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Power Quality Improvement of Three Phase Single Stage and dual Stage Grid tied PV System with UPQC

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Abstract-A simplified inverter topology using switching pulse Feed Forward Control Loop (FFCL) for grid integration of photovoltaic (PV) system is proposed. A Dual-stage three-phase grid-connected photovoltaic (PV) system operating with a dual compensating strategy has been proposed for smooth operation of PV system for various modes of operation. Efficiency comparison between conventional Voltage Source Converter (VSC) and proposed inverter topology for PV system configurations is discussed. Potential improvement using the proposed adaptive configuration is sited. The system is designed in MATLAB simulink to study its performance when connected to the grid.

Keywords: Feed Forward Control Loop (FFCL), Renewable Energy Sources (RES), Voltage Source Converter (VSC), Grid Integration, Total Harmonic Distortion (THD), Current Source Inverter (CSI).

I. INTRODUCTION

The production of electrical energy from renewable energy sources (RES) has grown a lot in recent decades, mainly due to increased demand for electricity, as well as the global intensive efforts to overcome the harmful environmental impacts caused by pollutant energy sources, such as oil, coal, natural gas, and others. Distributed generation (DG) systems based on RES have contributed to find new modern solutions for planning conventional power systems [1]. Inserted in this scenario, solar energy has emerged as a promising RES due to its abundance across the earth's surface. In particular, by means of photovoltaic (PV) cells, PV panels have been properly designed to produce energy by converting sunlight into electricity. Normally, grid-connected PV systems can be deployed by means of single-stage (S-S) or double-stage (D-S) power conversion [2], [3]. S-S PV systems are usually composed of only a grid-tied inverter (dc/ac converter) [4]–[9]. In this case, the PV array is directly connected to the dc-bus of the grid-tied inverter. On the other hand, in D-S PV systems, an additional dc/dc converter is placed between the PV array and the inverter [10]–[12]. In grid-connected photovoltaic systems, a key consideration in the design and operation of inverters is how to achieve high efficiency with power output for various modes of operation.

The requirements for inverter connection include: maximum power point, high efficiency, control power injected into the grid, and low total harmonic distortion of the currents injected into the grid. The performance of the inverters connected to the grid depends largely on the control strategy applied. In the proposed work FFCL type topology has been discussed as shown in fig-1.

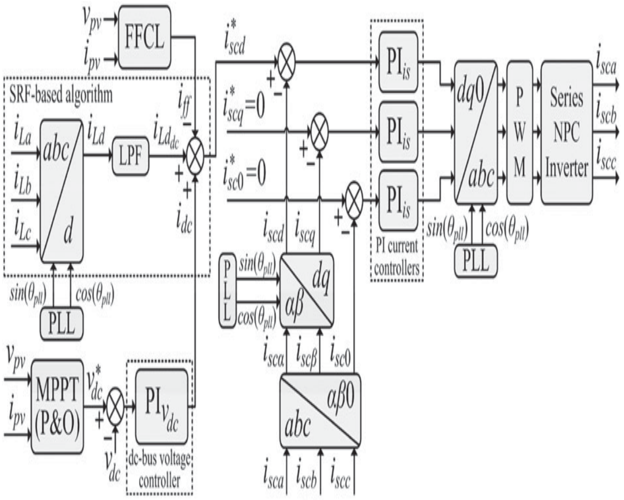

Fig-1 Feed Forward Control Loop

The FFCL contributes to speed up computation of the input current references during the occurrence of fast variations in solar radiation. As a consequence, possible disturbances in the dc-bus, such as voltage oscillations and voltage overshoot/undershoot are reduced.

II. DUAL STAGE GRID TIED PV SYSTEM

In this Dual Stage Grid tied PV SYSTEM, the complete power circuit scheme of the proposed Dual stage grid tied system comprises of three phase four wire PV system. To obtain desired DC voltage the generated output of the PV panel is boost using DC-DC boost converter. This configuration is then connected to the DC to AC converter and their respective passive filtering elements, and three single-phase coupling transformers employed to connect the series inverter to the grid, as shown in Fig. 1.

The distributed generation source, without storage, is composed of a PV array, which is formed by a single string with thirty six series-connected PV panels, making possible the direct connection between the PV array and the dc-bus of the inverters using boost converter as the interfacing medium. The PV system is designed to operate with dc-bus voltage reference *vdc* determined by the DC-DC boost converter. Thus, at under standard test conditions (STC), the PV system operates at a constant dc-bus voltage amplitude of around 616 V.

In literature broadly two types of solar energy generation system is proposed for grid integration.

1. *Single-Stage Grid-Connected System Three-Phase Solar Photovoltaic System.Fig-2*
2. *Dual-Stage Grid-Connected Three-Phase Solar Photovoltaic System.Fig-3*

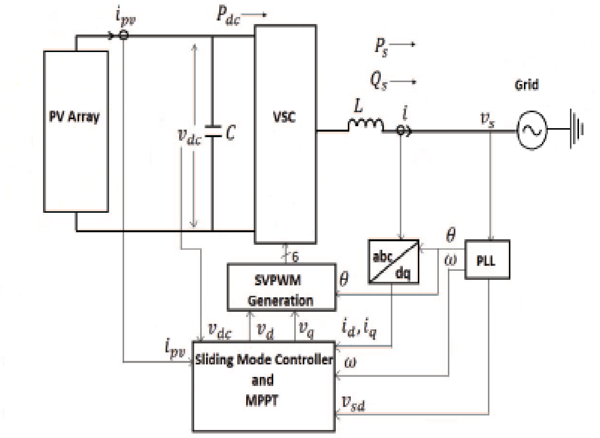

Fig-2 Single Stage Grid Connected Three Phase Solar Photovoltaic System

In single stage system the DC output of the solar panel is directly connected to the DC/AC converter to for grid integration. This is a single stage conversion. While in Dual-stage system the DC output firstly synthesized using DC-DC converter to obtain constant DC-bus voltage. Than between DC bus and AC bus at three phase converter is designed for grid integration of the solar panel. This paper presents a control topology for Dual-Stage Grid-Connected Three-Phase Solar Photovoltaic System for harmonic mitigation and voltage stability.

III. PROPOSED WORK

Although PV systems are emerging as power solution to meet the increased demand of electricity, but the reliability and robustness of the PV panel is always questionable. We are designing a dual stage PV converter to stabilize the output of solar system at various modes of operation. A dual compensating strategy is adopted to operate the PV system, where the parallel converter is controlled to act as a sinusoidal voltage source, while the series converter is controlled to operate as a sinusoidal current source. The DC/AC converter is controlled through FFCL in order to suppress load harmonic currents and compensating reactive power. Furthermore, regulated, balanced, and harmonic-free output voltages are provided to the load. The proposed system is shown in Fig-3.

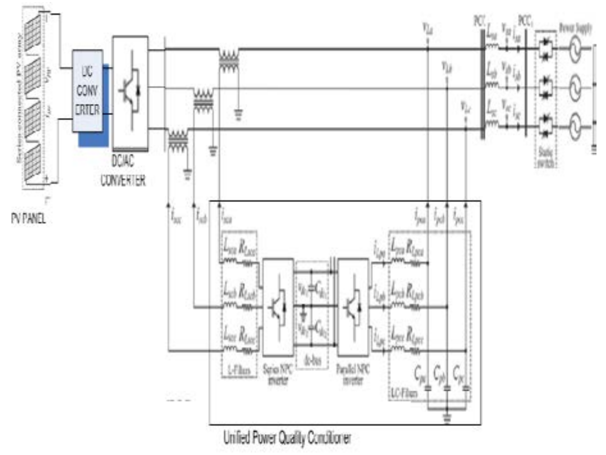

Fig-3 shows the proposed system for dual stage grid tied PV system

In the paper D-S 3P4W grid-connected PV system with combined operation with a unified power quality conditioner is presented. The performance analysis of the proposed PV-UPQC system under following two operating mode has been carried out;

- Ideal PV system connected to the grid without battery for static resistive load (OPM-1).
- For unbalanced RLC loading (OPM-2).
- PV system connected to the grid with UPQC Ppv=0 (OPM-3).

Comparative results have been presented for single stage and dual stage grid tied system.

IV. SIMULATION MODEL

A PV system is modeled using the generalized circuit of Fig-4 in MATLAB simulink at 250 and 1000 w/m2 with equation as;

$I= I_{PH}- I_S[\exp (q(V+I_{RS})/(KT_C\ A)-1]-(V-I_{RS})/R_{SH}$

The modeled PV system is connected to the grid with dual converter, one is DC-DC another is DC-AC as shown Fig-3. DC-DC converter regulates the output voltage of PV array and Dc-AC converter converts the Dc output into equivalent Ac output for grid interconnection of the PV system. The system is synchronized with the grid using PI controller and Phase Lock Loop. Three phase voltage source is considered as a AC bus, replica of grid with rms voltage of 127.2 volts and frequency 60Hz. The system description of the simulated model with load characteristics is mentioned in Table-2. To design a UPQC system two back to back DC/AC converter is connected through a dc link capacitor with 1micro farad capacitance. One side of the converter is connected to the synchronized AC output of the PV system and other side to the grid. The simulation model of the proposed system is shown in Fig-5.

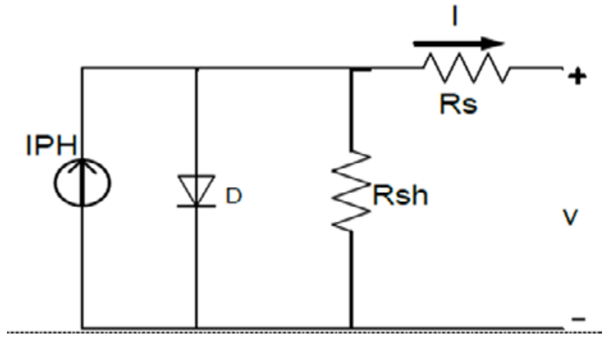

Fig-4 Generalized circuit model of PV system

Table-1 Design parameters of PV module

Parameter	Values
Series Cell Ns	50
Parallel cell Np	45
Ideality factor A	1.3
Shunt Resistance Rsh	142.84
Series Resistance Rs	0.1059
saturation current of cell Isc	3.11

Table -2 System description.

Parameter	**Symbol**	**Value**
Nominal utility voltages (rms)	V	127.27
Nominal Frequency	*Ω*	60Hz
Inverter inductance	*L*	45mH
Filter Capacitance	C	60e-6 F
Filter Inductance	L_f	10.45e-3 H
Nominal Load 1	P_{Load1}	40 ohms
Load 2	RL(phase a) RL(phase b) RC(phase c)	6Ω , 15.6 mH 8Ω , 24.2 mH 53Ω ,470 μF

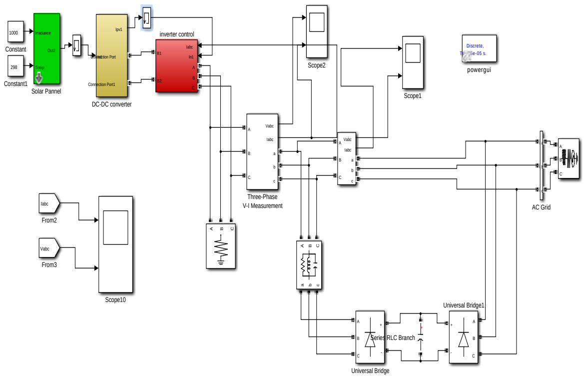

Fig-5 System simulation model of grid connected PV system.

V. RESULT ANALYSIS

The result of the proposed topology of dual stage grid tied inverter is compared with the single stage grid tied inverter for all the three phases of voltage and current at grid side and converter side. The output waveforms of dual stage grid tied PV system for opm-1 are shown in Fig 6 and 7 for static loading condition. Fig-8 and 9 presents the output waveform for UPQC system for grid side and unbalance loading respectively.

Table-2 shows the comparative analysis of the THD for the Single stage and dual stage system. It does not exceed the grid code that is less than 5%, whereas for unbalanced loading it is about 30% which is very high in case of single stage converter. The comparative analysis of single stage and dual stage grid tied PV system for THD % in out voltage and out current for all the three phases are shown in Table 3, 4, 5 for opm1, opm2, opm3 respectively.

Table-3 comparison of THD of S-S and D-S grid tied three phase PV system for OPM-1

CURRENT						
	SSPV			DSPV		
THD%	Ia	Ib	Ic	Ia	Ib	Ic
Grid	2.8	2.7	2.6	0.15	0.08	0.18
Converter	26.8	21.4	28.36	0.07	0.17	0.17
THD%	VOLTAGE					
Grid	1.7	1.9	1.8	0.17	0.07	0.17
Converter	2.3	1.9	1.4	0.17	0.07	0.17

CURRENT						
	SSPV			DSPV		
THD%	Ia	Ib	Ic	Ia	Ib	Ic
Grid	2.0	1.9	2.2	0.16	0.18	0.19
Converter	29.7	30.4	77.1	0.07	0.17	0.17
THD%	VOLTAGE					
Grid	1.7	1.9	1.8	0.17	0.07	0.17
Converter	3	2.9	3.1	0.17	0.07	0.17

Table-4 comparison of THD of S-S and D-S grid tied three phase PV system for OPM-2

CURRENT						
	SSPV			DSPV		
THD%	Ia	Ib	Ic	Ia	Ib	Ic
Grid	6.7	6.5	6	0.63	3.39	3.58
Converter	27.2	27.2	26.4	0.65	3.4	3.6
THD%	VOLTAGE					
Grid	2.1	2.2	2.1	0.15	0.19	0.09
Converter	2.6	2.7	1.7	0.15	0.19	0.09

Table-5 comparison of THD of S-S and D-S grid tied three phase PV system for OPM-3

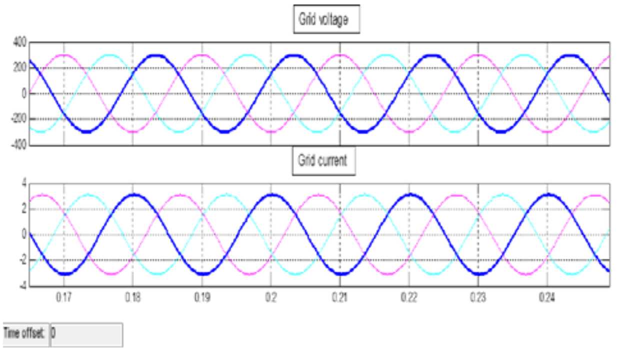

Fig-6 Output voltage and current of Grid side (opm-1)

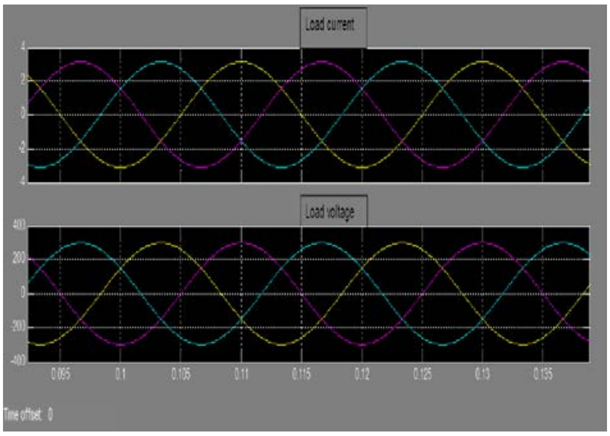

Fig-7 Output voltage and current at Converter side (opm-1)

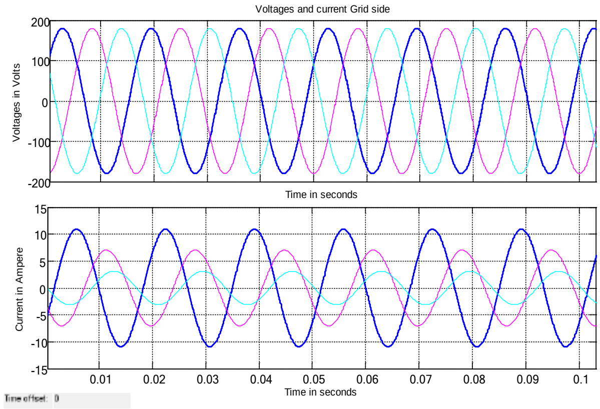

Fig-8 Output voltage and current at Converter side (opm-2)

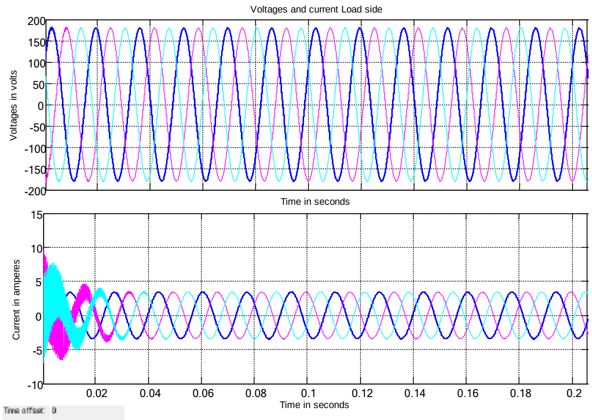

Fig-9 Output voltage and current at Converter side (opm-3)

VI. CONCLUSION

Static and dynamic performances of the system were evaluated under three operating modes grid conditions. The designed system maintains the output voltage at mostly constant value with acceptable deviations. The system proposed mitigates sags, unbalances of voltages, and harmonics. Apart from series compensation, suppression of load harmonic currents, carried out, such that an effective Unified power conditioning was achieved. Comparative analysis of the obtained results with base paper is presented and the results of the proposed topology are better as the THD at maximum cases are below 1-2 in the proposed topology.

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