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Performance Analysis of Grid Interacted Solar PV Array Fed 5-Level Auxiliary Switch VSI

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Abstract—*In this paper a Solar PV (Photo Voltaic) array fed 5 level auxiliary switch VSI is depicted. A Boost converter is to control is dc link voltage is also used which is controlled based on incremental conductance (INC) maximum power point tracking (MPPT). The auxiliary switch 5 level VSI is used and controlled based on sinusoidal pulse width modulation (SPWM). The performance of the grid is studies and presented in this paper. The performance of the system is obtained under variable solar irradiance. The proposed system is modelled in MATLAB/ SIMULINK environment using the Sim Power System and SIMSCAPE tool boxes. The performance of the system is analyzed with simulation.*

1. INTRODUCTION

The rapidly vanishing conventional energy sources (fossil fuels) have put an alarming energy crisis situation in front of the world. Moreover, the deteriorating environmental conditions have moved world's attention toward nonconventional green energy sources.

All available source of renewable energy PV and Wind are most prominent and growing technology. To get optimize utilization of PV as it is nonlinear energy source, it is necessary to provide an electronic controller in between PV source and VSI for various operating conditions and environmental effects. Using this electronic controller it is possible to operate the PV source at maximum power point (MPP), thus improving the energy efficiency of the PV system. Many control algorithms have been reported in the literature to track maximum power from the PV arrays, such as incremental conductance (INC), constant voltage (CV) and perturbation and observation (P&O) etc.

Solar photovoltaic (PV) energy generation systems can be broadly classified into two main categories that are standalone and grid interfaced. Several standalone systems for PV power generation systems considering rural electrification, three-port converters for PV application, PV-based battery charging station, and battery energy management are shown in [3]–[4][5][6]. The batteries are integral part of standalone PV-based system. However, they require frequent maintenance and timely replacement. Therefore, battery-less grid interfaced PV generation systems are more preferred where the grid is available.

To boost the renewable energy application in modern power system, government agencies all over the globe are introducing new schemes and policies. Agencies are trying to motivate the customers by initiating monetary benefits for using renewable source of energy for power generation. People all over the world are awaked by the importance and benefits of solar photovoltaic power system. But the solar power itself is not sufficient to fulfill the requirement of the consumers. So next possible solution emerges is the grid connected system. In grid connected system, the requirement of power is being filled by both an infinite source of power called grid and solar photovoltaic power. Thus the evolution of grid connected photovoltaic system evolved. Few standards are also being imposed by the governments so that the quality and safety of existing power system could be maintained. IEEE has also prepared the standards for connecting distributed resources like solar photovoltaic with the power system, which is accepted globally.

This paper is divided in five section. Section II deals the proposed system configuration and its design criteria in Section III control strategy including INC MPPT algorithm Section IV results and discussion and conclusion in Section V.

2. PROPOSED SYSTEM CONFIGURATION AND ITS DESIGN CRITERIA

DC Link Voltage (Vdc)

The required DC link voltage is estimated as

$$V_{dc} = \sqrt{2} \times V_{rms} = \sqrt{2} \times 230 = 325.26V \quad (1)$$

Hence, DC link voltage is chosen to be 350V.

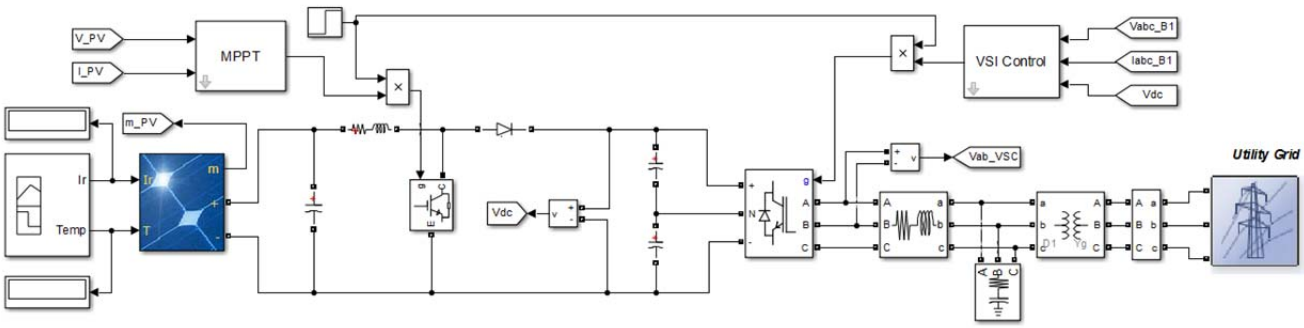

Figure 1. Proposed Model

PV Array Design

	Single Module SPV Array	Complete SPV Array Module
Power at MPP (P_{mp})	160.2W	1602W
Voltage at MPP (V_{mp})	35.6V	178V
Current at MPP (I_{mp})	4.5A	9A
Open Circuit Voltage (V_{oc})	43.8V	219V
Short Circuit Current (I_{sc})	5A	10A
Fill Factor	0.7315	0.7315
No. of Series Module (N_s)	5	
No. of Parallel Module (N_p)	2	

Design of Boost Converter

Boost converter is designed such that it always worked in continuous conduction mode (CCM) irrespective of climatic condition. The duty cycle (D) Inductance Value (L) and DC link capacitor (C) is given as [1].

$$D = \frac{V_{dc} - V_{mp}}{V_{dc}} = \frac{350 - 178}{350} = 0.4914 \quad (2)$$

$$L = \frac{V_{mp} \times D}{\Delta I_L \times f_s} = \frac{178 \times 0.4914}{0.2 \times 9 \times 5000} = 9.7188mH \quad (3)$$

$$\frac{1}{2} \times C \times \left[V_{dc}^{*2} - V_{dc}^{2}\right] = \alpha \times V \times I \times t \quad (4)$$

$$\frac{1}{2} \times C \times \left[305^2 - 325.26^2\right] = 1.2 \times 230 \times 9 \times 0.005$$

$$C = 1486.897\mu F$$

Parameter	Data Calculated	Data Selected
V_{dc}	325.26V	350V
D	0.4914	0.4914
L	9.7188mH	10mH
C	1486.897µF	1500µF

Where, D is duty ratio, C is DC link capacitor.

3. CONTROL STRATEGY

INC MPPT Algorithm

The MPPT approach based on an INC is adopted to track an optimum point on the current–voltage (I_{PV}-V_{PV}) characteristics of the solar PV array. This method explores that the power slope of a PV array characteristics is null at MPP ($dP_{pv}/dV_{pv} = 0$), negative at right of MPP and positive at left of MPP. Therefore, an optimum operating point is derived based on an INC. INC algorithm flow chart is given in fig.2.

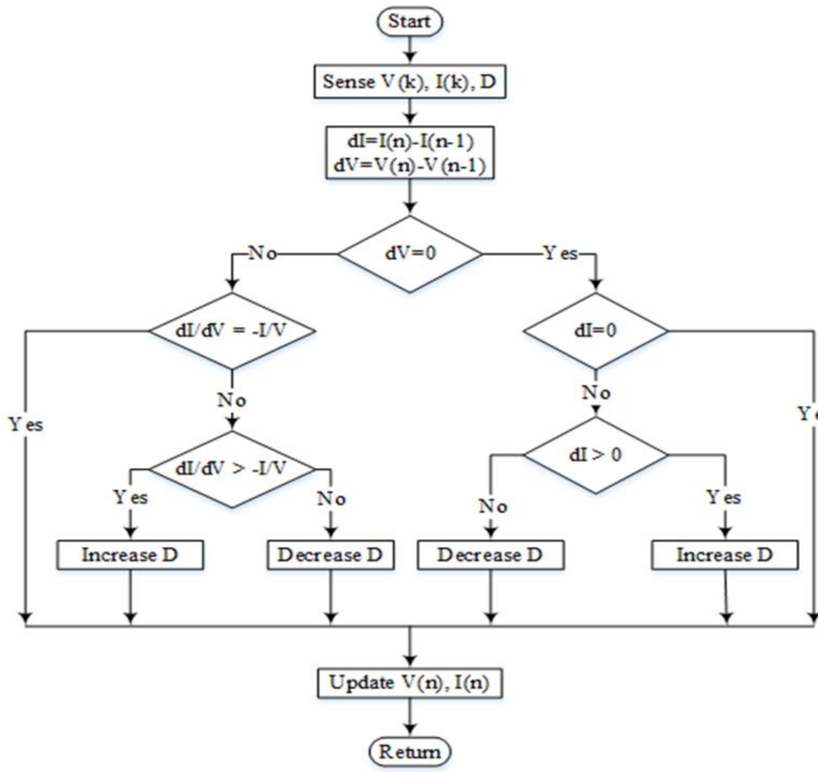

Figure 2. INC MPPT Algorithm Flow Chart

VSI Control

An Auxiliary switch configuration of VSI is given in fig 3 below. By cascading this configuration we can make a three phase VSI.

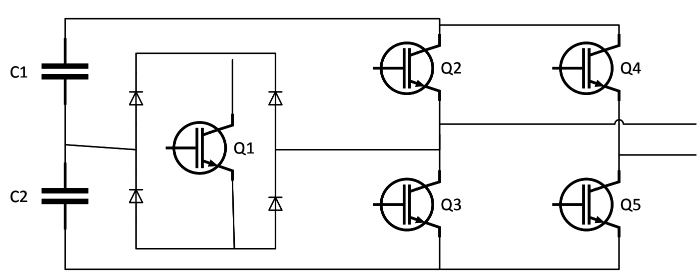

Figure 3. INC MPPT Algorithm Flow Chart

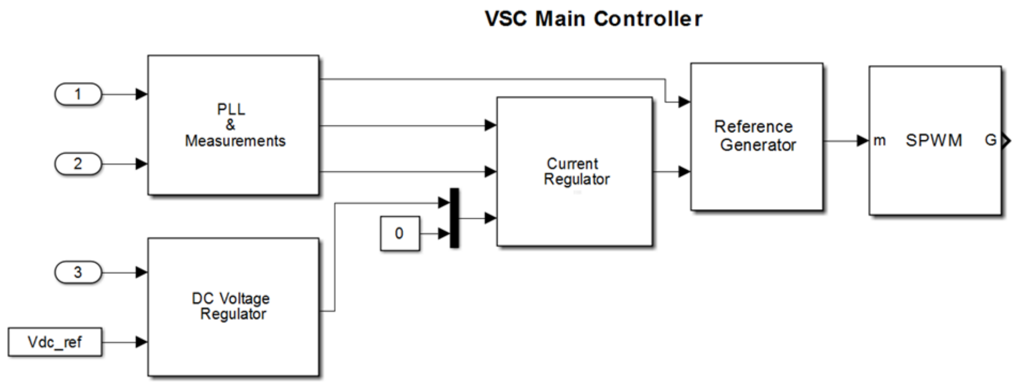

Figure 4. VSI Control

4. RESULTS AND DISCUSSION

The Performance of proposed system is simulated in MATLAB 2016a and given here

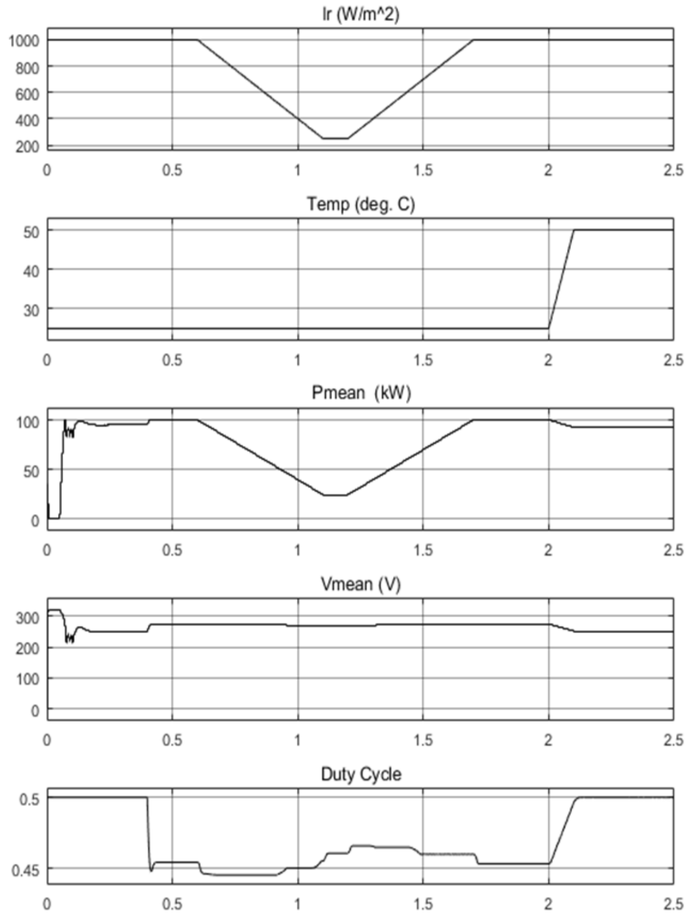

Figure 5. PV Performance and Boost Duty Ratio

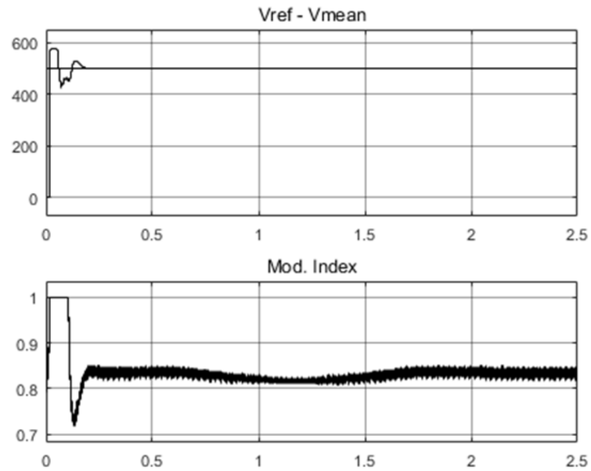

Figure 6. Boost Converter output and VSI Modulation Index

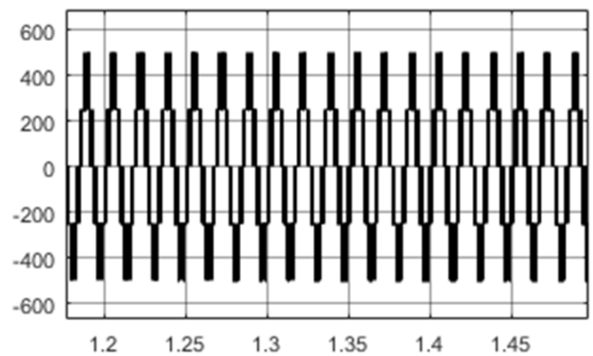

Figure 7. VSI Output

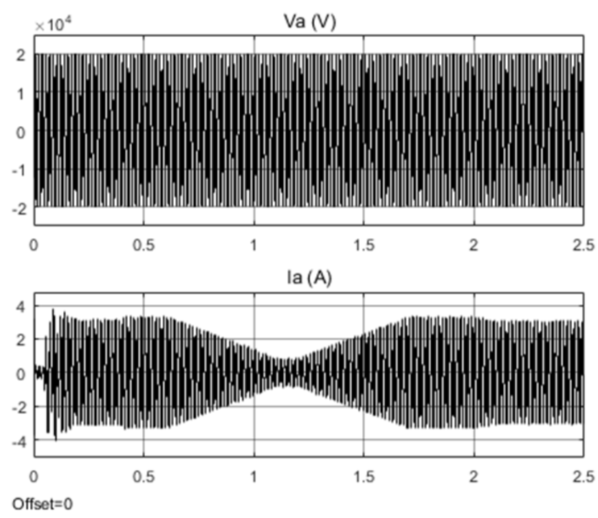

Figure 8. Grid Voltage and Current

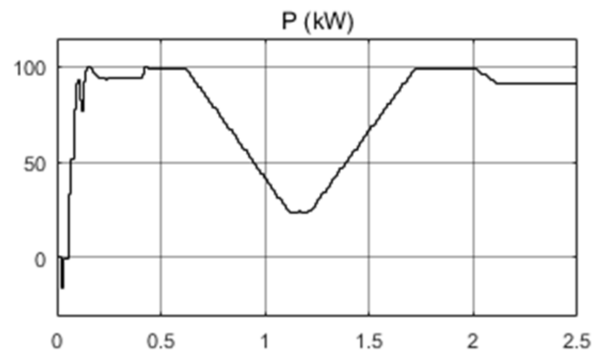

Figure 9. Power transfer to Grid

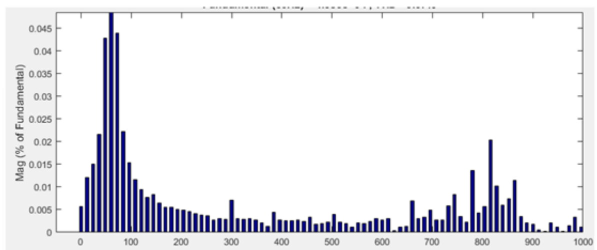

Figure 10. THD in Grid Voltage

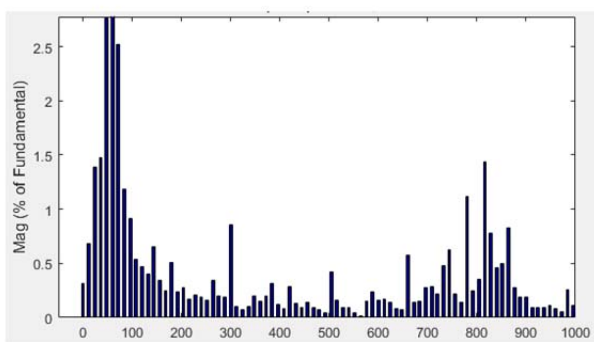

Figure 11. THD in Grid Current

5. CONCLUSION

All simulated result of grid interacted auxiliary switch VSI is shown in section 4 and it gives as per theoretical conclusion. A comprehensive analysis of grid interacted auxiliary switch VSI carried out and simulated result gives desired solution as per theoretical conclusion. The simulation result show 0.07% THD in Voltage and 10.51% during dynamic operation and 4.7% THD during normal operation which is in permissible limit as per IEEE-519 standard. So this system can operate effectively with grid.

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