A Dual Operation of PV-Statcom as Active Power Filter and Active Power Injector in Grid Tie Wind-PV System

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Abstract- This paper presents the concept of utilization of PV-solar farm as static synchronous compensator (PV-Statcom) to mitigate power quality issues like poor power factor, voltage variations and current harmonics in power systems. The proposed system includes non linear load, wind generator and solar PV- Statcom. The solar PV – Statcom compensating harmonics produced by local load, supplies reactive power required by the wind genrator in addition to active power injection is demonstrated in this reseach work. The PV-Statcom control pattern for enhancing quality of power is simulated in MATLAB / Simulink in simpower system block set.

Keywords- Power Factor correction;harmonics; Solar PV; PV-Statcom; Wind Energy; Power Quality improvement; Grid intigrated Wind-PV system; Reactive power management.

1. Introduction

Exploitation of Green Energy Resources like wind and solar energy are the only way to reach the capital electric power demand, because these energy sources are the cleanest and renewable in nature. Also the Distribution Generation (DG) system (Wind and Solar) provides a better voltage regulation [1]. Modern power converters embloyed in sloar and wind are capable of injecting or absorbing an variable reactive power into the grid integrated system for improving quality of power [2-9]. The distribution network consists almost all reactive components, which always absorbs the reactive power. The integration of distributed generators (DG) like PV Solar plant and Wind farm into the distribution network leads many advantages such as reduction in losses, reaching local electric power demand relief of transmission congestion [7-9], [11-14] . These distribution generators can also supply the reactive power to the loads, but earlier IEEE 1547 didn't permit to inject the reactive power into the grid system. Due to the fast advancement in the technology the earlier version IEEE 1547 was revised as IEEE 1547.8, which is expected to permit the injection of reactive power into the grid by distribution generation system for the enhancement of power quality[15]. In this paper the PV Solar plant acting as Hysteresis current control based static synchronous compensator (PV- Statcom) to mitigate the power quality issues like poor power factor, current harmonics etc. And also for injection and absorption of active and reactive power into the grid integrated Wind-PV system for power quality improvement during Day and Night time applications.

The present article reminds as follows, The sections II, III, IV, V and section VI represents power qualıty ıssues and ıts consequences, proposed system for power quality improvement, control scheme, results analysis and conclusion respectively.

2. Power Qualıty Issues and Its Consequences

The term *Power Quality* is one of the most prolific buzz words in the power concept. The utilization of non-linear loads or sensitive loads have been increasing exponentially which may raises power quality issues by drawing non-sinusoidal currents in the power systems. The major power quality issues are poor power factor, voltage variations, current harmonics, reactive power demand, voltage flickering, voltage interruption, power frequency variations and etc.

The power quality problems like flickers, transients, voltage sag or swell, harmonics and interharmonics may causes over heating, saturation of transformers, overloading, data loss, mall-operation of equipments like logic controller and power meters. Particularly on conductors the harmonic causes skin effect, proximity effect and overheating of the conductor which may effect on the active performance and life span of the equipment.

3. Proposed System for Power Quality Improvement

Mitigation of power quality concerns like current harmonics, voltage variations, low power factor etc. and also the active power (P) and reactive power (Q) control or management can be studied in the proposed grid integrated Wind-PV system as shown in "Fig.1". The Photovoltaic solar plant provides the active power during day time and it is acting as power quality compensator during night time and also during less power generation time.

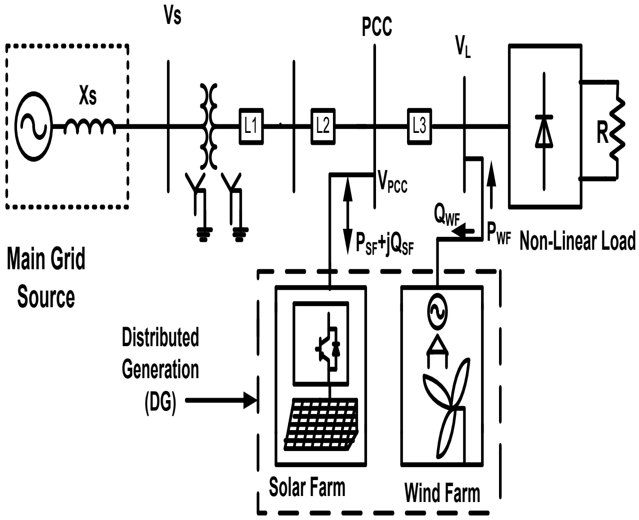

Fig.1. Grid Integrated proposed system: power Quality

The active power generated by wind farm is varied due to variations in the wind speed [1], which absorb the reactive power so that the induction generator terminal voltage will significantly affect. The solar plant acting as PV-Stacom in the grid tie system will compensate the reactive power (VAr) and injects the active power (watt) to balance the load. By Maintaining the DC link capacitor voltage constant in the proposed system the harmonics mitigation and also for power factor correction can be achieved [4].

The complete dual operation of PV Solar plant (PV-Statcom) as reactive power compensator and active power injector can be clearly analyzed with the help of the proposed system. The "Fig.2" describes the complete 24 hours working process of grid integrated proposed system to intensify the quality in electric power.

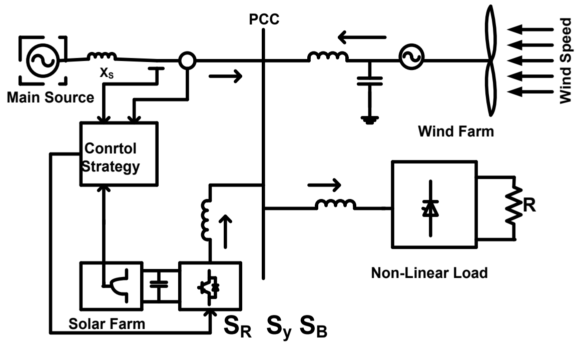

Fig.2. Complete operational scheme of proposed system.

4. Control Scheme

The control algorithm called "Bang-Bang Current Controller" is utilized to generate the switching signals for the active performance of PV Solar plant as PV-STATCOM with help of the hysteresis current control technique [4, 10] for power quality improvement in grid tie Wind-PV system. The reference current signal can be generated for controller is as shown in "Fig.3". The reference currents are extracted with the assist of unit vector templates as [4].

$$i_{sr}^{*} = I.u_{sr} \quad (1)$$

$$i_{sy}^{*} = I.u_{sy} \quad (2)$$

$$i_{sb}^{*} = I.u_{sb} \quad (3)$$

Where u_{sr}, u_{sy} and u_{sb} are three phase unit vector templates derived from sampled peak voltage and respective phase voltages as shown below.

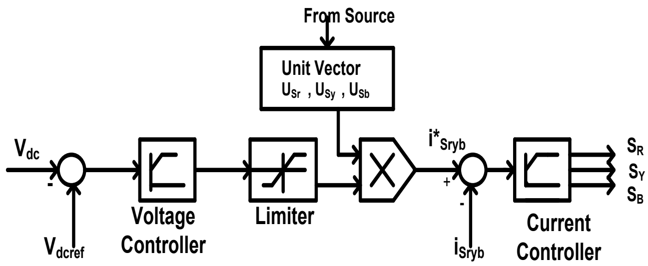

Fig.3. Reference current signal generation for controller.

$$u_{sr} = \frac{V_{sr}}{V_{sm}}, u_{sy} = \frac{V_{sy}}{V_{sm}}, u_{sb} = \frac{V_{sb}}{V_{sm}}. \quad (4)$$

Where V_{sm} is known as sampled peak voltage and it is computed as

$$V_{sm} = \{\frac{2}{3}(V_{sr}^2 + V_{sy}^2 + V_{sb}^2)\}^{\frac{1}{2}} \quad (5)$$

The ON/OFF switching signals for IGBT based PV-Statcom can be acquired from the proposed controller [4]. The S_R is the switching function for phase ***"r"*** is depicted as

$$i_{sr} < (i_{sr}^{*} - HB) \rightarrow S_R = 0 \qquad (6)$$

Here ***HB*** is the hysteresis current band. Similarly S_Y and S_B are the switching functions for phase ***"y"*** and phase ***"b"*** respectively. "Table-1" represents the proposed system parameters and their ratings.

Table 1. System Parameters description

S.No	Ratings	Parameters
1	3-phase, 415 V, 50 Hz	Source Voltage
2	0.05 mH	Line inductance
3	0.65 mH	Shunt inductance
4	Power: 25kw	Distorting Load
5	3.35 kVA, 415 V, 50 Hz, N=1500 rpm, P=4, Rr=20ohm, Lr=0.06H	Wind Generator
6	Dc link Voltage = 800V, C=10 mF, Switching frequency = 2kHz	Inverter Parameters
7	3.75 kVA	Solar plant
8	Collector Voltage=1200V, I=50A, Gate Voltage=20V	IGBT Ratings

5. Result Analysis

The MATLAB / Simulation results are studied for the proposed grid integrated system in which Photovoltaic (PV) Solar plant acting as static synchronous compensator (PV-Statcom) to nullify the power quality problems. The simulation results also represent the dual operation of PV-Statcom as active power injector and reactive power compensator for an enhancement of power quality during whole day and night time applications. The harmonics generated by the non-linear load can be completely cancelled out by PV-Statcom injected currents (Fig 4). The source current now having desired magnitude and phase angle as shown in "Fig.5". For the measurement of performance of grid tie Wind-PV system the PV-Statcom is switched ON from 0.1s to 0.2s, so that with help of compensation action the current harmonics are completely cancelled out. From "fig.5" it is clearly observed that due to lack of compensation action before 0.1s and after 0.2s the power is polluted due to harmonic contents.

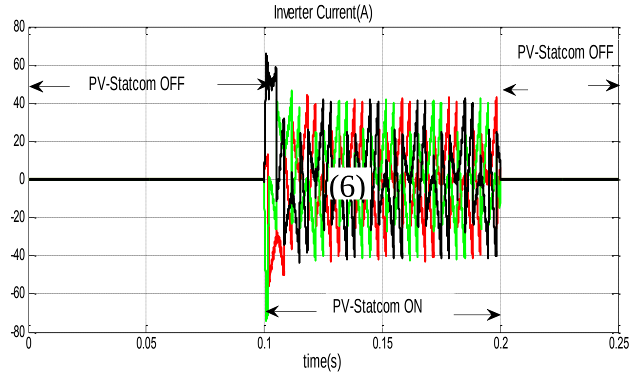

Fig.4. PV-Statcom Injected Current for Quality of Power.

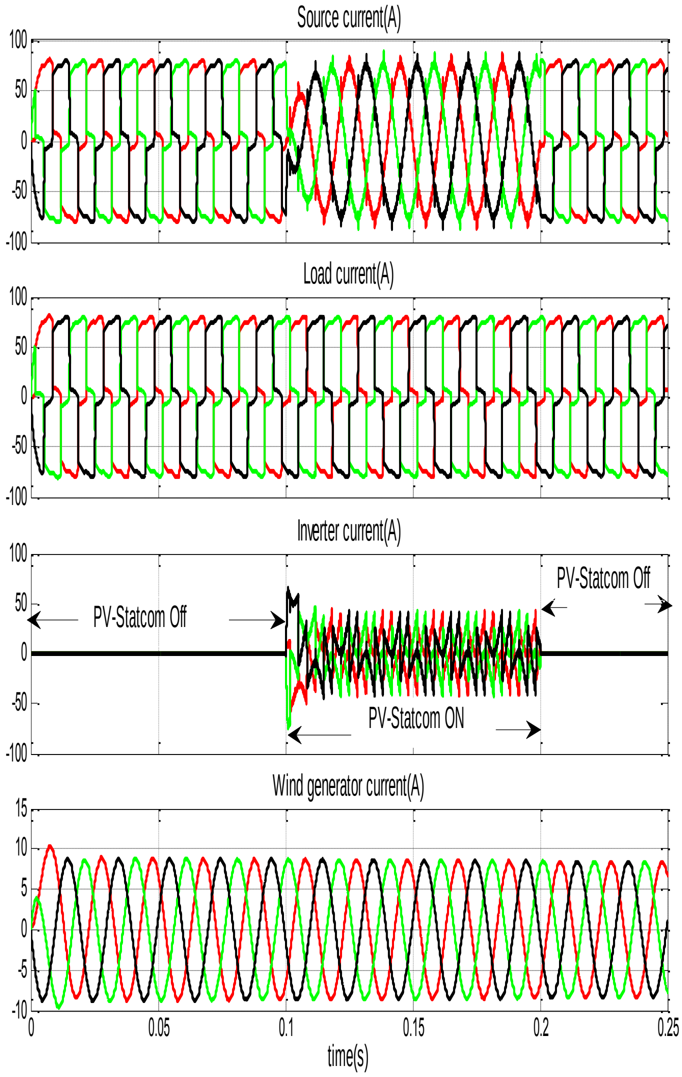

Fig-5. (i) Source Current (ii) Load Current (iii) Inverter injected Current (iv) Wind Generator Current (A).

The "Figure.6" shows the reactive power compensation and active power injection by PV-statcom in variable wind speed grid integrated Wind-PV system. It is clearly observed that before 0.1s and after 0.2s the wind speed is less compared to nominal wind speed 12 m/s as shown in Fig.7, which indicates the reactive power demand in the proposed system. The reactive power demand which is more than 4KVAr is compensated to required level of source and load by PV-statcom from 0.1s to 0.2 s as shown in "Fig.6 (a) and Fig.6 (b)". By observing Fig.6 (a) from 0.1s to 0.2s both main source and wind generator are supplying less than 15KW to connected load, to make the load power constant the required active power is injected by PV-Statcom as shown in Fig.6 (b).

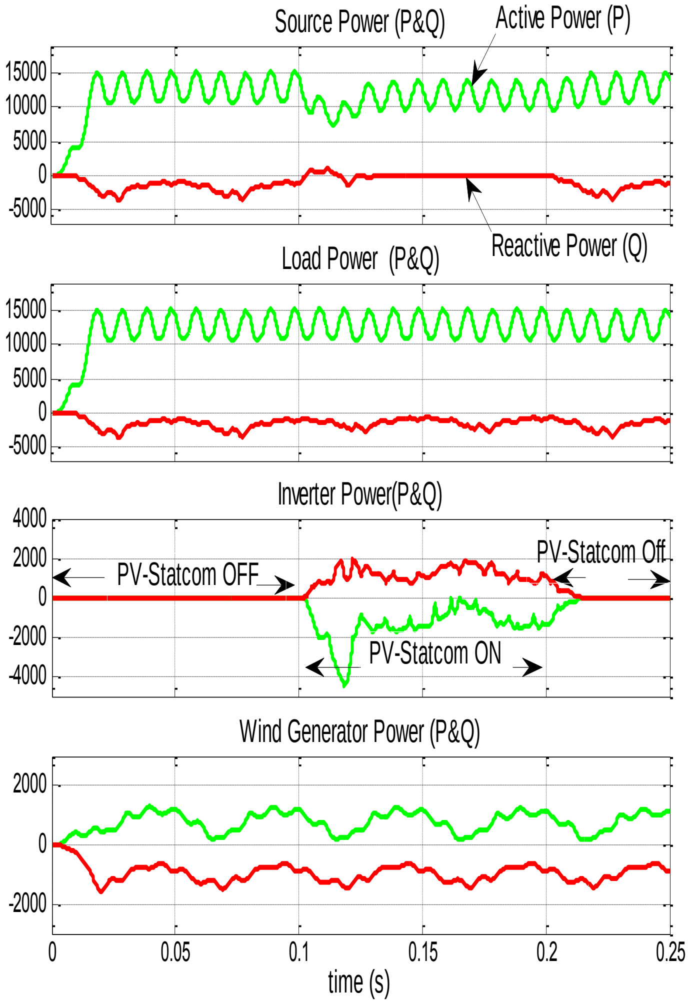

Fig.6.(a) Source Power (P&Q) (b) Load Power (c) PV-Statcom injected Power (d) Wind Generator Power

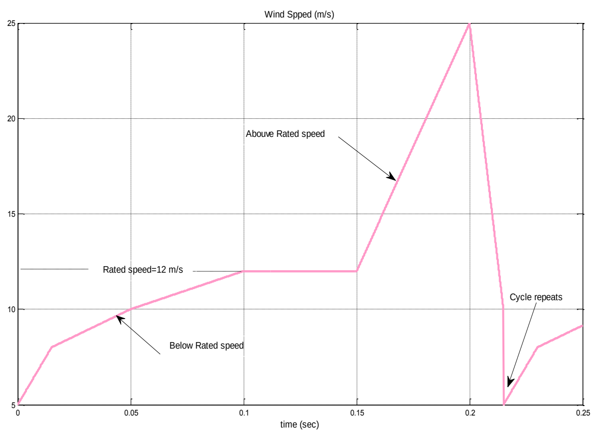

Fig.7. Variable ***Wind Speed*** in proposed system.

The "Fig.8" represents the PV-Statcom output voltage at Gauge point (PCC) for power quality improvement.

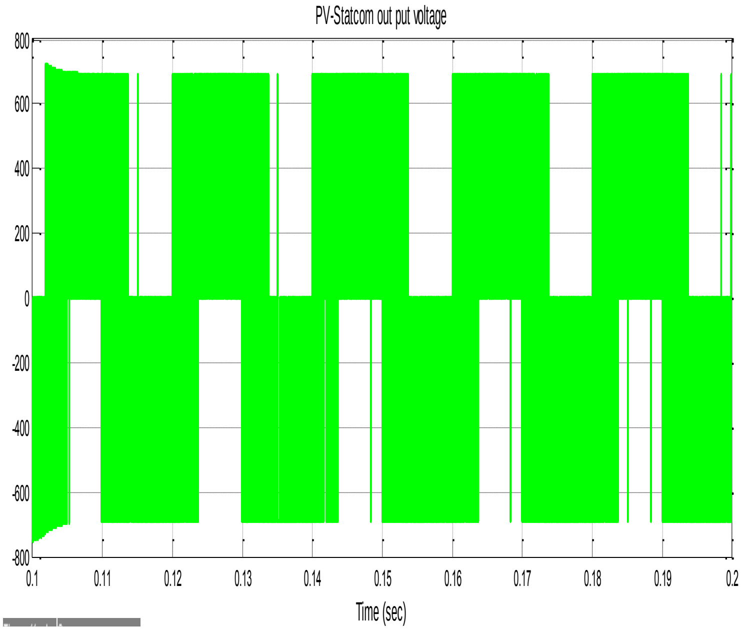

Fig.8. PV-STATCOM output Voltage at gauge point

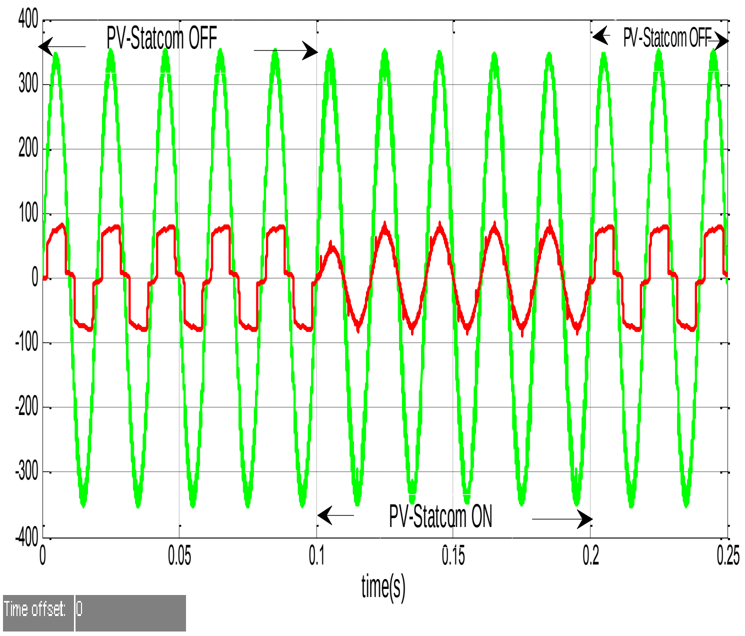

Fig.9.Power Quality improvement at PCC. (Unity PF)

The "Fig.9" describes the dynamic operation of PV Solar plant as static synchronous compensator for power quality improvement. It is clearly observed that the source voltage and source current have the desired phase relationship with the help of active compensation action of PV-Statcom from 0.1sec to 0.2sec (PV-STATCOM On time), which indicates the improvement in power factor and quality of wave form (unity PF).

6. Conclusion

This paper represents the dual operation of PV solar plant (PV-Statcom) as active power injector and reactive power compensator for the enhancement of quality of power in the variable wind speed grid tie Wind-PV system. It also reminds power quality issues and its consequences and need for reactive power compensation. With active performance of PV Solar farm as PV-Statcom the current harmonics are completely nullified and power factor is improved. The active power injection and reactive power compensation results are simulated in MATLAB/Simulink in simpower system block set with the help of the proposed control scheme to improve the utilization factor of the system and for power quality improvement in grid integrated power system.

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