Solar Fed Unified Power Quality Conditioner to Improve Power Quality in a Grid Connected Mode

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Abstract— Distributed Generation (DG) frameworks in view of RES have contributed to discover new present day answers for arranging control of traditional power frameworks. Embedded in this situation, Photovoltaic (PV) system has developed as a promising RES because of its wealth over the earth's surface. Specifically, by methods for PV-cells, PV-panels have been appropriately intended to deliver vitality by changing over daylight into power. Typically, framework associated PV frameworks can be conveyed by methods for single-stage (S-S) or dual-stage (D-S) control transformation. S-S PV frameworks are typically made out of direct coupled grid tied inverter (DC/AC conditioning converter). The designing of PV system as PV-UPQC (Unified Power Quality Conditioner) compensator is the objective of the research. A D-S 3P4W grid-connected PV system with combined operation with a unified power quality conditioner (UPQC) is presented.

Keywords: Photovoltaic (PV), single-stage (S-S), dual-stage (D-S), Total Harmonic distortion (THD), Unified Power Quality Conditioner (UPQC)

I. Introduction

There are several reasons for waning of use of fossil fuels for the production of power and three reasons for increasing interest in electricity production from renewable energy resources (RER). The only disadvantage is its maintenance cost is high and the deploying technology is complex. But the technological advancement in the Power Electronic Converters (PEC) has successfully overcomed the above disadvantages. Now a days the per unit electricity cost from the RER is compatible with the conventional one.

The grid connected operation of renewable resources generates power quality issues which are threat to the utility system. For wide spread grid integrated operation of renewable resources the power quality problem has to be solve immediately for which there has been an increased research scope for the researcher.

Accessibility of sun energy around the earth and the advancements in sunlight based innovation had made a sun based energy system a dependable wellspring of vitality today. There are number of overwhelming issues for the most part identified with control quality like power factor, responsive power quality, voltage flicker and harmonics in a PV framework associated with grid. The general execution of the aggregate framework gets influenced and it turns into a genuine worry for the end clients. All in all, it diminishes the effectiveness and life of the gear and machines. The scientists constantly attempting to manage every one of these issues and to some degree a fruitful arrangement by planning appropriate control technique for inverter interfacing PV system to the grid, can be accomplished.

Distributed Generation (DG) frameworks in view of RES have contributed to discover new present day answers for arranging control of traditional power frameworks [1]. Embedded in this situation, Photovoltaic (PV) system has developed as a promising RES because of its wealth over the earth's surface. Specifically, by methods for PV-cells, PV-panels have been appropriately intended to deliver vitality by changing over daylight into power. Typically, framework associated PV frameworks can be conveyed by methods for single-stage (S-S) or dual-stage (D-S) control transformation [2], [3]. S-S PV frameworks are typically made out of direct coupled grid tied inverter (DC/AC conditioning converter) [4] – [9]. For this situation, the PV exhibit is specifically associated with the dc-transport of the matrix tied inverter. Then again, in D-S PV systems, an extra dc/dc converter is put between the PV panel and the inverter [10] – [12]. In this design, the maximum power point tracking (MPPT) is performed by the dc/dc converter [11]. Considering SS-PV frameworks, the errand to play out the MPPT is expected by the network tied inverter, joined with the upside of accomplishing more productivity when contrasted with DS-PV frameworks [7], [8].

In both the specified PV framework topologies, the dc/ac conditioning converter controls the plentifulness of the streams infused into the network, in request to ensure the harmony between the power delivered to the PV cluster and that consumed by the grid.

Researcher here had tried to develop a dual- stage grid connected three phase four wire solar system and its performance analysis has been carried out under various modes of operation.

II. Dual Stage Grid Tied PV System

The two important issues of grid tied solar system are efficiency and low cost are. They are broadly two type of GTIs namely; single-stage (SS) and multiple-stage. Because the more stages reduce the efficiency of a GTI much more, a multiple-stage GTI mainly has two stages. In SS single converter take care of both DC/DC as well as DC/AC conversion. While two-stage GTI is comprised of a DC/DC stage and a DC/AC stage, as depicted in (Fig. 1). SS and DS GTIs have their own advantages and disadvantages, so it is hard to say which is better.

They are all implemented in different suitable occasions. Generally, small-capacity-scale grid-connected systems are more like to use DS GTIs due to their flexible feature. However, big-capacity-scale systems mainly uses SS GTIs for their high efficiency and reliability.

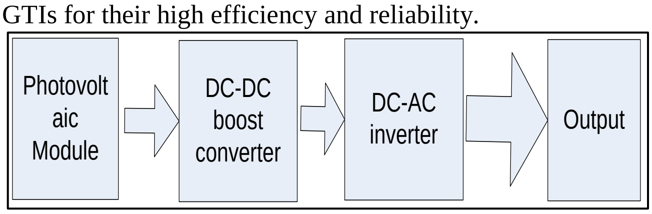

Fig. 1: Dual stage solar system

Fig-2 shows the simulation model of solar panel converter. The panel is designed using equation-1 which has been derived from the generalized single diode model as shown below;

$$I = I_{PH} - I_S\left[\exp\left(q(V + IR_S)/kT_C A\right) - 1\right]$$

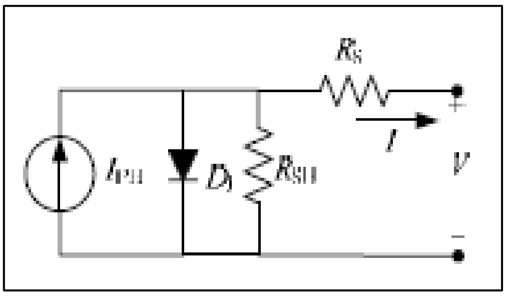

Fig. 2: Generalized single diode Solar cell model.

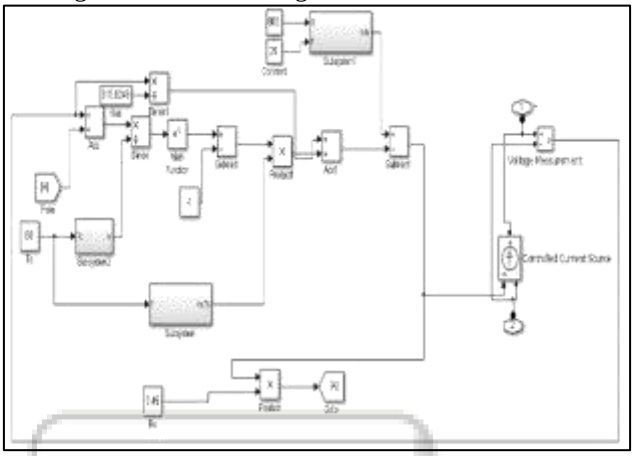

Fig. 3: simulation model of solar panel

The choice of MPPT technique depends upon the application whether grid connected or stands alone system, efficiency of the technique control variables, and cost of implementation.

III. PV-UNIFIED POWER QUALITY CONDITIONER (PV-UPQC)

Universal power quality conditioners (UPQCs) permit the moderation of voltage and current unsettling influences that could influence delicate electrical burdens while remunerating the heap responsive power. It goes for the mix of arrangement dynamic and shunt-dynamic power channels. The fundamental reason for an UPQC is to make up for voltage unevenness, responsive power, negative grouping current and sounds.

Real parts of Unified power quality conditioner are Power Source, Shunt Active Filer and Load.

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 PV-UPQC converter to stabilize the output of solar system at various modes of operation.

A dual compensating strategy is adopted to operate the PV-UPQC 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 proposed system is shown in Fig-4

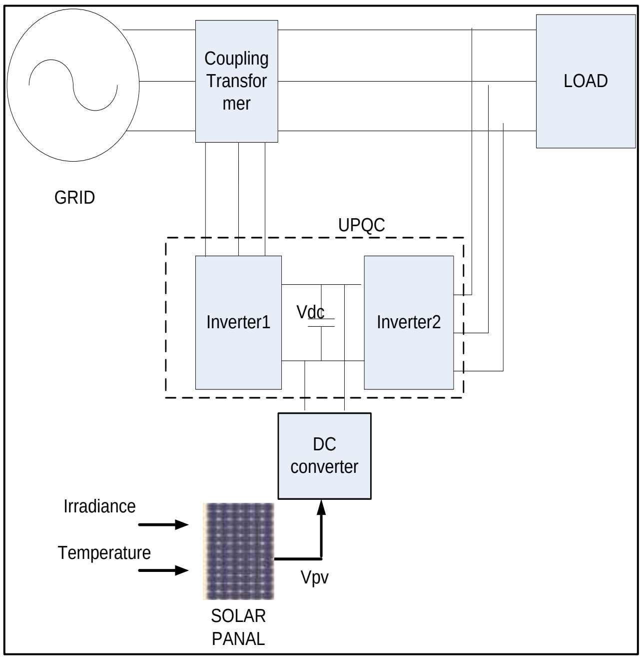

Fig. 4: Shows the proposed system for research

IV. PROPOSED WORK

A PV system is designed, 50 parallel strings and 10 Series-connected modules. The rated capacity of the PV panel is 100 KW. To obtain the constant DC output from Solar system a DC-DC boost converter is designed with switching frequency 3Khz. The output voltage of the boost converter is approx. 720 V.

To integrate the PV system with the grid a DC/AC inverter is simulated three level universal bridge.

The proposed PV-UPQC system consist of two converters namely series and shunt. One side of the converter is connected to the synchronized AC output of the PV system and other side to the load.

The system is synchronized with the grid using PI controller and Phase Lock Loop.

The parameter considered in designing the proposed system is presented in table 1.

The designing of PV system as PV-UPQC compensator is the objective of the research. A D-S 3P4W grid-connected PV system with combined operation with a unified power quality conditioner (UPQC) is presented. The performance analysis of the proposed PV-UPQC system under following three operating mode has been carried out;

1) Ideal PV system connected to the grid with feed forward control loop.
2) Operation under balanced linear loading.
3) Operation under unbalanced non-linear loading.

arameter	Symbol	Value
Nominal utility voltages (rms)	V	415
Nominal Frequency	ω	50Hz
Inverter inductance	L	45mH
Filter Capacitance	C	60e-6 F
Filter Inductance	L_f	10.45e-3 H
Nominal linear Load 1	P_{Load1}	40 ohms

Non-linear Load 2	Three phase load through rectifier	R=40 ohms

Table 1: System parameters solar system with proposed work

V. RESULT AND DISCUSSION

In general PV systems find applications in supplying local loads or connected to the distribution system or operate as a microgrid where local generation is carried out. This work has been carried out in lieu of the below mentioned objectives;

Grid connected PV system has been modeled in MATLAB simulation frame work. The output power of the system is approx. 4KW.

Static and dynamic performance analysis of the system has been carried out.

Two type of loading has been done to test the efficiency of the system constant linear and constant non-linear loading.

The non-linear loading has higher harmonic content which could be the threat to the grid stability; hence a controller namely unified power quality conditioner (UPQC) has been developed to improve the power quality of the system in a grid connected mode. The simulation model of the proposed system is presented in fig-5. The results for all the modes of operation are presented below.

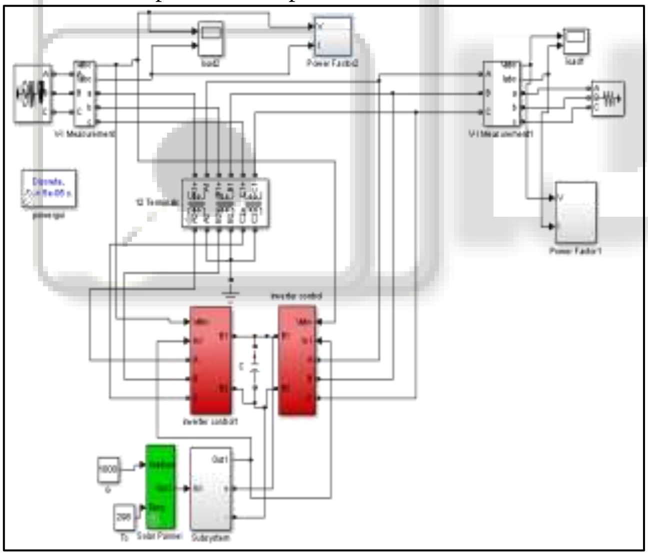

Fig. 5: Simulation Model of D-S PV system with proposed topology

A. Simulation model of Dual stage grid tied three phase PV system (OPM-1)

This is the first operating mode of the proposed work. In this mode of operation the solar energy generation system is synchronized with three phase AC utility gird using dual stage feed forward control topology. The simulation model of the proposed system is shown in fig-5. The system is connected with three phase voltage source which is the replica of grid. The components of the system are inverter with active filtering characteristics, a DC-DC voltage regulator and PV panel. The output waveforms are presented in Fig 6 and Fig-7.

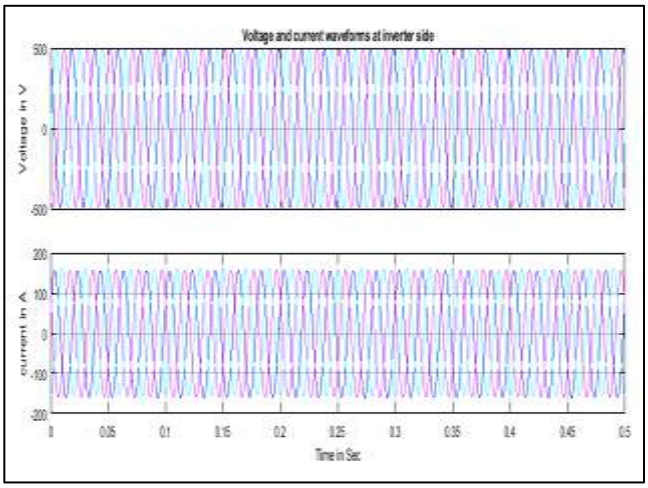

Fig. 6: Output of Solar system with proposed topology

B. Operation under balanced linear loading (OPM-2)

In this mode of operation balanced linear loading is applied to the system to study the behavior of the proposed topology. The output waveforms at grid side and source side are presented in fig- 7 and 8.

C. Operation under unbalanced loading. (OPM-3)

In this mode of operation balanced non-linear loading is applied to the system to study the behavior of the proposed topology. A three phase balanced non-linear load of characteristics as shown in Table-1 is connected. The output waveforms at grid side and source side are presented in fig- 9 and 10.

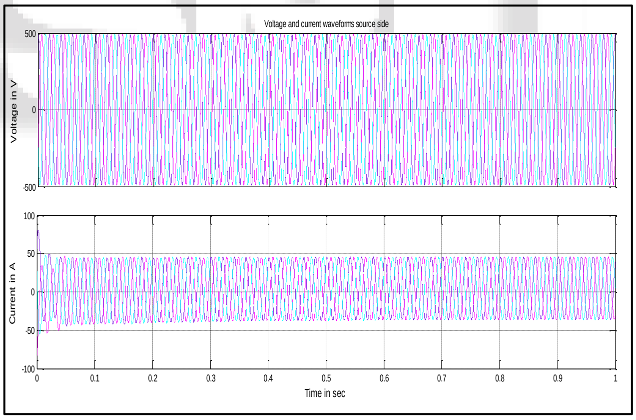

Fig. 7: Output voltage and current waveforms source side for linear loading

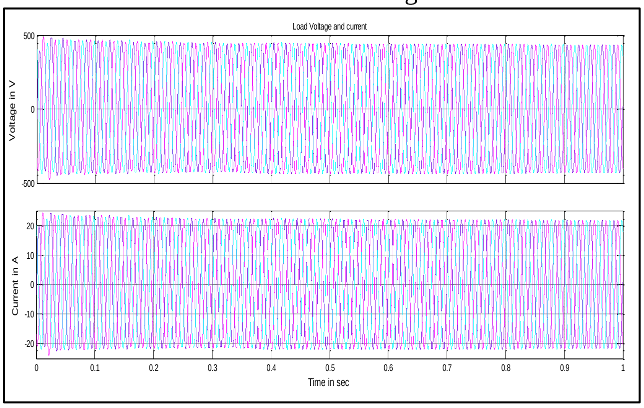

Fig. 8: output voltage and current waveforms load side for linear loading

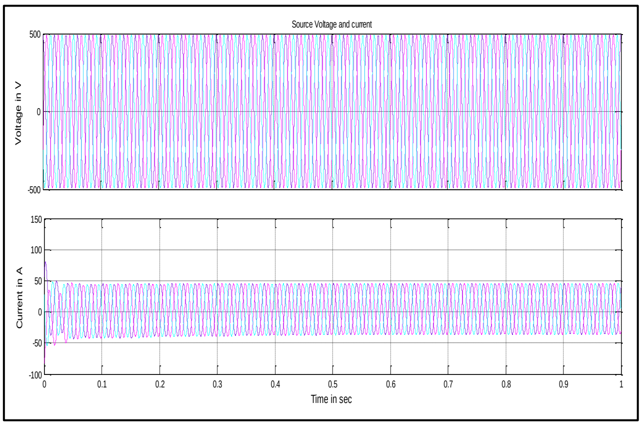

Fig. 9: Output voltage and current waveforms source side for non-linear loading

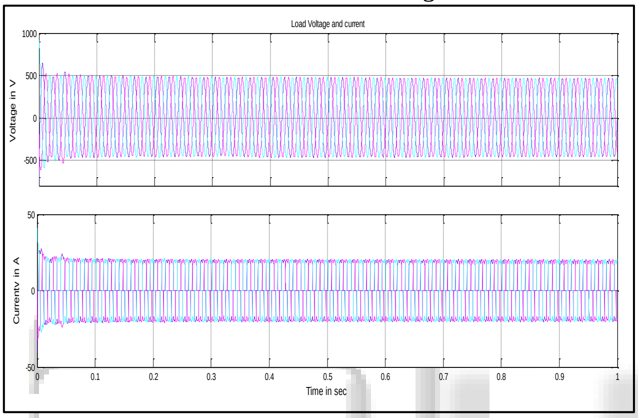

Fig. 10: output voltage and current waveforms load side for non-linear loading

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.

THD% SOURCE CURRENT						
	SSPV			DSPV		
	Ia	Ib	Ic	Ia	Ib	Ic
OPM-1	2.0	1.9	2.2	0.0	0.0	0.0
OPM-2	2.8	2.7	2.6	1.36	1.06	1.61
OPM-3	6.7	6.5	6.0	1.8	1.5	1.9
THD% SOURCE VOLTAGE						
	Va	Vb	Vc	Va	Vb	Vc
OPM-1	1.8	1.6	1.5	0.17	0.07	0.17
OPM-2	1.7	1.9	1.8	0.0	0.0	0.0
OPM-3	2.1	2.2	2.1	0.0	0.0	0.0

Table 2: Comparison of THD for unbalanced linear loading

THD% LOAD CURRENT						
	SSPV			DSPV		
	Ia	Ib	Ic	Ia	Ib	Ic
OPM-1	29.7	30.4	77.1	0.0	0.0	0.0
OPM-2	29.7	30.4	77.1	3.7	3.0	3.2
OPM-3	27.2	27.1	26.4	22.3	20.1	20.2
THD% LOAD VOLTAGE						
	Va	Vb	Vc	Va	Vb	Vc
OPM-1	3.0	2.9	3.1	0.17	0.07	0.17
OPM-2	2.3	1.9	1.4	0.0	0.0	0.0
OPM-3	2.6	2.2	1.7	0.0	0.0	0.0

Table 3: Comparison of THD for balanced non-linear loading

VI. CONCLUSION

- Static and dynamic performances of the system were evaluated under various modes of operation of grid voltage conditions, including sags, unbalances, 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 single stage PV system is presented and the results of the proposed topology are better as the THD at maximum cases are below 1% in the proposed topology as compared to near about 5% in single stage grid tied system.

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