Reactive Power Compensation in Grid Connected Photovoltaic System Using Static Synchronous Compensator

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***Abstract*— Generally, when reactive power is considered, it is primarily focused upon the disadvantages and losses that it brings. Those are mainly active power losses, voltage losses, reduced power quality, deterioration of cos φ, etc. However, reactive power is an integral part in electrical grid and has its contributions. Reactive power is an essential factor in operation of electric motors as rotating magnetic fields are dependent on reactive power. Utilization of a photovoltaic (PV) system with static synchronous compensator (STATCOM) is a modern and efficient method of regulating active and reactive powers. In this paper is presented compensation of reactive power by utilizing a PV system with STATCOM connected to the grid. A simulation model in MATLAB/Simulink environment is also presented.**

Keywords— PV system, reactive power, STATCOM

I. Introduction

Renewable energy sources (RES) are undoubtedly presenting an alternative method of producing electrical energy with no contamination as photovoltaic (PV) and wind systems are widely spread throughout the globe. However, as they are primarily consisting of electronic elements, they introduce some challenges to already existing grids, namely harmonics, reduced power quality, etc. Apart from said disadvantages, there is one significant application which can be often put on background. That is compensation of reactive power and voltage regulation by PV systems connected to the grid [1] – [8].

Reactive power which is usually considered for sinusoidal regimes of grid's operation. However, many loads with non – linear V-A characteristics, low power factor (PF), etc. cause the operation to become non – sinusoidal. In non – sinusoidal regimes reactive power cannot be defined unambiguously. Thus, compensating reactive power by means of a PV system connected to the grid is widely spread. In addition, employing a static synchronous compensator (STATCOM) into the schematic becomes even more attractive method.

A STATCOM is a static device based on utilizing an inverter as a voltage source (VSI or VSC) [2], [3], [7]. Typically, they are consisting of MOSFET's or IGBT's. Output voltages and currents of a STATCOM are sinusoidal and almost identical to the ones of respective grid [3]. STATCOM's are part of parallel connected type compensation devices to the point of common coupling (PCC) [1], [2]. Unlike static VAR compensators (SVC), STATCOM's are able to supply or to consume the grid with reactive energy to improve power quality and voltage stability. A STATCOM will supply the grid whenever output voltage of the inverter becomes greater than the grid's voltage. Respectively, it will consume reactive energy from the grid whenever inverter's output voltage has lower value than grid's. Furthermore, STATCOM's are able to be used for PF correction, filtering of higher harmonics, etc. [2].

II. Simulation model

A simulation model of a reactive power compensation in a grid connected PV system using STATCOM has been developed in MATLAB/Simulink environment. The model is shown on Fig. 1. It is constructed from the following components – PV array, inverter, grid, load, transformation's subsystem, reference voltage Vref subsystem, pulse – width modulation (PWM) subsystem and measurements' subsystem. PV array's parameters are shown in Table I. Operation of PV array is considered with constant temperature at 25 °C and three irradiances, namely 1000, 500 and 100 W/m^2. The plots for volt – ampere (VA) characteristics and voltage – power characteristics are shown on Fig. 2. Measurements of PV array's output are shown at diagrams on Fig. 3 and Fig. 4.

Grid is modelled with line voltage of 400 VAC and frequency of 50 Hz with source resistance of 1μΩ and source inductance of 1μH. Load is considered as star connected (Y connected) active-inductive (RL) with the following parameters – phase to phase voltage Vrms = 400 V, nominal frequency fn = 50 Hz, active power of 100 kW and inductive power of 1 kVAr.

Transformations' subsystem is shown on Fig. 5. It includes transformations of voltages and currents from stationary frame to their respective d-q counterparts, following p-q theory.

Following transformations' subsystem is reference voltage Vref subsystem and PWM's subsystem which are shown on Fig. 6 and Fig. 7 respectively. Vref is further used to perform PWM in PWM's subsystem. PWM's subsystem employs conventional method of obtaining gate signals by comparing Vref to a triangular voltage with amplitude between 1 and -1 and with frequency of 20 kHz.

Inverter's subsystem is shown on Fig. 8. A three – phase inverter is considered with insulated gate bipolar transistors (IGBT's).

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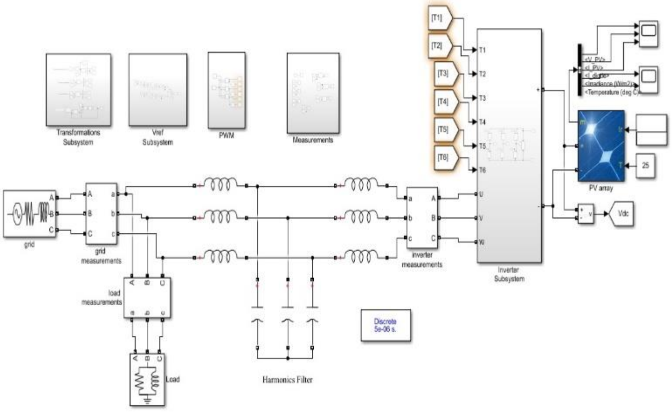

Fig. 1. Simulation model of grid connected PV system using STATCOM for reactive power compensation

TABLE I. Modelled PV array's parameters

№	PV array		
	Parameter and denotation	***Value***	***Units***
1	Parallel strings	40	-
2	Series-connected modules pre string	10	-
3	Module: 1Soltech 1STH-215-P		-
4	Maximum power	213.15	W
5	Open circuit voltage V_{oc}	36.3	V
6	Voltage at maximum power point V_{mp}	29	V
7	Temperature coefficient of V_{oc}	-0.36099	%/ ºC
8	Cell per module	60	
9	Short-circuit current I_{sc}	7.84	A
10	Current at maximum power point I_{mp}	7.35	A
11	Temperature coefficient of I_{sc}	0.102	%/ ºC
12	Light-generated current IL	7.8649	A
13	Diode saturation current I0	$2.92*10^{-10}$	A
14	Diode ideality factor	0.98117	-
15	Shunt resistance Rsh	313.3991	Ω
16	Series resistance Rs	0.39383	Ω

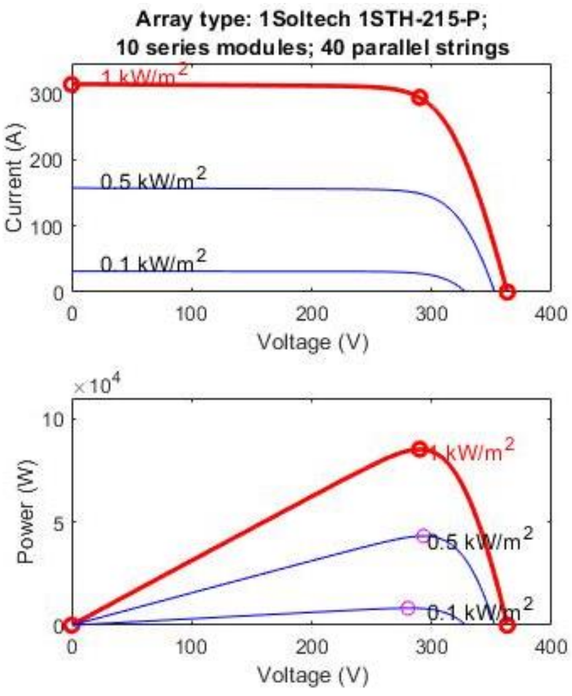

Fig. 2. PV array's V-A and V-P characteristics

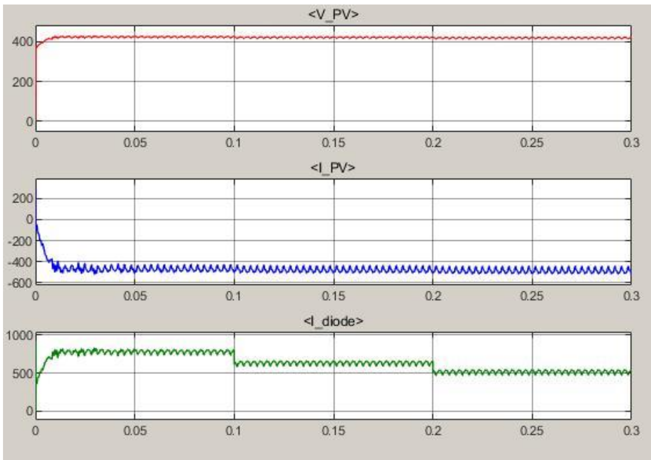

Fig. 3. PV array's voltage, current and diode current

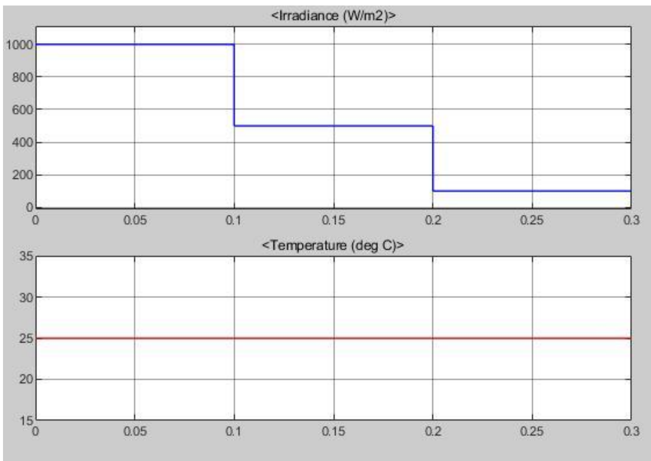

Fig. 4. Modelled irradiance and temperature

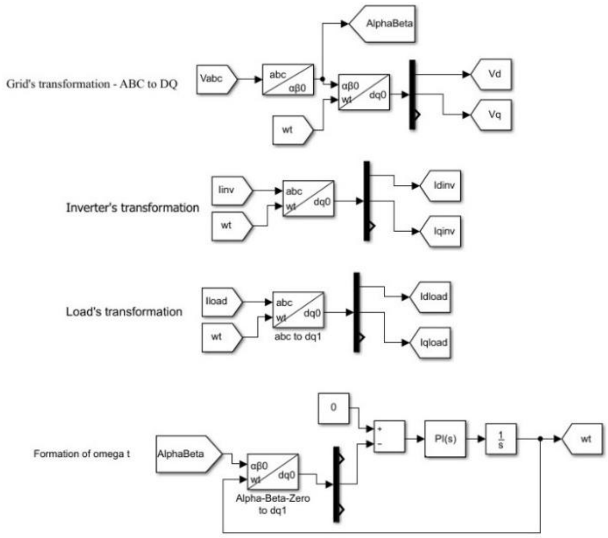

Fig. 5. Transformation's subsystem

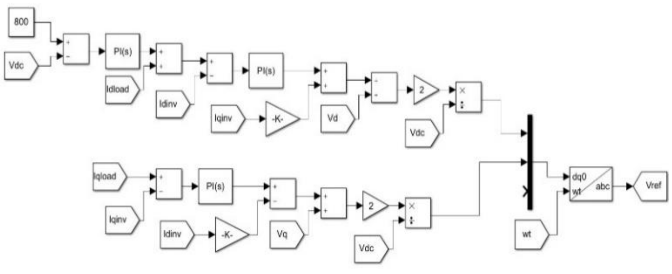

Fig. 6. Reference voltage subsystem

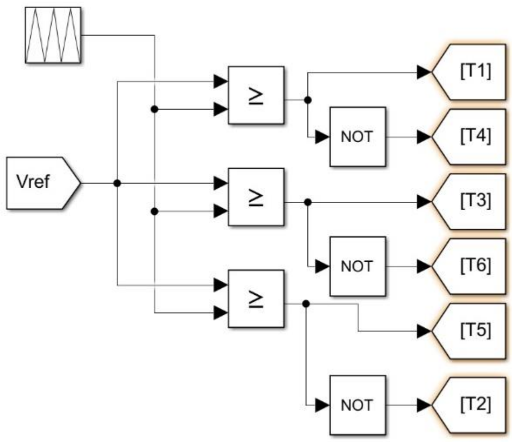

Fig. 7. PWM formation

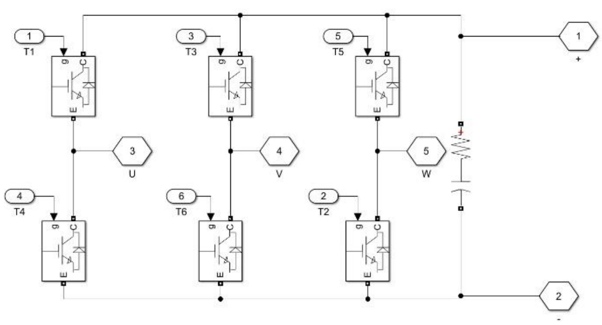

Fig. 8. Modelled inverter

III. Simulation results

Simulation results are considered in measurements subsystem. Measured quantities in consideration are DC voltage, grid's voltage and current (Vabc and Iabc), grid's active and reactive powers, inverter's voltage and current (Vinv, Iinv), inverter's active and reactive powers, load's voltage and current (Vload, Iload), load's active and reactive powers and a plot comparing inverter's current to load's current for easier comparison. The measurements of said quantities are displayed on Fig. 9 to Fig. 16.

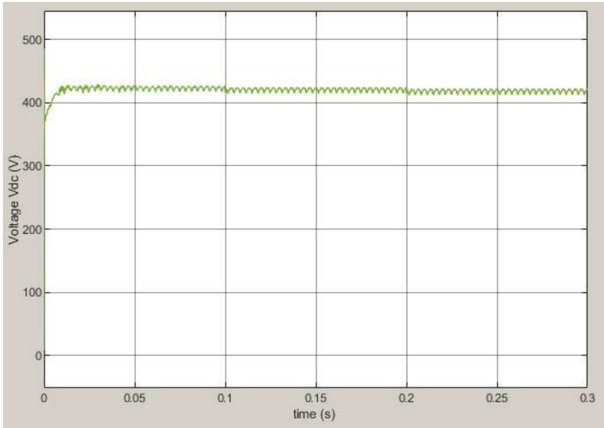

Fig. 9. DC voltage Vdc

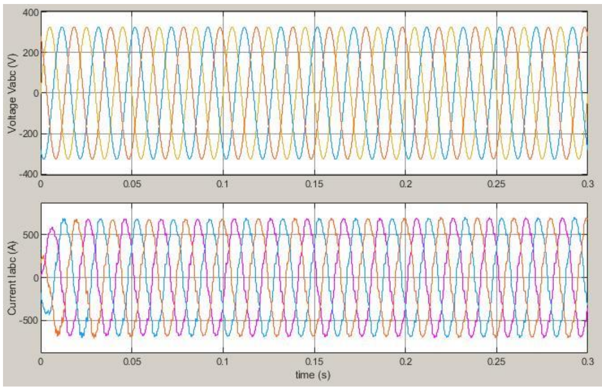

Fig. 10. Grid's three – phase voltage and current

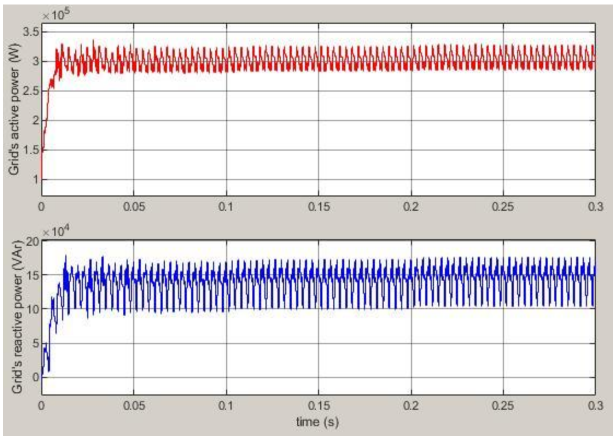

Fig. 11. Grid's active and reactive power

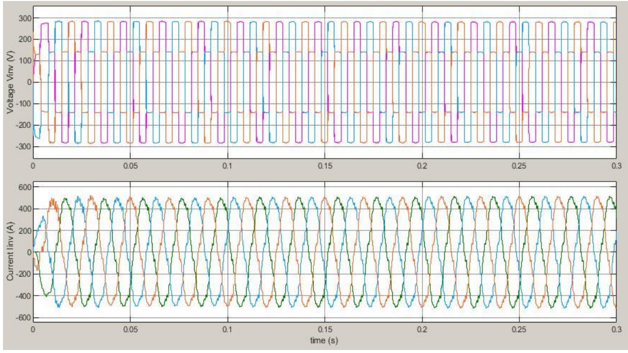

Fig. 12. Inverter's three – phase AC voltage and current

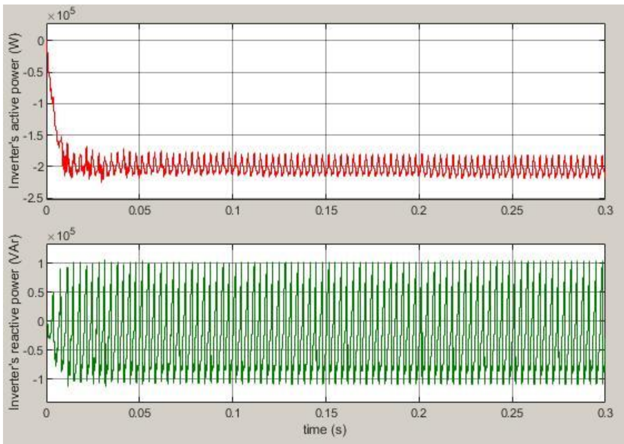

Fig. 13. Inverter's active and reactive powers

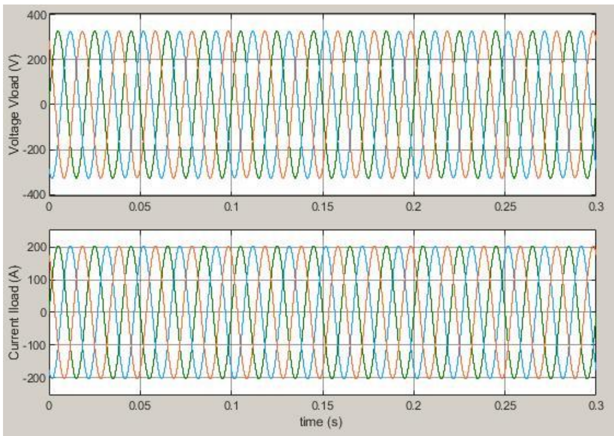

Fig. 14. Load's voltage and current

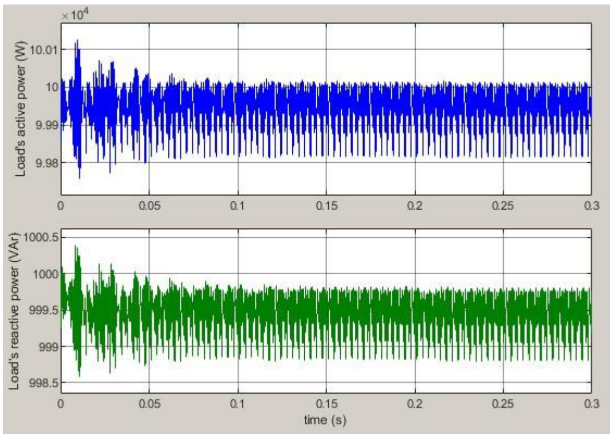

Fig. 15. Load's active and reactive powers

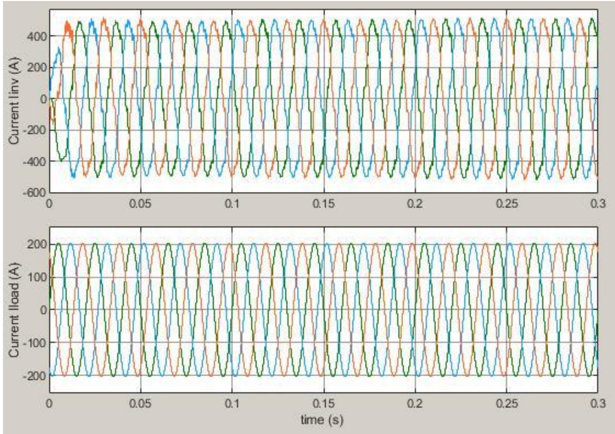

Fig. 16. Comparison between Iinv and Iload

IV. CONCLUSION

A simulation model of a PV system connected to a grid with utilization of STATCOM for reactive power compensation is presented in this paper. PV systems and STATCOM's are a modern way to control and compensate reactive energy in a grid.

Based on simulation results it can be observed that load's three – phase voltage and current have satisfactory sinusoidal waveforms. Inverter's voltage is observed to have a waveform closer to rectangular which is as expected of voltage source inverters. Furthermore, inverter's current has a slightly distorted waveform due to harmonics, but its waveform is significantly close to that of Iload. In the considered case inverter's active power has negative values which corresponds to that the PV system is supplying the grid. On the DC side of the inverter, the plot of Vdc exhibits that DC voltage is following its reference fairly closely. As a general conclusion it can be said that even with the simplicity of the considered simulation model the purpose of the paper has been achieved and obtained simulation results are satisfactory.

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