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Performance Improvement of Grid-Integrated Solar PV System Under Uncertainties and non-linearities

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ABSTRACT:

The various power quality (PQ) issues in a grid connected solar system arises because of intermittent nature of solar and uncertain loads at the consumer end. The reasons of uncertainties are; nonlinearity, disturbances or unbalanced loads. A three-phase grid-integrated solar photovoltaic (GISPV) system incorporating a control technique based on a modified partial integral (PI) based inverter control algorithm. The controller is so designed so as to obtain the streamline overall performance of the GISPV under adverse conditions.

KEYWORDS: *Grid-integrated Solar Photovoltaic, Photo Voltaic (PVP), Phase Lock Loop, and feed forward control loop.*

1. INTRODUCTION

Harmonised global effort under the aegis of United Nations framework convention on climate change (UNFCCC) is being endeavoured to contain the rise of global atmospheric temperature below 2^0 C. This convention stresses on the centrality of renewable energy sources (RES) as prominent alternative to the fossil fuel based sources of electrical power generation. RES are grooming especially when petroleum products are being replaced as fuel by electrical energy for vehicles which are among the major sources of environmental pollutants. While RES includes many new and existing and evolving resources in its fold. Solar power leads the pack currently, which is because of the extensive research and development undergoing on the technology making it commercially more competitive.

PV systems can provide clean power for small or large applications. Hence they could be installed as standalone or grid connected system. PV systems are preferred as stand-alone systems, where it is difficult to connect to the grid or where there is no energy infrastructure. Electricity can be imported from the network when there is no sunlight. Such small installations are also easy to set up and connect to the grid. The rules about grid connection vary from country to country, but almost in all countries it is compulsory to contact the local network system operator.

In grid-integrated solar photovoltaic (GISPV) system, inverters are essential interfaces to connect RES with the utility grid. To reduce the investment, operation and maintenance cost, man-hour, as-well-as the bulk, and enhance the cost-effective feature of the GISPV grid-connected inverters plays important role [17–26]. The GISPV inverter control can connect RESs and storage devices to utility grid, and simultaneously enhance the power quality at their points of common coupling (PCCs). Hence they are capable of saving capital investment and system space.

A lot of ongoing research has been reported in literature for auxiliary services on power quality improvement through proper control of converters. These converters can perform dual work of interfacing solar system with the grid and also conditions the power at point of common coupling.

The state-of-the-art of the converter is its design feature which optimally achieve the multi-functionality, hence the work done presents a cost effective solution to power quality issues. In this paper the various power quality (PQ) issues in a grid connected solar system because of intermittent nature of solar and uncertain loads at the consumer end have been addressed. The reasons of uncertainties are; nonlinearity, disturbances or unbalanced loads. A three-phase grid-integrated solar photovoltaic (GISPV) system incorporating a control technique based on a modified partial integral (PI) based inverter control algorithm. The controller is so designed so as to obtain the streamline overall performance of the GISPV under adverse conditions.

2. GRID-INTEGRATED SOLAR PHOTOVOLTAIC (GISPV)

Integrating solar power to the grid mostly have adverse effect on the power quality in the grid. In a few PV based framework, the inverter is a key segment which is responsible for the control of power quality in GSIPV. The installation of the GISPV comes along with many challenges that need to be addressed before they can be incorporated into the utility grid. This is because the operation of these plants can be uncertain due to the intermittency of the solar moreover uncertain grid operation. It is important to investigate the establishment of grid codes for the installation of GISPV and how they can help to achieve reliable operation and long-life production. The effect of high GISPV connection to the existing power grid should be evaluated in terms of the power flow patterns to ensure a high quality of the delivered power and overall system reliability and stability. The system under study is presented in figure-1.

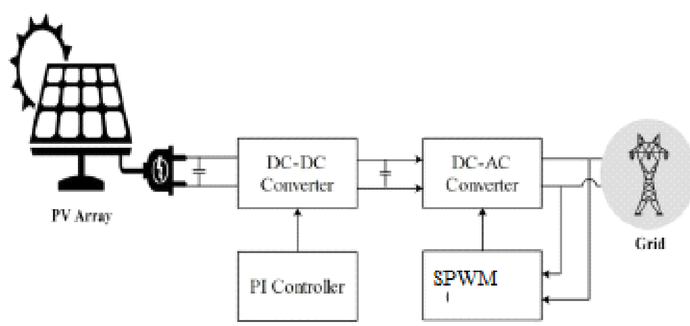


Fig. 2- Block diagram of the proposed system.

3. PROPOSED WORK

The stochastic behavior of the PV system may leads to unreliable grid connected operation. A proper DC-voltage regulator may some extent help to stabilize the solar performance. Also for efficient grid integrated operation; the designed inverter must meet the grid code requirements. Hence in the proposed work, to integrate the PV system with the grid a DC/AC inverter is simulated using FFCL with PI controller. The designed inverter is also efficient under uncertain loading like unbalance and non-linear loadings.

This work deals with a modified PI-based control algorithm for a dual-stage solar PV system integrated into the main grid. The feed forward control loop (FFCL) based synthesizing of grid voltage has been done to obtain the reference signal for PI controller. For three phase system to reduce complexity an abc-dq transform is used as shown n figure-1. A conventional three leg full bridge universal inverter is used. The inverter is synchronized with the grid using phase lock loop. A 3 KW PV system with 55 V PV Dc output. A Matlab Simulink model is developed for single diode PV system as shown in figure-2. The proposed system is analysed under three operating conditions;

- Under static condition with constant irradiance.
- Under dynamic conditions with variable irradiance.
- Under the condition of unbalance non-linear loading.

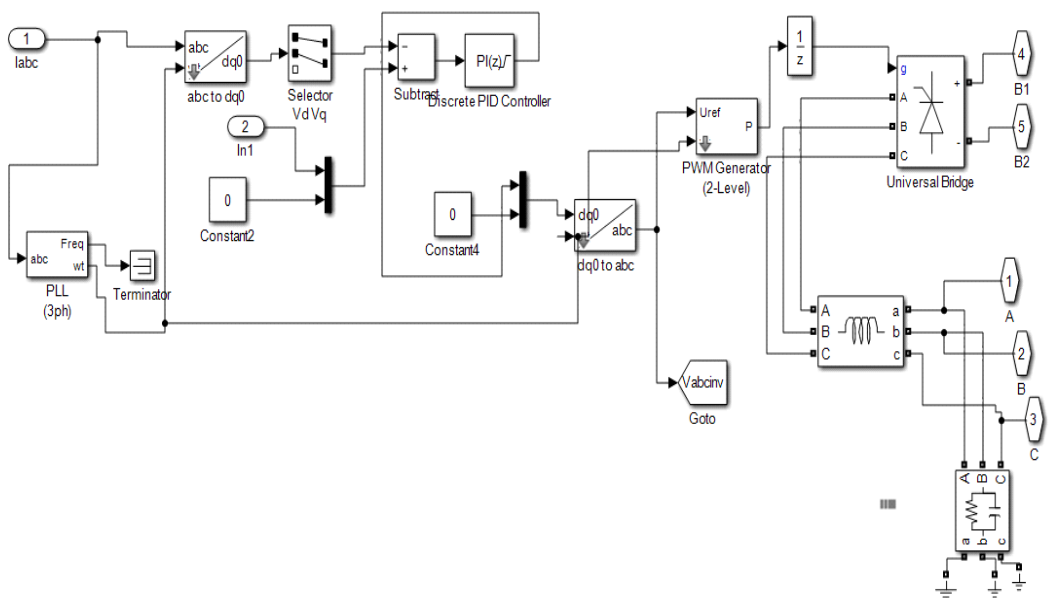


Figure-3: Simulation model of proposed PI controller.

Figure 2 single cell solar module

4. SIMULATION

The simulation model of the proposed system is presented in figure 3. The designed GISPV is of dual stage category; that is two converter is employed. One is DC-DC and another is DC-AC. The DC-DC converter regulate the Dc output of solar and DC-AC is an inverter. The inverter is designed with PI control and PLL which performs dual function of converting Dc into AC and another is mitigating all the power quality issues under uncertainties arise due to nonlinearity, disturbances or unbalanced loads. A filter is designed tuning the system frequency so as to eliminate harmonic in output voltage and current at PCC. The parameter selection for the system designed is presented in table-1.

The static operation for constant irradiance and linear loading presents the constant voltage and current at PCC and grid side. Also Active power at inverter side is 4KW, load side is 0.8 KW and at grid side is 3.1 KW. Approx 100 W of power is losses. For variable irradiance system posses constant voltage and current at PCC and THD is same as in constant irradiance condition. For non-linear and unbalanced loading, the THD for grid voltage is 0.1 %, for grid current is 2.3% and for load current is 22.1 %.

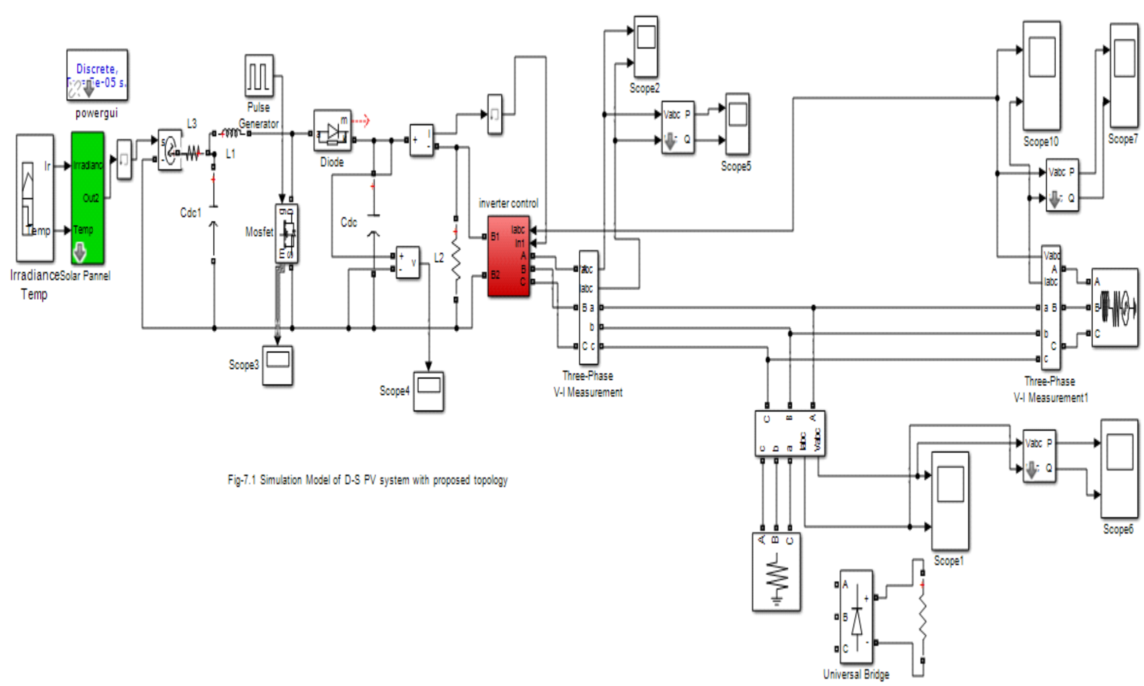
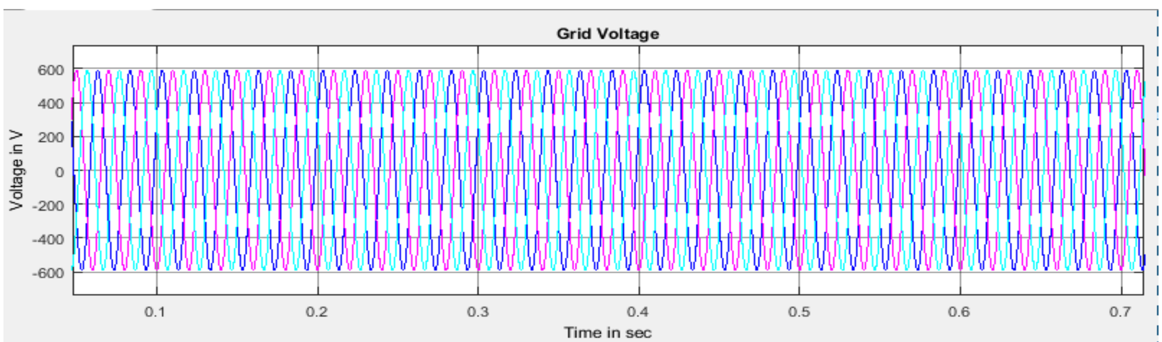


Figure 3 simulation model of the proposed work

Table-1: Parameter & its value

Parameter	Values
PV rating	3KW
C_{dc}	1500µF
DC converter inductance	5 mH
Inverter parameter	
Effective nominal voltage of the utility (RMS) VS	415 V
Nominal utility grid frequency fS	50Hz
Switching frequency of the converters fch	5khz
inductance of filter	0.4 mH
Series resistance converter	0.01 ohms
Capacitances of the parallel filters	1000µF
Resistances of the converter filter	0.01 ohms
dc-bus voltage Vdc	415V



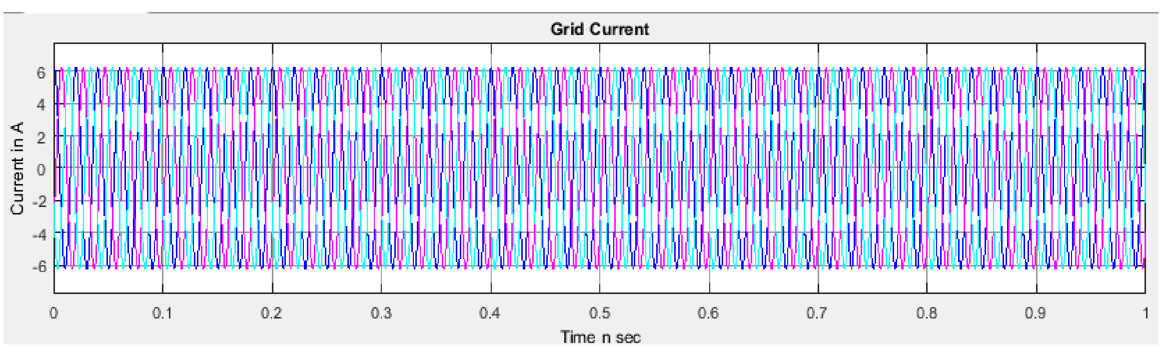


Figure-4: Output voltage and current of proposed topology grid side

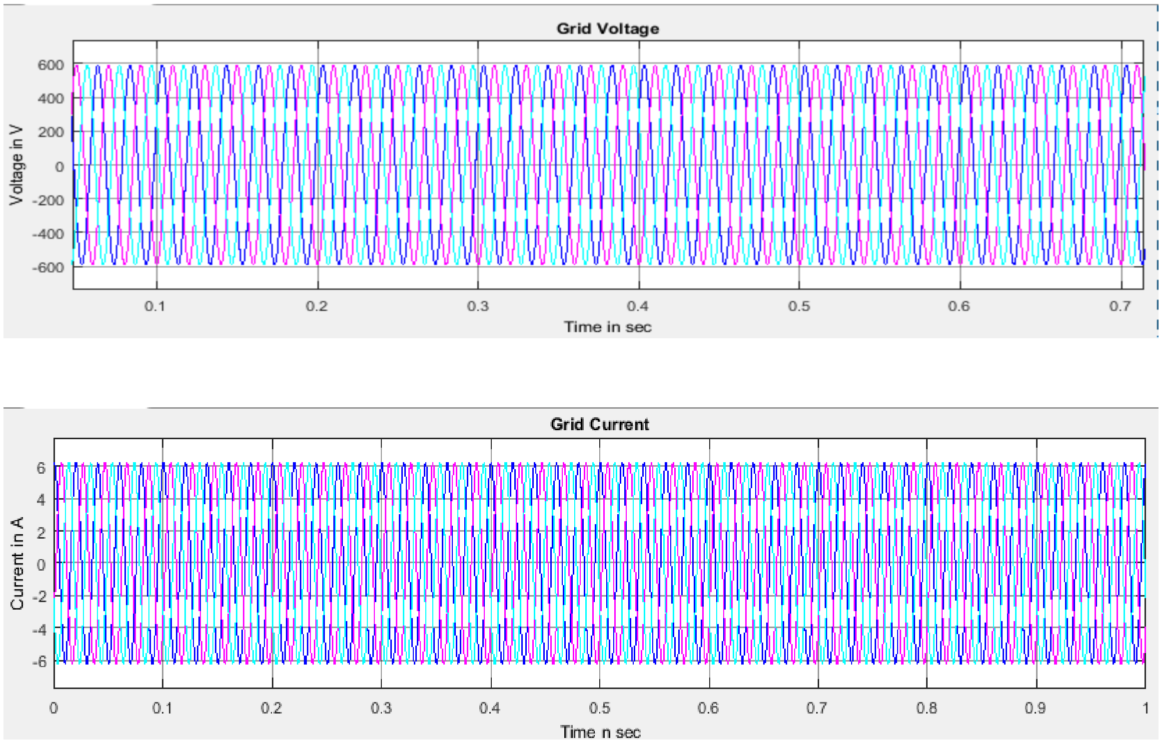


Figure-5 Output of proposed topology under variable irradiance

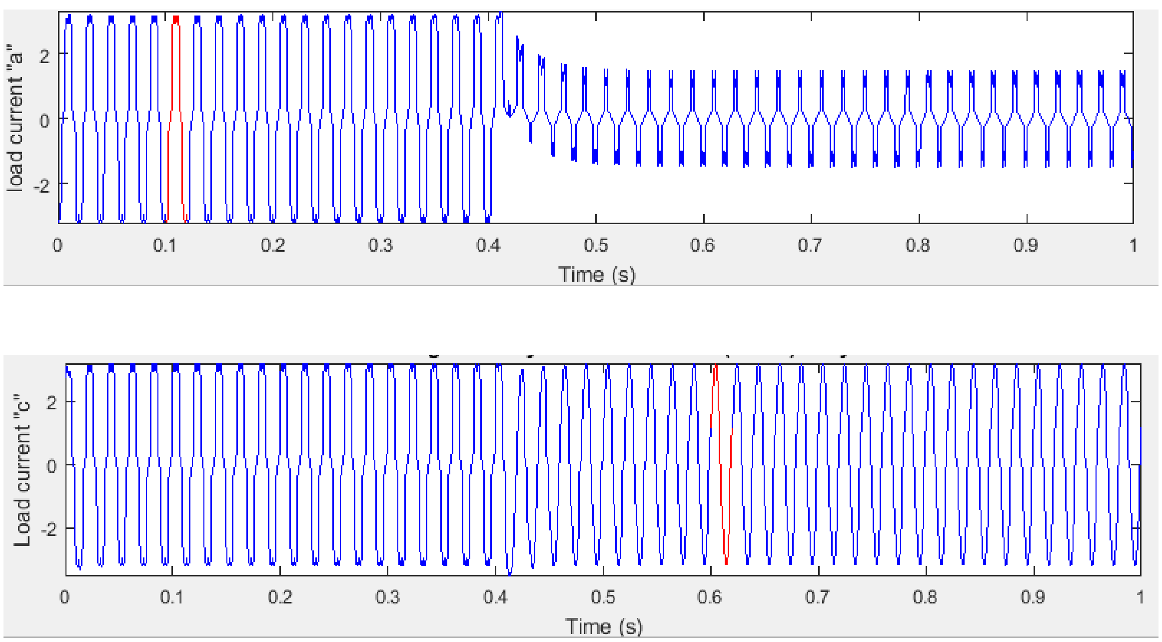


Figure6 Output of proposed topology for unbalanced non-linear loading

5. RESULT DISCUSSION

The controller is so designed so as to maintain the harmonic free constant output. Figure 4 presents the output voltage and current waveform of proposed topology for constant irradiance. Figure 5 presents output for variable irradiance and 6 gives the dynamic performance for non-linear loading. In figure 6, at 0.4 sec the load for phase ‘a’ is suddenly reduced and the voltage and current output is analysed for non-linear loading connected through three phase rectifier. The THD analysis for the work done is presented in table-2.

Table-2 THD analysis

Operating mode	Proposed work
THD of grid voltage	0.1%
THD of grid current	3.4%
THD for load current	22.1%

6. CONCLUSION

The proposed GISPV is designed using modified PI controller. The purpose to design the controller is that it should maintain constant voltage under the condition of nonlinearity, disturbances or unbalanced loads. Also it should maintain low harmonics under such conditions. The grid current THD has been observed as 2.3 % fulfilling the requirement according to the IEEE-519 standard. Active power flow has been observed from the test results. A satisfying performance has been recorded under dynamic conditions.

REFERENCES

[1] Wang, Yeqin, and Beibei Ren. "Fault ride-through enhancement for grid-tied PV systems with robust control." IEEE Transactions on Industrial Electronics 65.3 (2017): 2302-2312.

[2] Mojallal, A., & Lotfifard, S. (2017). Enhancement of grid connected PV arrays fault ride through and post fault recovery performance. IEEE Transactions on Smart Grid, 10(1), 546-555.

[3] Abdelmalik ZORIG, Mohammed BELKHEIRI, “Control of Single-Stage Grid-Connected Three-Phase Solar Photovoltaic System Using Sliding Mode Control; IECON2015-Yokohama.

[4] Sandipan Patra, Nand Kishor, Soumya R. Mohanty, Prakash K. Ray. “Power quality assessment in 3-phase grid connected PV system with single and dual stage circuits; Electrical Power and Energy Systems 75 (2016).

[4] S. Deo, C. Jain, and B. Singh, “A PLL-less scheme for single-phase grid interfaced load compensating solar PV generation system,” IEEE Trans. Ind. Informat., vol. 11, no. 3, pp. 692–699, Jun. 2015..

[5] D. G. Montoya, C. A. Ramos-Paja, and R. Giral, “Improved design of sliding-mode controllers based on the requirements of MPPT techniques,” IEEE Trans. Power Electron., vol. 31, no. 1, pp. 235–247, Jan. 2016.

[6] W. Li, Y. Gu, H. Luo, W. Cui, X. He, and C. Xia, “Topology review and derivation methodology of single-phase transformer less photovoltaic inverters for leakage current suppression,” IEEE Trans. Ind. Electron., vol. 62, no. 7, pp. 4537–4551, Jul. 2015.

[7] S. Deo, C. Jain, and B. Singh, “A PLL-less scheme for single-phase grid interfaced load compensating solar PV generation system,” IEEE Trans. Ind. Informat., vol. 11, no. 3, pp. 692–699, Jun. 2015.

[8] Olivares, Daniel E., Claudio A. Cañizares, and Mehrdad Kazerani. "A centralized energy management system for isolated microgrids." IEEE Transactions on smart grid 5.4 (2014): 1864-1875.

[9] Y. Tang,W. Yao, P. C. Loh, and F. Blaabjerg, “Highly reliable transformer less photovoltaic inverters with leakage current and pulsating power elimination,” IEEE Trans. Ind. Electron., vol. 63, no. 2, pp. 1016–1026, Feb.2016.

[10] Y. Kim, H. Cha, B. M. Song, and K. Y. Lee, “Design and control of a grid-connected three-phase 3-level NPC inverter for building integrated photovoltaic systems,” in Proc. IEEE PES Innovative Smart Grid Technol., 2012, pp. 1–7.

[11] S. A. O. Silva, L. P. Sampaio, F. M. Oliveira, and F. R. Durand, “Feedforward DC-bus control loop applied to a single-phase grid-connected PV system operating with PSO-based MPPT technique and active power-line conditioning,” IET Renew. Power Gener., 2016.

[12] G. Ding et al., “Adaptive DC-link voltage control of two-stage photovoltaic inverter during low voltage ride-through operation,” IEEE Trans. Power Electron., vol. 31, no. 6, pp. 4182–4194, Jun. 2016.

[13] S. Bacha, D. Picault, B. Burger, I. Etxeberria-Otadui, and J. Martins, “Photo voltaics in microgrids: An overview of grid integration and energy management aspects,” IEEE Ind. Electron. Mag., vol. 9, no. 1, pp. 33–46, Mar. 2015.