Pv-Statcom Power Quality Enhancement with Shunt Active Power Filter

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Abstract: Power consumption and energy demand are the major crises in the emerging world, leading to the increment in reliable resources. Reliability concerns were raised with the incorporation of solar energy sources employing typical electricity systems alignments. Furthermore, the fast-expanding use of electronically powered loads leads to problems of power quality in distribution networks. The significant power disturbances in the system occur due to the reactive power reduction, harmonic variation, and high voltage in distribution networks. An Active Power Filter is carried out to minimize the power quality disturbances in the distribution network to overcome the power quality defects. PV-STATCOM combined with the shunt Active Power Filter (APF) is the central part of the proposed work, which combines with the Unit Vector Template Method and Pulse Generator Techniques. In the distribution systems, PV-STATCOM, based on Voltage Source Converter, can inject and absorb the reactive and active power required in PCC to reduce power quality problems. The Low Voltage Ride analyses the performance of the PV-STATCOM system Through (LVRT) in an integrated grid system. The result analysis using MATLAB/SIMULINK shows that the proposed PV-STATCOM improved the performance rate in the power quality factor at the line of distribution systems. The Power outcomes of the proposed work changes from lagging power factor to unity Power factor with the changes in phase value of 26.7% to 5.0%, which lies with the IEEE standard limits.

Keywords: Shunt Active Filters, Low VoltageRide Through, PV-STATCOM, Voltage Source Converter (VSC), Power Quality Enhancement

1. Introduction

Electric power consumption outweighs production in the current electricity environment. Demand is growing gradually because key activities in society, including household, municipal, commercial, transit, agricultural and industrial, have been significantly related to electrical energy in recent decades. Alternative energy sources like wind, geothermal, tidal, and solar are regarded as appropriate alternatives to the grid-integrated system to satisfy the load of capital energy. Modern electricity converters are used in solar and wind sources that may absorb or inject actual energy and reactive (VAR) electricity into the network of combined energy systems to improve the power quality. The electric power distribution system now comprises all reactive and non-linear demands (Power Electronic based loads). As non-linear loads are gradually more used, distribution systems' reactive power or burden will increase feeder losses and reduce the existing electrical distribution system's flow capacity (P).Substantial asymmetrical fluctuations in AC power can increase the Power Quality (PQ) problems such as voltage variations, current harmonics, reactive power request, poor power effects by non-linear loads as electric bowls, electronic gadgets (computers, televisions, monitors, etc.) The street lights, digital meter, and one-phase, 3-phase power converters, adjustable ASD, etc. At present pure energy transfer (pollution-free power) is an essential challenge for power engineers to have a power system running efficiently and effectively **(Arnold, G. 2011).**The low power quality can lead to overheating, overloading, additional power losses, a saturation of transformers, equipment defects, data mistakes, service, product quality, and the economy of the industries **(Liu, Y., & Tian, L. 2016).**The passive filters consisting of inductors, condensers, and damping resistance played a critical role in the first stages of the 1930s and 1940s in mitigating the power quality concerns in distribution networks, but because of few significant disadvantages of passive filters such as their heavy dimensions and weight, poor performance, resonances and the execution of constant compensation, etc. Hence the active power filters have been researched, and a massive amount of work has been published **(Lakshman, N. P., & Palanisamy, K. .2017).** Thus, active power filters replace the passive filters shortly. The classical model of the typical electricity system is presented in Figure. 1**(Bollen, M. H. .2001)**.

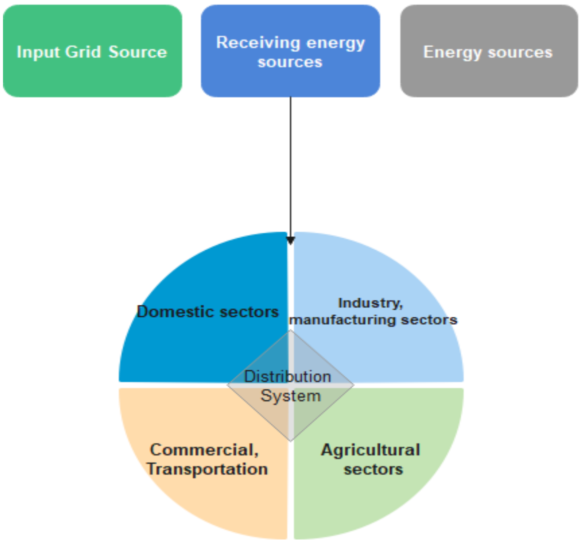


Figure 1. Classical Model of Typical Electrical Power System

The shunt Active Power Filter (APF) play an essential part in mitigating concerns about the power quality of distribution and transmission system among the different power filters. The Shunt APFs have demonstrated that nearly all end users deal with energy quality issues rarely. This research focuses on PV-based STATCOM as an active energy compensator and power injector for power improvements in a network-integrated system. In this proposed study, the shunt-connected device known as the Static Synchronous Compensator has been provided by PV solar farm, thus PV-STATCOM. The solar photovoltaic farm generates actual power only throughout the day, and while night time, it is completely idle. Power feeders have significantly lower loads throughout the night than daytime. Due to increasing wind speeds, the wind farm generates high power, and reverse current flows from PCC to the primary grid source might result **(Varma, R. K., Rahman, S. A., & Vanderheide, T. .2014),** often creating voltage variations in the grid-tie system of ±5 %. To keep the system voltage within allowed limits of power quality increase in a grid-integrated test model, the VSC shunt APF balance active and reactive power at the PCC (**Lee, C. T., Hsu, C. W., & Cheng, P. T. .2011**). This proposed work shows the operational performance of PV-based shunt APF, using the Proportional Integral, Hysteresis Current Controller and P-Q control theory to relieve current harmonics, compensating for reactive power injection, increasing the power factor, reducing the THD value, reducing the diminished violation as required for the low-voltage ride-through with critical phase and magnitudes.

Power quality is currently one of the leading research issues for all electricity sectors and commercial enterprises. A rise in demand for dependable electricity, high quality, and higher use of nonlinear loads might lead to an increase in public service and consumer awareness of high-quality electricity. Non-sinusoidal currents are derived by distortion or power-based electronic charges, making power pollution a significant problem in distribution and transmission systems. Polluted electricity will not only impair the system's functioning but also harm productivity and the national economy. For power researchers, the transfer of quality power from generation stations to consumers is one of the primary challenges because reactive and distorting charges are present in the distribution system. Nonlinear loads (PE loads) are accountable for the complexities in the power system's power quality. Initially, passive filters were employed to attenuate energy quality difficulties. However, they cannot fully attenuate power quality difficulties owing to the few notable limitations caused by passive filters.

The lack of traditional equipment to improve power quality requires critical and adaptive solutions to concerns about power quality. This has prompted custom power devices to be created. Shunt Active Filter is a modern and favourable custom power device that addresses difficulties linked to power quality. Because of their performance, various studies have been carried out in several power quality problems, unlike typical linear and nonlinear loads. Because of its performance as recognized equipment, different control mechanisms for improving the power quality of the distribution systems should be further studied. These need active shunt filters to be modelled and developed with its power quality management mechanisms in the proposed grid-tie system. Controllers for PV-STATCOM can raise the distribution capacity of current distribution lines. Power engineers at photovoltaic solar farms have suggested a new research project to use power transmission and distribution lines as shunt APFs for increasing performance factors. The grid-built PV solar farm converter is used as an active shunt filter in this proposed work. This approach is known as PV-STATCOM to use solar photovoltaics as shunt offsetting devices. The reactive force whose output can be successfully performed conforms to IEEE standards to improve the power quality in network systems. The PV-based shunt compensator may absorb or produce reactive power

2.Background Study of Power Quality and Custom Power Devices

Increased use of nonlinear, distorting or sensitive PE loads such as electric arc furnace, switch-mode power, ASD, etc., to enhance the management and effectiveness of the Power System raises customer end facilities distortion levels. One of the most critical issues for power researchers is to transmit contamination-free power generation. Today the electrical distribution system contains all of the sensitive or distortions loads and loads and consequently large energy requirements for VAR. It is very essential to attenuate the originated power quality hitches in the power system, because the polluted (non-qualified) power may lead to enlarged power losses, which will affect the productivity and efficiency (performance) of the power system. At the initial stage (during 1930 and 1940) the LC passive filters performed a major role to mitigate the originated distortions in the distribution networks. Because of a few determinant drawbacks, the passive filters cannot attenuate the power quality complications completely in the distribution system. The very important drawbacks of passive filters are listed below

- Poor isolation between input and output.
- Never provide any gain (power gain and voltage gain).
- Circuit becomes bulky with the inductor.
- Enforcement of fixed compensation.
- Source loading can take place.
- Creates resonance problem.

To overcome the demerits of passive filters are used to fast forward steps taken by the many researcher's power Electronics based active filters. In 1970 the flexible and adapted solution to overcome the demerits of active filters current or voltage distortion reduced using the active filters (**Banerji, A., Biswas, S. K., & Singh, B. .2012**). There is various research work carried out to analyse a quality concern in active power filter. Higher-order harmonics can be compensated by static synchronous compensators. The synchronous compensator is employed to overcome the sources during the distribution stage which also increase the power quality of the system (**Varma, R. K., Rangarajan, S. S., Axente, I., & Sharma, V. .2011**). Major applications of Active power filters are illustrated below. Active power filters are used in various applications due to the stable current flow in the three-phase system of the four-wire system. The power factor of the active filters is better as compared with the passive filters with the reduced reactive power compensation.

Increased demand for high quality, reliable power and growing use of non-linear loads can lead to an increase in awareness about power quality by both utilities and end-users by boosting the standard of living, improvement of the profitability and productivity of power generation units and the service industry and the beneficial use of Power Electronic (PE) technology. One of the most important increasing applications is customized power or power quality (**Hingorani, N. G. 1995**). Customized power is used to deliver the dependability and or quality of power required by both end customer and utilities to power the electronic controls on electric distribution networks (**Bollen, M. H., Sabin, D. D., & Thallam, R. S.2003**). In other words, Custom Power (CP) is meant to insulate end users from the complications of power quality, such as interruptions and voltage decreases in utility systems (**Hingorani, N. G.1995**). Custom power devices or controllers are processed with Active Filters, Static Switches, Dynamic Voltage Restorers (DVRs), Injection Transformers, Energy Storage Modules, UPQC (United Power Quality Condition), which can reduce power quality problems such as voltage or current interruption and voltage variations on distribution networks. The custom power devices or controls activate the end-users in a custom power system to receive the defined, qualified power. The following are the important aspects of customized power units which are reduction in power interruptions, voltage swags and swells during the available limits and the stable condition is carried out during the low phase.

All of the above may be done with individuals, end-users, business or industrial parks or a broad range of supplies for an outstanding high-tech community. The FACTS controls can extend the power transfer capability of current transmission lines. the Flexible AC transmission systems **(Rangarajan, S. S., Sreejith, S., & Nigam, S. 2014)**. Many researchers in the field of solar PV farms advised that the energy distribution line's performance should be increased by new research into shunting APFs. The grid built-in PV solar farm inverse is used as a shunt active filter in this dissertation. This approach is called "PV-STATCOM" to use solar photovoltaics as a shunt compensator. A reactive power (VAR power) compensation is a PV based shunt compensation. The reactive energy can be absorbed or generated by regulating the specific characteristics of the electrical distribution network with different outputs. The Solar Farm is used as a shunting active filter to mitigate the power quality issues caused by distorted loads in the Grid integrated PV modules. More attention is needed to the difficulties related to harmonics since more dispersed generators such as PV and wind are incorporated into a distribution system (**Rangarajan, S. S., Collins, E. R., & Fox, J. C. 2017**). To overcome the various demerits of passive filters the proposed technique is carried out to enhance the power quality in the PV system. The proposed solar photovoltaic system is fully idle and does not create real power at night, but the controller may adjust the voltage at PCC day and night. If the solar photovoltaic farm does not generate active electricity, the reactive power capacity is 100% accessible. By extracting a little amount of active power from the proposed grid system the DC bus capacitor voltage will remain at a constant value, while the PCC voltage also remains a constant value.

3.Proposed Design aspects of PV-STATCOM in Integrated Grid Systems

The proposed work deals with the power enhancement that can be carried out using reduction of power quality complications in a photovoltaic system. The equivalent circuit model of the PV system is explained with the proposed Current Controlled source (CCS). The design aspects of PV based compensator is explained to clarify the enrichment of power factor in the proposed PV grid model. With the aid of supporting phasor diagrams for reducing power quality issues in the power system, the active, reactive power injection and absorption are clearly illustrated. The proposed VSC based PV-STATCOM works under stable condition due to the adequate amount of active and reactive power in the shunt system for the injection process. The equivalent circuit of the 3-Phase, 3-Wire rectifying unit is energized using the major element in the grid source as shown in Figure.2. The circuit explains the grid integrated model with the series connection of the PV-inverter control unit. The VSC based active filter is a three-phase shunt-connected voltage source that is meant to eliminate power generated by PV (**Obando-Montaño, A. F., Carrillo, C., Cidrás, J., & Díaz-Dorado, E. 2014**). The VAR power distortion and current harmonic changes are maintained using the shunt active filter at the common coupling point. The power quality enhancement can be maintained by this progress from the elimination of sensitive load attenuation in the grid integrated system.

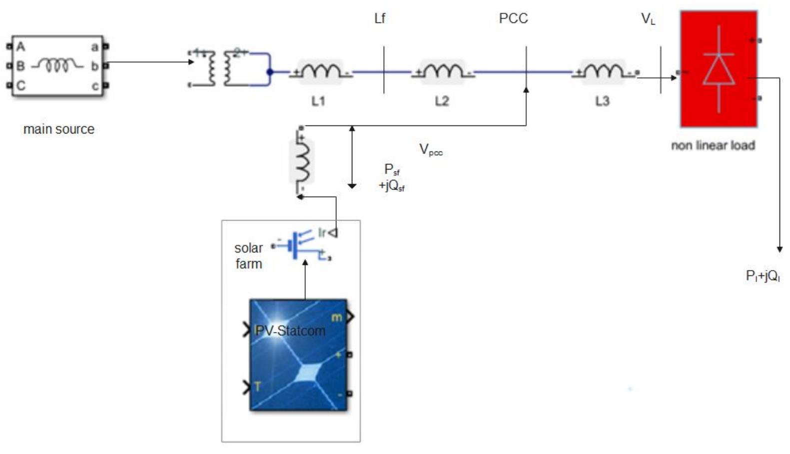


Figure 2. Single Line Power Quality Enhancement System

The shunt active filter connected PV-STATCOM unit is represented in Figure.3. The PV Shunt Active Filter is in the form of 3- phase device unit comprised of various AC/DC converters**.**

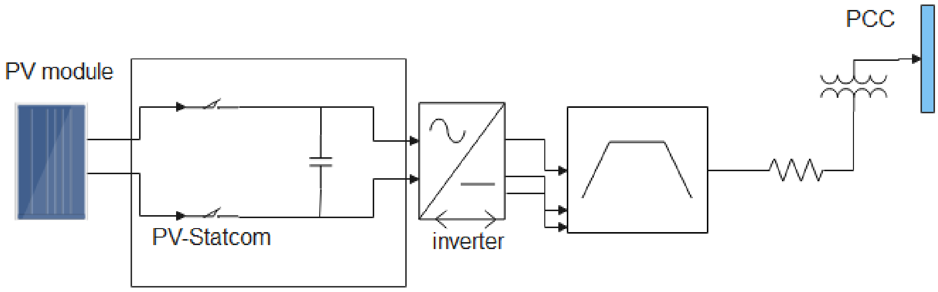


Figure 3. Solar farm with Shunt Active Power Filter

The solar PV Farm works as a shunt APF that offsets reactive power at PCCs for power quality reduction in distribution networks. The Shunt APF is powered by the photovoltaic solar system in this proposed work.

3.1. Voltage Source Converter Based PV-STATCOM

The VSC-based shunt active compensator consists of a DC-side condenser as well as the tiny AC-side reactor, which filters the IGBT-related high-frequency segments as shown in Figure.4. A PV-based compensator is a reactive power compensation unit that can absorb and or provide a necessary quantity of real and reactive power for stable power system operations. The PV-STATCOM is a VSC that transforms the photovoltaic (PV) solar farm to a set of output AC voltages and is connected by a little reaction (leakage induced by the coupling transformer or interfaces) to the associated AC system.

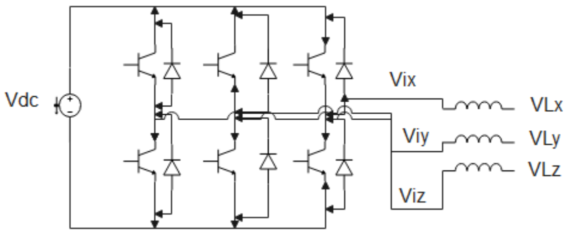


Figure 4. Proposed Voltage Source Converter with PV-STATCOM

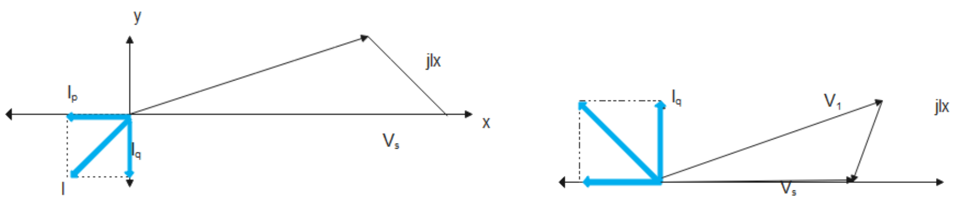
For the interchange of power between the inverter and proposed Grid system and the grid systems to the inverter, the voltage difference is extremely significant. The VSC based PV-STATCOM can reduce power quality problems by using the proposed control system efficiently. Enough actual power and reactive power are controlled by the PV-based APF shunt. The following constant state balances show that shunt APF provides actual and reactive power for the increase of energy quality on the distribution network.

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

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

Where P_s represents the real power, reactive power is indicated as Q_s, V_{s1} is system voltage unit, V_m is inverter voltage in PV-STATCOM, y_s is reactance and δ is the phase differences between the system and inverter voltage.In the following modes of operation, the active and reactive power injection/absorption by PV-STATCOM is explained

In capacitive operation, the voltage of the inverter is greater than the voltage of the system (which are phased in) and the inverter supplies only VAR (Q) power to the microgrid. The inverter voltage is lower in the inductive mode of operation than system voltage (though these voltages are in phase) and so the inverter pulls reactive power (Q) from the main system.



(a) **(b)**

Figure 5. Active and Reactive Injection in (a) Inductive mode (b) Capacitive mode

Figure.5a shows that the system voltage is higher than that of the inverter voltage so that the PV-STATCOM is supposed to supply actual power (P) and absorbs VAR energy. The system voltage is lagger (Q). It is also obvious from Figure.5b that the system voltage is smaller than the system voltage lags of the inverter voltage and the system voltage, thus PV-STATCOM injects enough reactive power and actual power (P).

3.2.Design characteristics of proposed PV-STATCOM

The PV shunt APF with the characteristic of VSC is applied with the desired actual and reactive powers in the grid test model due to the elimination of power quality complications. The general PV-STATCOM consists of various devices such as a DC bus capacitor, interfacing inducting unit(**Singh, B., & Solanki, J. 2009**). The proposed work consists of shunt connected APF unit in the PV-STATCOM has the following specifications.

The DC bus voltage of the proposed work is explained with the eqn.

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

where, V_I is the output voltage in the line of the system, m1 is the modulation index in the shunt unit. V_{dc} represents the bus voltage of the shunt APF.

By assigning the value of modulation index as 1 and line voltage as 416V the bus voltage is calculated as 679.32V which is fixed as the rate of 750V. The work concludes that the bus voltage should be more than the AC main voltage to get better modulation control in the VSC circuit. The DC bus capacitor is structured based on the increase in DC bus voltage by the elimination of loads and dejection unit in the voltage. This happens due to the law of conservation of energy (**Popavath, L. N., Palanisamy, K., & Kothari, D. P. 2016).** The eqn represents the DC bus capacitor voltage.

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

Where C_{dc} represents the DC bus capacitor calculation and the DC voltage is represented as V_{dc}, the minimum voltage between the DC bus system is represented as V_1, V_{pv} represents the phase voltage and the phase current indicated as I_{pv}, the constant is indicated as C, the timing sectors of DC bus voltage is indicated as t, F is the overloading aspect in the Shunt circuit. The Ac side of the PV-STATCOM consists of an interfacing inductor (L_i) which represents the main area of the proposed work. The neutralization occurs in the harmonics that comprises of square wave generated by the VSC unit in the proposed PV-STATCOM. The interfacing inductor is handled by the switching frequency and ripple current which is represented as f_s , i_{crp} . So the equation can be represented as

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

It is quite necessary to activate a voltage source converter-based shunt APF operation to achieve the intended operation of the PV-based shunt APF for the reduced power quality hitch in the power system. Different control techniques play an essential part in the development, of the proposed test system, of the gate signals for activation of the photovoltaic system-based shunt APF. Therefore, it is necessary to outline the power circuit, operating rules of the photovoltaic solar farm while performing the shunt APF which overcome the harmonics hitches.The PV-STATCOM keeps the constant voltage value across the DC bus capacitor through the compensating procedure. The following Figure.6 grid-integrated test model may be used to investigate mitigation of all above power quality and control concerns of true and VAR power control.

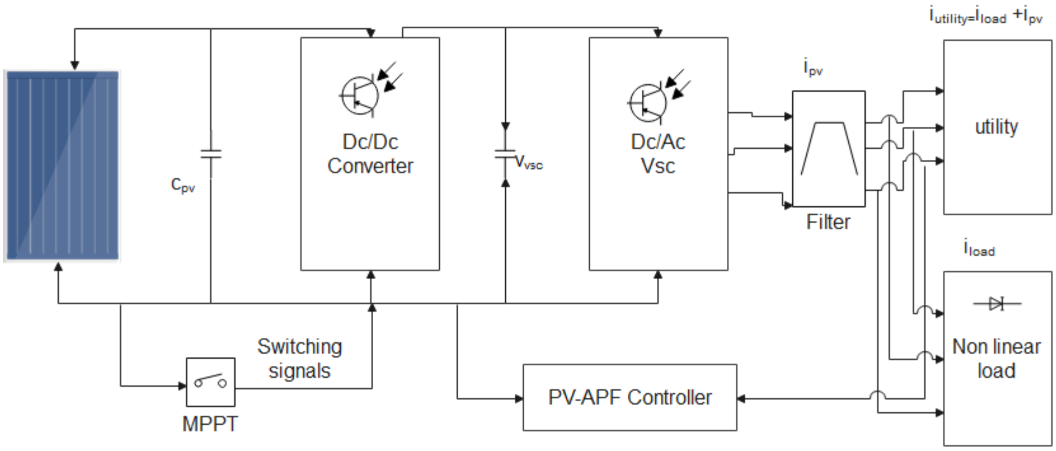


Figure 6. Proposed Work for Increasing Power Quality Factor

In this proposed work, the photovoltaic solar farm is used to mitigate difficulties in the power quality system as a shunt APF. Not only does the PV-STATCOM inject actual power into the distribution system, but it also acts as a reactive power compensation to manage the reactive power. PV-STATCOM is used in this invention to reduce power quality difficulties associated with the integration of power systems into the solar and nonlinear characteristics. The AC-side of the shunt-connected PV shunt active filter is linked to the three-phase RL type full-wave rectification. The photovoltaic solar farm, which operates as a shunt compensator delivers the genuine electricity (P) during the day and serves for low power generation and nighttime as a compensator. The VAR power feeds (wind farm, solar farm, DG) the loads, however before the 1EEE 1547 standard did not allow the VAR (Reactive Power) injection into the micro-grid. The older 1EEE 1547 Standard was changed as 1EEE p1547.8 due to the rapid advancement of the technology which implies the VAR power injection in the grid system to increase power quality standards**(Popavath, M. L. N., & Palanisamy, K. 2015).**

A hysteresis current control technology has been used in the suggested controller to maintain system variables within the hysteresis region limitations. The controller requires the quantification using the sensor of several variables like the 3-phased sources, inverter and DC bus tensions (**Mohod, S. W., & Aware, M. V. 2010**). Both real and reference currents are subtracted to enable voltage source converter base PV STATCOM is shown in Figure.7.

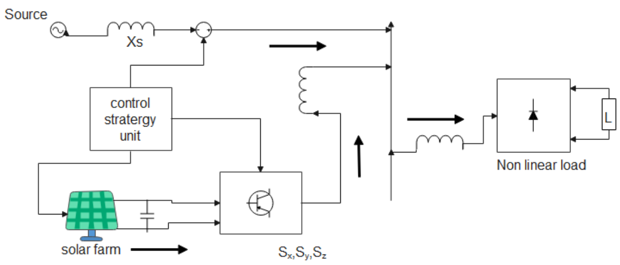


Figure 7. Operational Scheme of Grid-connected PV-STATCOM

As discussed before the unit vector template as well as pulse generation technique is used to analyze the reference current with the input voltage at the PCC unit. The root means square plays the major role in the performance analysis which is calculated by the square of two vectors. The sample peak voltage is given by the division of supply voltage which initiates the unit vector of separate phase.

3.3. Grid Synchronization to avoid Harmonic Defects

The proposed work consists of three phases which are represented namely(V_{sx}, V_{sy}, V_{sz}). The unit vector is based on the sample peak voltage and expressed as

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

The input source voltage from the PV system is represented as

$$V_{sx} = V_1 \mathrm{Sin}(\omega t) \quad (7)$$

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

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

The unit vector template u_{sx}, u_{sy}, u_{sz} of three phases are calculated with the sampled peak voltage is represented in the below eqn.10

$$u_{sx} = \frac{V_{sx}}{V_{sn}} \quad (10)$$

$$u_{sy} = \frac{V_{sy}}{V_{sn}} \quad (11)$$

$$u_{sz} = \frac{V_{sz}}{V_{sn}} \quad (12)$$

The error voltage in the DC link is calculated by the reference currents $(i_{sx}^*, i_{sy}^*, i_{sz}^*)$ and active current component. The error component is calculated using equation 13.

$$V_{\mathrm{err}(F)} = V_{d\mathrm{dof}(F)} - V_{dc(F)} \quad (13)$$
$$I_{m(F)} = I_{m(F-1)} + K_P V_{dc(F)}\left(V_{\mathrm{er}(F)} - V_{\mathrm{er}(F-1)}\right) + K_I V_{dc(F)} V_{\mathrm{err}(F)}$$

This error is generated by subtracting the actual and reference currents for the Hysteresis based controller. To generate reference currents for the reduction in power quality hitches, the proportional Integral (PI) control technique plays an important role. The measured voltage is compared to the reference voltage and the error voltage is created in this control scheme. Every sample point is utilized to generate gate signals for Shunt Active Filter as input to the PI controller. The PV system functions as an inductive system. Otherwise, the PCC voltage support is provided by the highest reactive power injected into the grid**(L. Liu, H. Li, Y. Xue, and W. Liu.2015).**

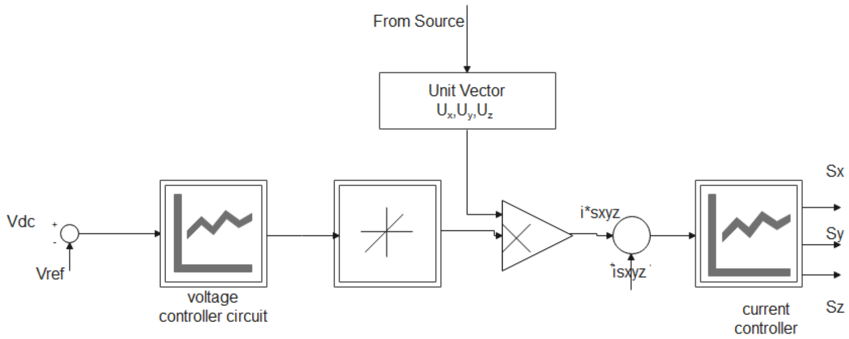


Figure 8. Controlling strategy of Proposed PV-STATCOM

The current hysteresis control approach is used for the inverter voltage control. The detected current is compared to the hysteresis levels and the comparison output is utilized to manage the switching sequence in the hysteresis control method **(Patnaik, N., & Panda, A. K. .2014)**. The hysteresis current controller is capable of handling switching signal from gate pulses that can be implemented in MATLAB/SIMULINK as shown in Figure.9.

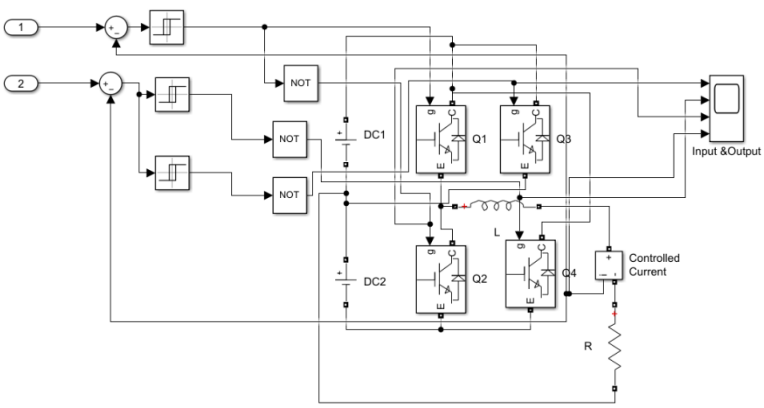


Figure 9. Simulink Diagram for Hysteresis Current Controller

The modulation signal plays a major role in the hysteresis controlling due to the movement of positive and negative switches randomly that is connected in the shunt filter. The switching process is represented in the form of S_x and S_y,S_z for three phases respectively. Table 1 represents the switching and error factors of three phases

Table 1. Switching Status of Three Phases

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	$i_{sy} > (i_{sy}^{*} - HB) \rightarrow S_y$
0	$i_{sy} < (i_{sy}^{*} - HB) \rightarrow S_y$
$S_z\ Status\ for\ phase - Z$	
1	$i_{sz} > (i_{sz}^{*} - HB) \rightarrow S_z$
0	$i_{\mathrm{se}} < (i_{sz}^{*} - HB) \rightarrow S_z$

This switching status decides the proposed PV-STATCOM stability with the Hysteresis Band (HB). i_{sx}, i_{sy}, i_{sz} represents the actual source current, $i_{sx}^{*}, i_{sy}^{*}, i_{sz}^{*}$ represents the reference currents. It is needed to enable VSC-based shunt APF operations to inject the appropriate real and reactive power to attenuate current (current distortions) harmonics and voltage dip into the grid-based integral test model to fulfil the Low Voltage Ride Through (LVRT) standards. An instantaneous reactive power theory is used to provide gate currents for starting a photovoltaic STATCOM operation to increase distribution system power quality.

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 values of grid current. So the average power quality can be calculated by

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

In the proposed grid connection model, the PV-STATCOM injects enough reactive power to enhance power quality which is analyzed and demonstrated in the experimental results.

4. Experimental Analysis of PV-STATCOM with APF

The proposed test model and control algorithm is verified with help of the MATLAB / Simulink platform. The operating behaviour of the test model under the presence of shunt connected PV-STATCOM is simulated. Three single-phase ideal sinusoidal AC voltage sources and induction generator is supplying power to non-linear RL load, the PV based active filter is connected at PCC through a three-phase circuit breaker as indicated. The DC capacitor is connected to the DC side of PV-STATCOM and the inductor is connected to the AC side. The electronic valves of IGBTs of PV-STATCOM are activated by the reference current signals generated by the proposed control algorithm. The simulation blocks of the proposed control theory are represented as depicted in Figure 10

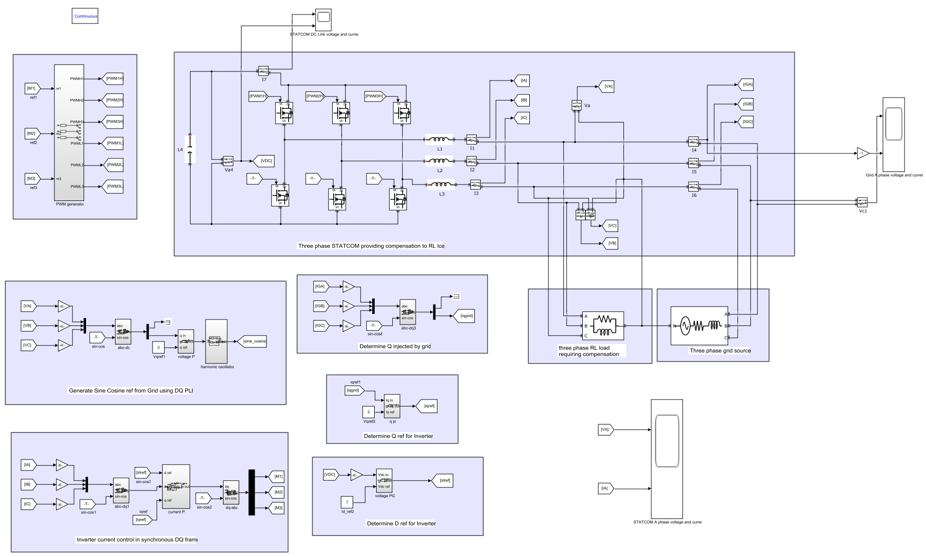


Figure 10. Proposed PV-STATCOMwith APF Simulink Diagram

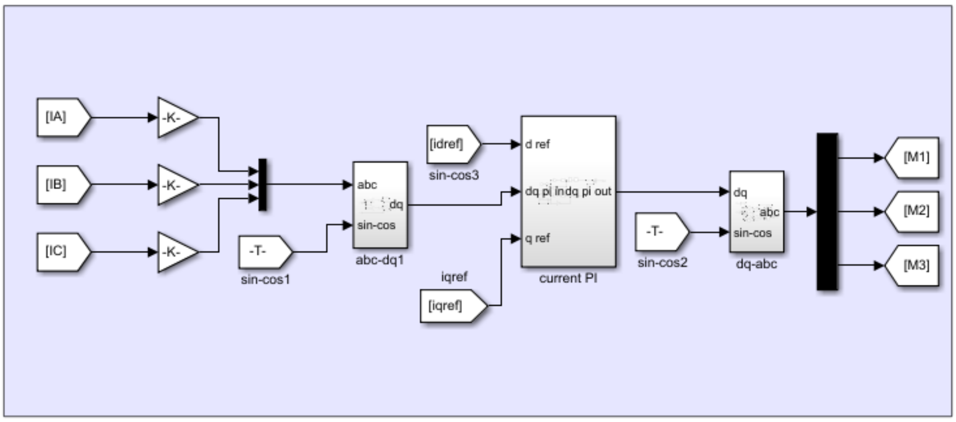


Figure11. Reference Current Generator Simulink Block

The MATLAB/ Simulink schematic of the reference current generator for the VSC-based static compensation (Shunt APF) start-up to enhance power quality issues in the proposed distribution network is illustrated in Figure 11.Table 2 indicates the input parameters to tune the proposed PV-STATCOM unit with the fixed voltage level.

Table 2.Parameters of Proposed work

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

A MATLAB simulation results are used to study the dynamics of a solar farm as the shunt active filter for the suggested test model and control algorithm. The findings for the MATLAB simulation show the twin functionalities of PV-based shunt compensators in the day and nighttime applications as real-life energy injector and reactive power offset for magnified power quality in network integrated systems. The values 2.5 and 1,25 respectively for the production of gate currents and the switching of signal for the electronic valves for switching shunt APF are considered for efficient analysis.The shunt coupled PV based STATCOM may operate from 0.1 sec to0.2 sec across the full MATLAB simulation duration (0.25 sec). The PV-based STATCOM injected in the current phase and magnitude as shown in Figure 12 to attenuate the current harmonics (current distortions) created by the load distortion of diode rectifiers.

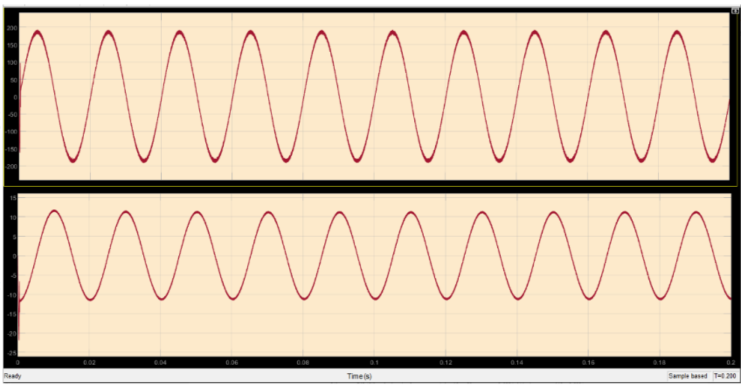


Figure12. The injected current in the Proposed PV-STATCOM with APF

The performance of the proposed PV-STATCOM depends upon the switches. When Switch is turned ON from 0.1 to 0.2 sec then it attains harmonic condition without altering the load value. When the switch is turned OFF after 0.2 sec the source current is contaminated with the harmonic conditions. The overall compensation of active as well as reactive power of the proposed PV-STATCOM based APF is shown in Figure 13.

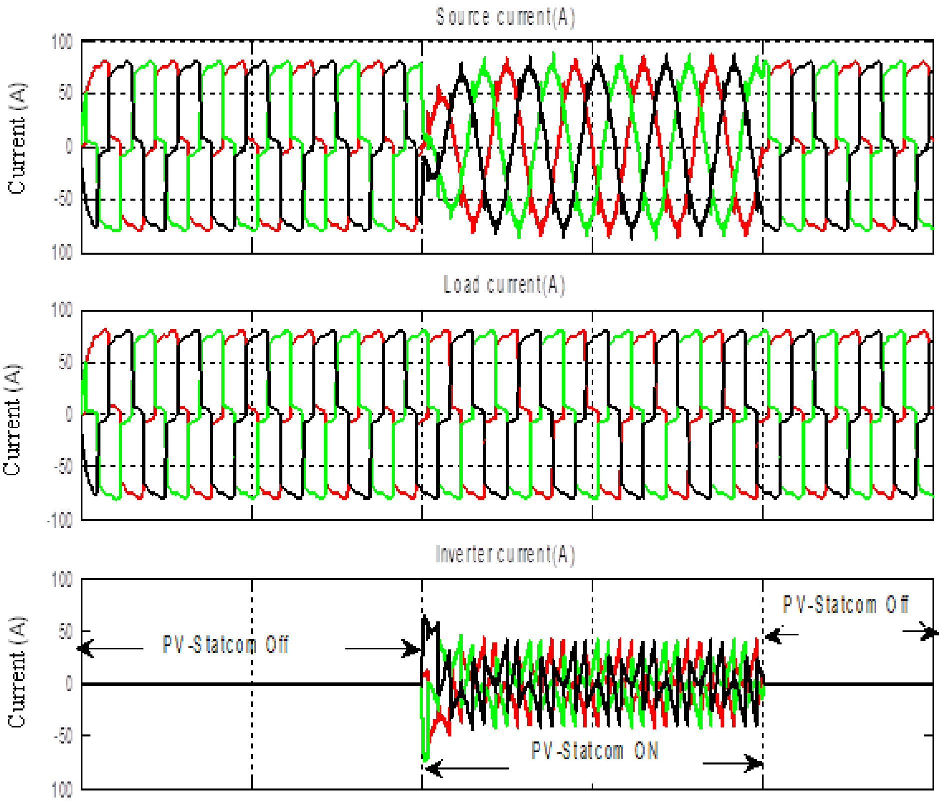


Figure 13. PV-STATCOM with Source current, Load current and Inverter Current

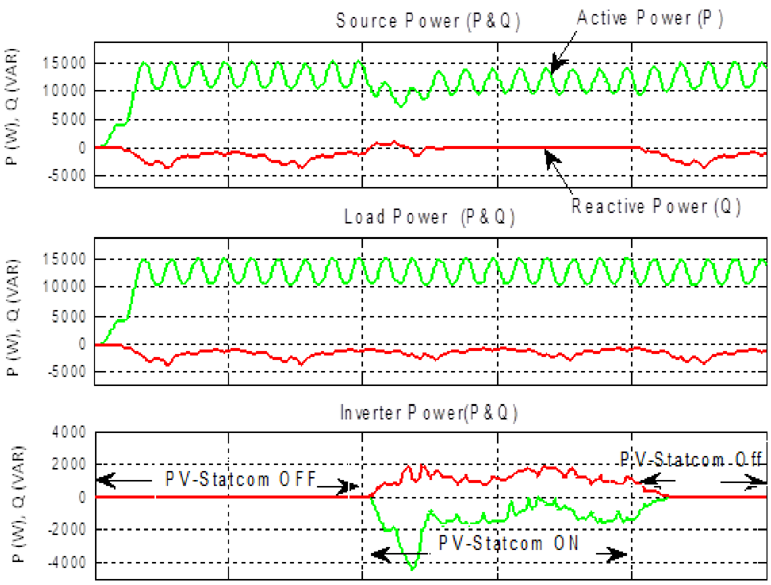


Figure 14. Power of PV-STATCOM with Source, Load and Inverter Power

Figure 15 Indicates a consistent value of the DC-Bus voltage in the grid integrated systems to decrease the power quality problems.

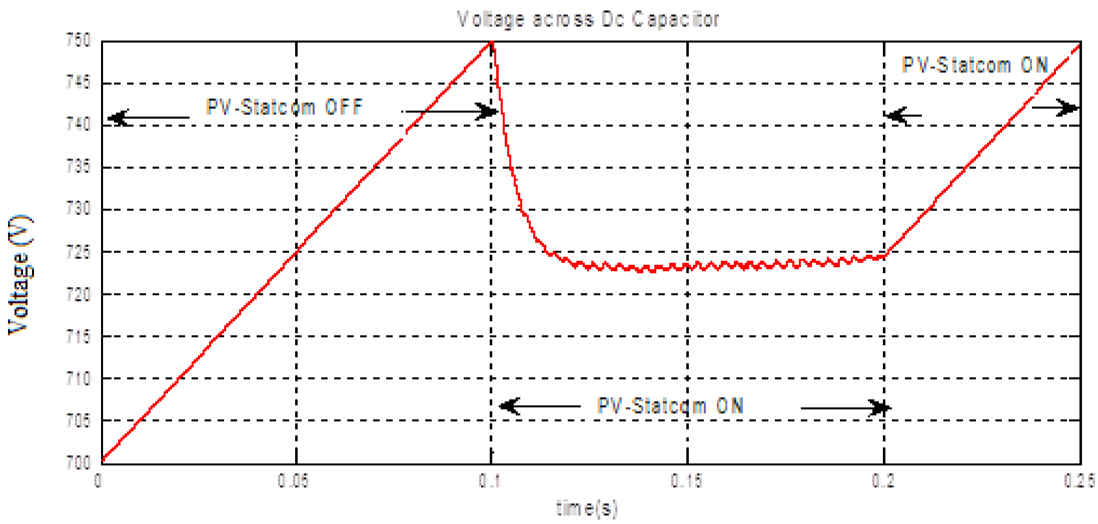


Figure 15. Average Voltage of DC bus capacitor

Figure 16 demonstrate the VAR power loss and active power injection analysis by the Active Power Filter gives the increment of power quality in the grid faults. Grid faults are one of the major grid sources which lie between the sample rate of 0.2 to 0.1 sec that decrease the power from 41.4kW to 18.78kW. It also demonstrates the real and active power during the Pv-STATCOM Shunt APF normal mode. When the grid is in the fault condition, the reactive power of 17.77 kVAR (which is more than typical reactive power) is injected by the shunt connected compensator to alleviate the voltage sags and harmonic tunnels.

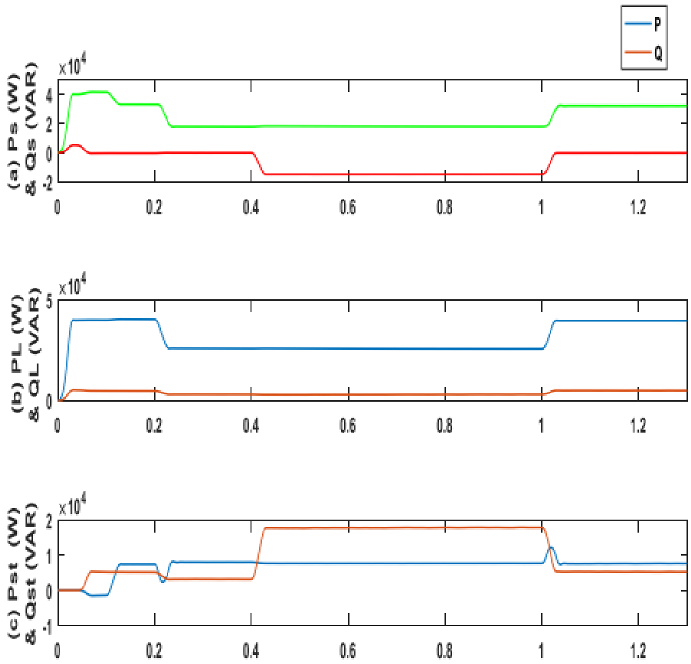


Figure 16. Power Injection in PV-STATCOM, Load and Source Powers

5. Conclusion

This proposed work concludes the effective and valuable performance analysis of PV-STATCOM in the solar farm as a static synchronous compensator unit which reduces the disturbances in the power quality factors. The injection and absorption mode of shunt APF filters is explained and the difficulty in the distribution system is carried out with the adjustment of Grid synchronization factors. The major role of VSC in the power quality enhancement carried out in the simulation work using MATLAB software. The Low Voltage Ride Through capability is handled to reduce the harmonic and voltage sag difference in the integrated grid system. By maintaining the DC bus capacitor at a constant state, the voltage comes under the control at PCC with the reduction in the harmonic distortion. Thus, the advancement in the topologies provides a better outlook to maximize the usage of the proposed grid system in various applications.

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