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Improved Power Quality in a Three Phase Two Stage PV Grid Interface

Neena Verma[1*], Neeraj Tripathi[2]

[1,2]*School of Electronics and Communication Engineering, Shri Mata Vaishno Devi University, Kakryal, India*

Abstract*: Due to the ever-increasing need for electrical energy and the challenges connected with traditional thermal power plants, solar energy has recently received increased attention. photovoltaic energy generation This study is based on the design and development of a three-phase system. Power electronics converter with grid interface for PV applications. With a dc-dc boost, the power electronic interface contains two-stage conversions. for grid integration and a dc-ac three-phase voltage source inverter, the dc-dc the solar panel's maximum power point functioning is taken into account by the boost converter and VSI. The dc-link voltage and the electricity supplied into the grid are controlled. The performance of the MPPT algorithm based on the Perturb & Observe and maximum power point tracking for solar using Incremental Conductance algorithms PV systems have been thoroughly examined. A PV module based on design methods. Solar insolation and temperature affect the output of a solar photovoltaic (SPV) panel. A step up the dc-dc converter circuit is simulated to develop algorithms. Perturb Observe and gradually increase your conductance. There has also been a qualitative comparison were undertaken to demonstrate the benefits and drawbacks of using LCL filter methods in the introduced into the were designed and minimized. The inverter has a 50kW grid interface and a maximum power point tracker algorithm. The use of a PI controller to synchronize with the grid has been completed.

***Keywords*: PV system, LCL filter, SDM, MPP.**

1. Introduction

Temperature and the PV module's output voltage in the literature, mathematical models of particular system components to better understand their performance, and PV systems are depicted and simulated [2]. The single-diode model is the simplest of the models proposed in the literature. Adding series resistance (Rs) and shunt resistance (Rsh) to the PV model improved it even more [3]. Although a single-diode model with series and shunt resistance yields more accurate findings, the carrier recombination losses in the depletion zone are not taken into account in the single-diode model [4], [9]. When we employ a two-diode model that accounts for recombination losses, the model's accuracy improves dramatically. A revised two-diode PV model for the PV system was proposed in [7] for additional accuracy improvement. To decrease the number of parameters, the model presented in [7] assumed that the reverse saturation current of both diodes is equal and that the idealist constant of diodes is 1 and 2, respectively. [8] recently introduced a new approach for PV modeling that combines the benefits of prior models by combining simplicity, ease of modeling, and accuracy. When we employ a two-diode model that accounts for recombination losses, the model's accuracy improves dramatically.

A revised two-diode PV model for the PV system was proposed in [7] for additional accuracy improvement. To decrease the number of parameters, the model presented in [7] assumed that the reverse saturation current of both diodes is equal [8] recently introduced a new approach for PV modeling that combines the benefits of prior models by combining simplicity, ease of modeling, and accuracy. The multi-string SPV module outperforms traditional solar photovoltaic systems by allowing for the tracking of maximum power points on each solar photovoltaic panel [2]. Designers of photovoltaic (PV) systems want an easy-to-use and trustworthy model to estimate PV energy generation under various insolation and temperature circumstances. Due to its simplicity, the ideal single diode model (ISDM) does not guarantee a faultless characteristic at the maximum power point (MPP) (ii) The single diode model (SDM) is commonly employed in photovoltaic (PV) investigations due to its accuracy. Because output current is a function of both voltage and current, a numerical solver is required to implement the simulation model for the single diode model (SDM) technique. For the ideal single diode model, the proposed hybrid technique includes two new mathematical modeling equations designed to predict solar PV parameters.

2. Objectives of the Study

The goal of this study is to improve the performance of a two-stage three-phase grid interfaced solar photovoltaic (SPV) system by reducing total harmonic distortion and enhancing power quality during grid interfaced situations. The three factors, insolation, harmonics, and power quality improvement capability owing to load fluctuations, are all based on assigning a THD performance index. When applied to a grid-connected solar photovoltaic system, the foregoing three characteristics gave a quantitative and qualitative basis for comparing performance. Because output current is a function of both voltage and current, a numerical solver is required to implement the simulation model for the single diode model (SDM) technique. As a result, a novel hybrid solar PV modeling technique is developed, which incorporates the advantages of

*Corresponding author: vermaneena52@gmail.com

both ISDM and SDM techniques, such as ease of modeling, simplicity, and accuracy. For the ideal single diode model, the proposed hybrid technique includes two new mathematical modeling equations designed to predict solar PV parameters.

3. Research Methodology

As a result, the goal of this article is to improve the performance of a two-stage three-phase grid-interfaced solar photovoltaic (SPV) system by reducing total harmonic distortion and enhancing power quality during grid interfaced situations. The three factors, insolation, harmonics, and power quality improvement capability owing to load fluctuations, are all based on assigning a THD performance index. When applied to a grid-connected solar photovoltaic system, the foregoing three characteristics gave a quantitative and qualitative basis for comparing performance.

4. Findings

A. *Discussions and Results of Simulations*

In the presented work, simulation for inverter control analysis was performed. To validate the performance of the solar photovoltaic system, the proposed current control technique was simulated using Matlab/Simulink. MATLAB /Simulink is used to create the SSDM Solar PV generator, which produces 10kW of power by joining series-parallel configurations.

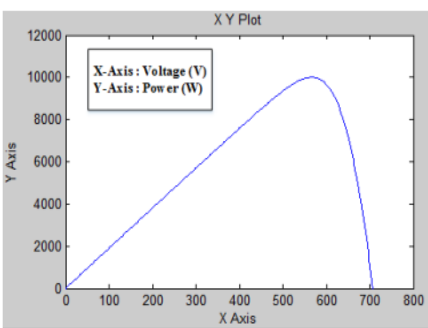

Fig. 1. SSDM PV generator output P-V characteristics

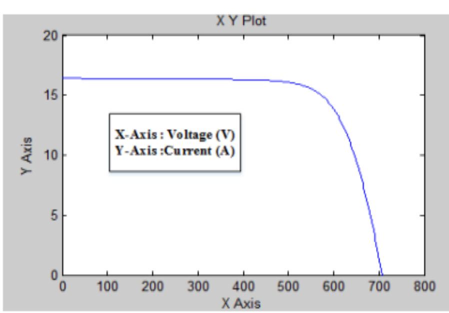

Fig. 2. SSDM PV generator output I-V characteristics

On the aforementioned terms, the simulation results have been evaluated and explored. The grid's three-phase line voltages and currents are shown separately.

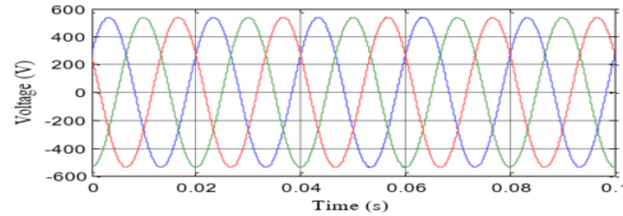

Fig. 3. Three phase line voltage of the grid

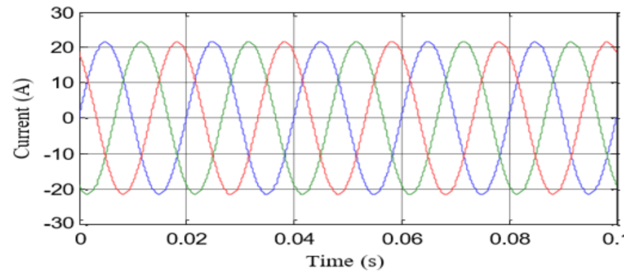

Fig. 4. Three phase current of the grid

The results of the simulation are presented with different loads, which consist following terms:

Vdc: dc-link voltage, Vg: grid voltage, Ig: grid current,

Viv: photovoltaic voltage PV: photovoltaic current, Ia, Ib, Ic: inverter current, P: active power, Q: reactive power.

For Resistive Load:

Shows the voltage and current waveforms of a 10kVA linear (resistive) load when the grid's solar insolation is 1000W/m^2. indicates the per-phase current and voltage of the VSI inverter. At t =1sec, the system returns to its starting state. Because the system operates at unity power factor, the grid's current and voltage are in phase, and the load requires reactive power, which is provided by solar electricity. When there is a chance that the solar system will not produce enough electricity due to poor insolation, the grid delivers some of the reactive power (in low insolation). Inverter current and voltage on linear load per phase. As a result, demand of load power increases, current of grid is changed to fulfil the demanded load. Therefore, the increase in the active power is supplied by the grid, and is represented in Fig. The unity power factor the system is operating as the demand of reactive power of the load which is given by the photovoltaic power & the zero reactive power Q of the grid. The power balance theory and control technique of generation of reference active power & reactive power are easily obtained.

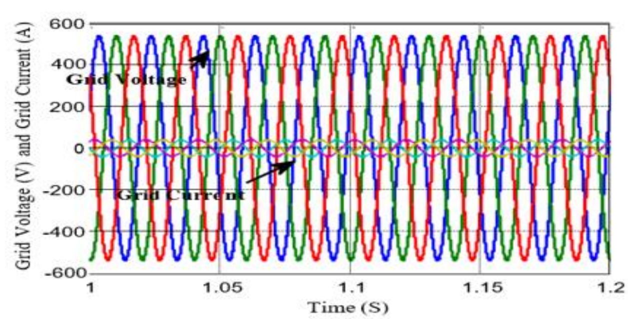

Fig. 5. Three phases grid voltage & grid current on resistive load (10kVA)

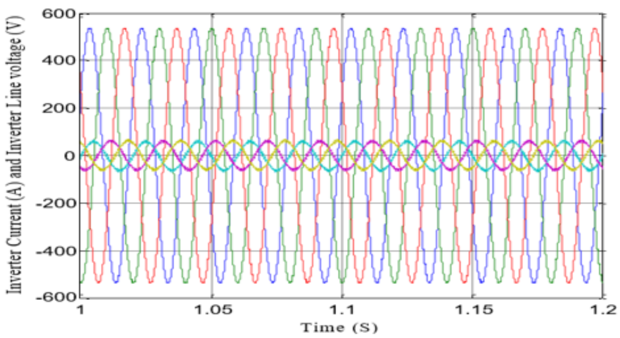

Fig. 6. Voltage source inverter's current and voltage on resistive load (10kVA)

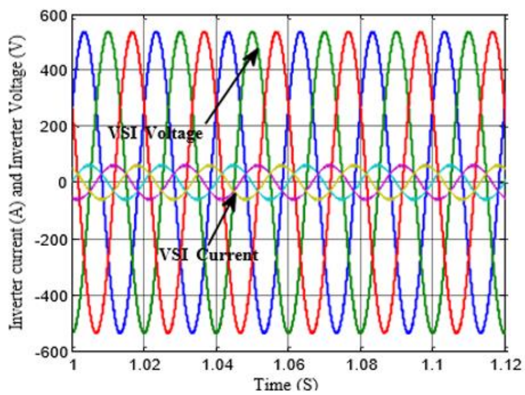

Fig. 7. Grid three-phase line voltage and grid current on resistive load

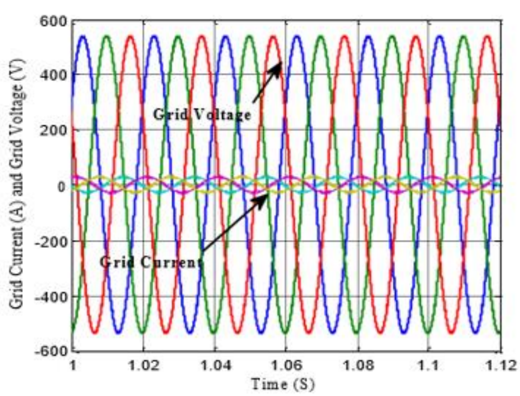

Fig. 8. Voltage source inverter's current and inverter's line voltage on resistive load

B. Design of LCL Filter

An electromagnetic interference filter attenuates the large frequency harmonics of the current output, caused by the inverter switching. The interactive solar photovoltaic system consists of only L or LC filter usually and results in a large inductance (L) value, bulky and expensive for low rated systems. The LCL filter is, therefore, more effective than the L filter, because the latter has a complete frequency range with a small attenuation of 20 dB/decade. Due to the mutation of the resonance frequency of the grid inductance, the LC filter suffers. Hence, the LC filter is not appropriate for a grid. The procedure for the design of the LCL filter is to use the grid interfaced inverter step by step.

$$L_1 = \frac{V_g}{2\sqrt{6} f_s\, i_{ripple\ peak}}$$

$$C = \frac{0.05}{\omega_n Z_{base}}$$

$$Z_{base} = \frac{V_{gLL}^2}{P_n}$$

Where,

Vg=phase voltage of grid (RMS), fs=switching frequency of the inverter, I ripple, peak= output peak current 15%, L2=inductance grid side, L1=inductance inverter side, C= LCL filter capacitor, Pn= rated power of inverter and ωn=frequency of operation. The inductance of grid off LCL filter (L2) is calculated as follows for current ripple attenuation of 20d Bat switching frequency:

$$L_2 = 0.8 L1$$

Total Harmonic Distortion (THD):

Under resistive load, the total harmonic distortion (THD) of the load current is presented.

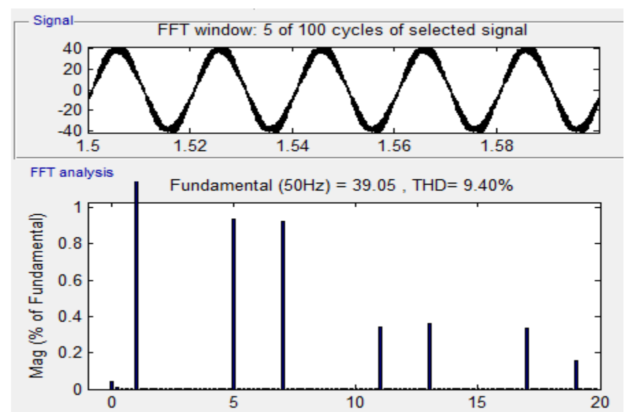

Fig. 9. TDH spectrum of the grid current phase "a" under without LCL filter

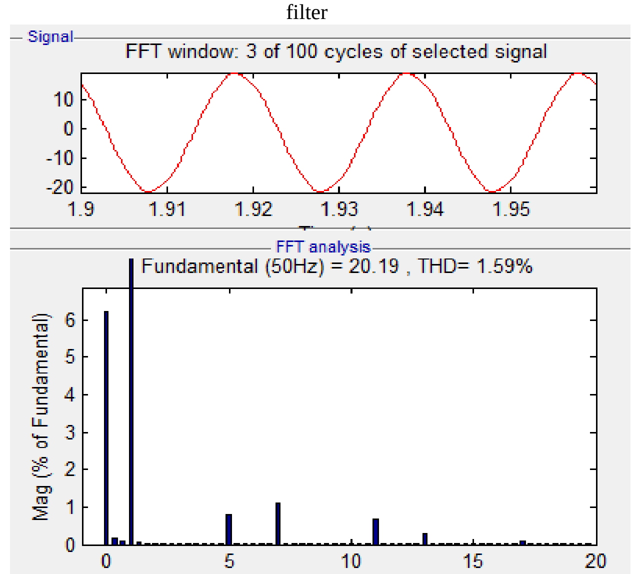

Fig. 10. TDS of grid current phase "a" under LCL filter

Figures show the harmonic spectrum without and with an LCL filter.

Table 1
Performance of LCL filter

S. No.	Filters	Loads	THD (%)	IEEE Std 519 (%THD)
1	Without LCL	Linear (Resistive)	9.40	5
2	With LCL	Linear (Resistive)	1.59	5
3	Without LCL	Non-Linear	17.60	5
4	With LCL	Non-Linear	5.39	5

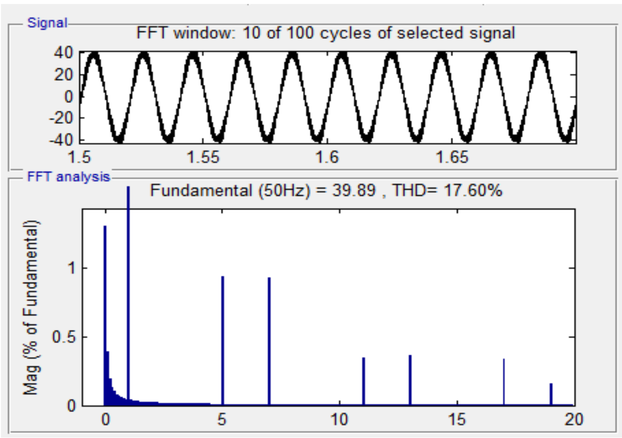

Fig. 11. TDS of grid current phase "a" under t(Ig) under nonlinear load without LCL

The THD analysis proves that the proposed technique improves the harmonics mitigation. The spectrum analysis of the THD waveform meets the standard of IEEE Std.519 requirements. The grid current's THD under non-linear load without/with LCL filter is shown in fig.

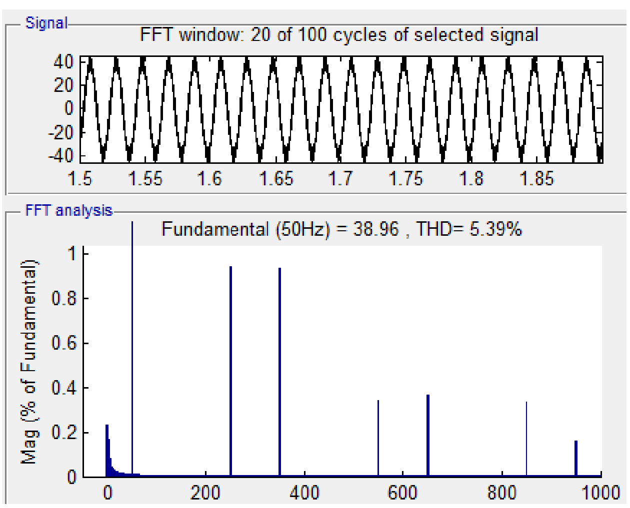

Fig. 12. TDS of grid current phase "a" under (Ig) under nonlinear load with LCL

The total harmonic distortion (THD) of a three-phase inverter interfaced to the grid under linear load is 1.59 percent and 5.39 percent, respectively, as shown in Figures. THD is present in the waveform's spectrum analysis, which fits the IEEE Std.519 criterion. The table compares two THD filters, with the LCL filter having lower THD and being recommended as superior.

5. Conclusion

A 50kW grid-connected inverter with a maximum power point tracker algorithm and a PI controller for grid synchronization has been shown. The feature of a VSI inverter with an LCL filter connected to the grid allows for grid indirect current regulation. used to shape grid current Because using the feedback variable as the grid current causes instability, it should only be used for current output from the inverter. When a damping resistor is used in an LCL filter, the traditional approach of employing stability reveals that feedback may be utilized for grid current. The spectrum analysis (THD) complies with IEEE Std.519 specifications. Because the current-controlled VSI inverter is designed to provide high-quality sinusoidal output current, an LCL filter is employed to reduce output current harmonics. Because the current-controlled VSI inverter is designed to provide high-quality sinusoidal output current, an LCL filter is employed to reduce output current harmonics. The grid current of the inverter is in phase with the grid voltage. In terms of transient performance, the two-stage grid-connected PV system outperformed the single-stage system and reduced total harmonic distortion (THD) in the grid.

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