issues.

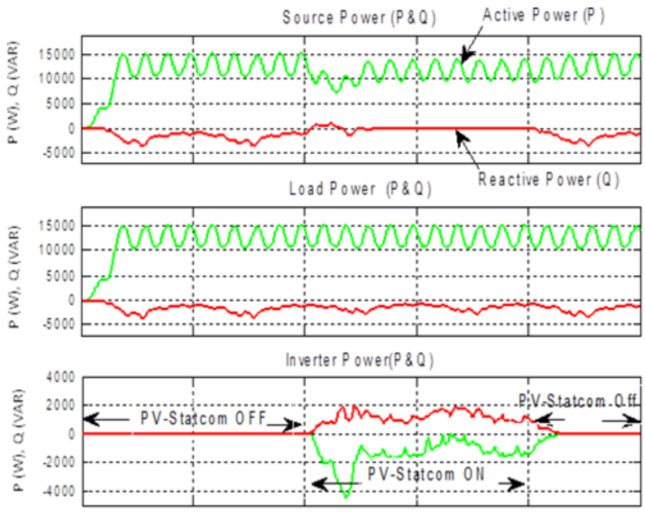


Fig. 15 Input Unit-Capacitance

Fig. 16 depicts how the Active Power Filter analyses VAR power loss and active power injection to decide whether or not there is an improvement in power quality in the event of a grid breakdown. Among the most prevalent grid sources are failures of the distribution grid, which have sampling rates that range from 0.02 to 0.01 seconds and result in a drop in power from 41.4 to 18.78 (kilowatts). During the regular mode of the Pv-STATCOM Shunt APF, it displays actual & active power levels. 17.77 kVAR of reactive power is injected by the shunt-connected compensator (which is greater than average reactive power) into the grid when the grid is experiencing a fault scenario, which helps to eliminate voltage sags and harmonic tunnels.

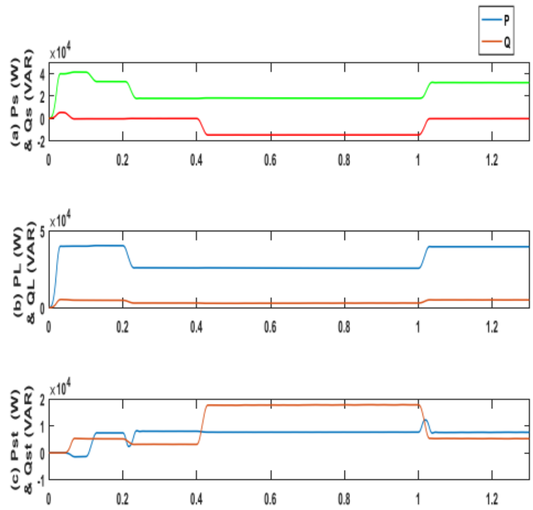


Fig. 16 STATCOM Input Voltages

5. Conclusion

It is possible to successfully complete PV-STATCOM with "solar farm" as a "static synchronous compensator device": a useful and effective performance study that decreases power quality factor disturbances based on the findings of this suggested research using the results of this research. An explanation is provided of the injection and absorption modes of shunt APF filters, as well as how the issue in the distribution system may be rectified by changing the Grid synchronisation settings of the filter. Improvements in the power quality of electrical grids are the primary goal of the VSC's simulation work using the MATLAB software package, The LVRT abilities, the harmonic and voltage sag difference in the integrated grid system is decreased. The voltage is under control at PCC, and harmonic distortion is reduced as a consequence of the capacitance on the DC bus being kept at a constant value. As a result, advancements in topologies increase the likelihood of optimising the utility of the proposed grid system in a broad variety of application situations in the future.

Conflicts of interest

The authors declare no conflicts of interest.

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