Simulation of FPGA based Solar Power Distribution & Stabilization System for Fluctuating Load & Grid using MATLAB

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Abstract— This work focuses on the novel control scheme to improve the MPPT performance in Solar PV power in spite of a wide variation in the solar radiation level. The proposed scheme uses FPGA to its versatility and it allows customizable bit widths & massive instruction level parallelism. The proposed FPGA control Scheme for MPPT, Load Stabilization and Power Fed monitoring. Our proposed model has power distribution system which channelize power into battery & grid, according to power demand. It has priority based load stabilization system which stabilize the output even in unbalanced solar radiation & fluctuating load. FPGA is used for parallel processing of multiple parameters like weather condition, temperature, Solar Irradiance etc. The simulation studies are carried out in MATLAB/SIMULINK.
Key words: Solar Cell, Photovoltaic (PV) Maximum Power Point Tracking (MPPT), Array Junction Box (AJB)

I. INTRODUCTION

Growing concerns about energy security & climate change & impeding scarcity of fossil fuels have heightened the interest for harnessing renewable energy resources like Solar PV. The efficient harnessing of solar energy by PV System and directly feeding it to grid in fluctuating load & fluctuating solar irradiance has always been a baffling & profound task. The solar PV power is highly dependent on the fluctuating solar irradiance, the PV cell's temperature, shadowing etc. The solar PV generates DC power whereas Grid supply needs steady AC supply at 50Hz & 230V. So, there is need of grid power stabilization system which monitors and controls the power fed into grid.

The solar PV system is divided into two categories according to its working: non-scheduling type grid connected PV system and schedulable type battery connected system. The system block diagram is shown in fig.2. In this paper, the intended objective is the schedulable grid-connected PV system controlled through FPGA Controller for its optimum performance.

II. MODELLING OF PV SYSTEM

Several PV Modules are connected into series to form PV Array and such PV array connected in parallel through Array Junction Box (AJB) in parallel so that it meets the required voltage and current range of the MPPT in the inverter. Our Proposed simulated model is designed for 250KW Solar PV Installation, where PV modules of Vikram Solar 250 W were used. 1000 such panels are utilized and connected in array in order to form 15 panels in series and such 67 arrays are connected in parallel through AJB.

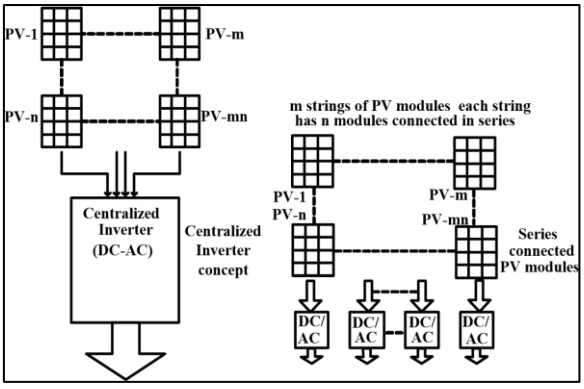


Fig. 1: PV Modules Interconnection [1]

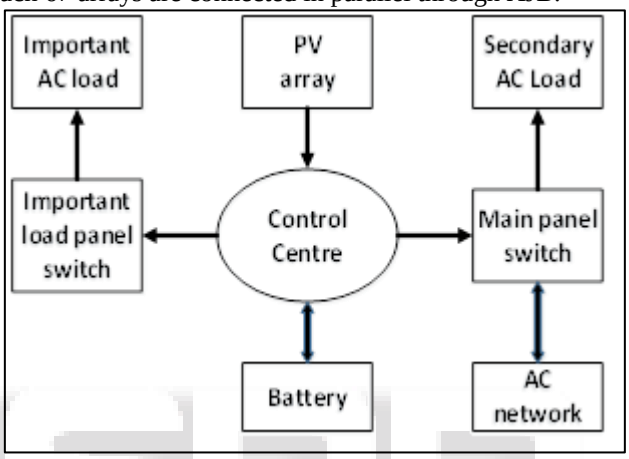


Fig.2. Control Center for priority based Load Switching

Apart from MPPT tracking, FPGA is used to monitor the load requirement and prioritize load according to the requirement. Thus it Controls the system as shown in fig which have dedicated parallel channels to stabilize system individually.

III. MODELLING OF 3 PHASE GRID CONNECTED SYSTEM

In this paper, an FPGA based dedicated MPPT tracker is designed & simulated in HDL Coder of MATLAB/SIMULINK. The FPGA monitors the weather condition, PV cell temperature, Solar Irradiance Shadowing etc. and controls the maximum power point tracking(MPPT) of Solar PV Array. In order to extract maximum generated power from PV during its operation. This designed system consists of three parallel interdependent stages which operates according tovariation of differrent parameters.

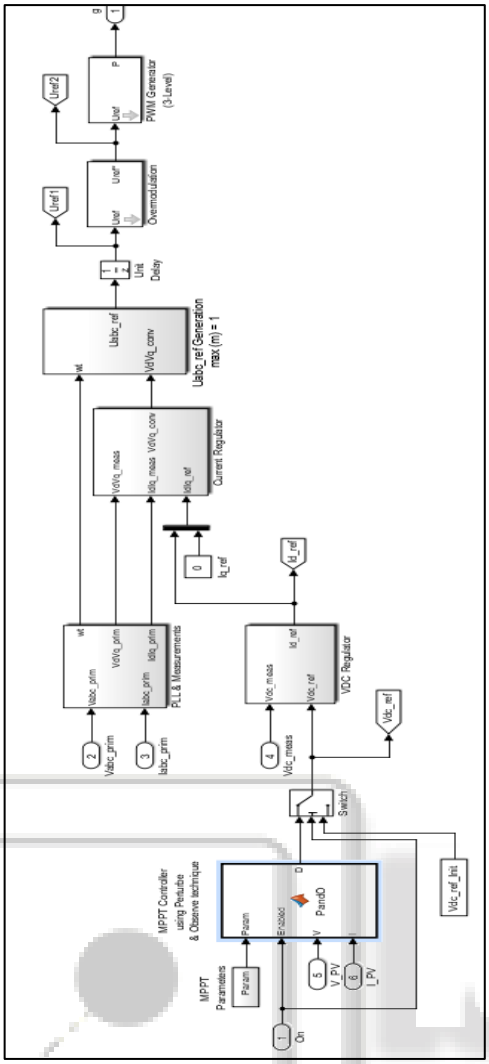


Fig. 3: Modelling of Solar PV powered three phase Grid Connected System

The circuit diagram for photovoltaic system connected to three phase grid at the point of common coupling (PCC) is controlled by FPGA is shown in fig.3. The main components of the system are photovoltaic array, FPGA controlled three-stage converter comprising of DCDC converter, local load and the grid. The photovoltaic array is connected to DC-DC converter which helps in controlling PV array voltage thereby extracting maximum power from it using maximum power point tracking (MPPT) algorithm.

The system is loaded with both static and dynamic load. The FPGA controls the output power by regulating the switching pulses of 3-phase IGBT bridge. And controls the power fed to load.

A. Design of Inverter Logic

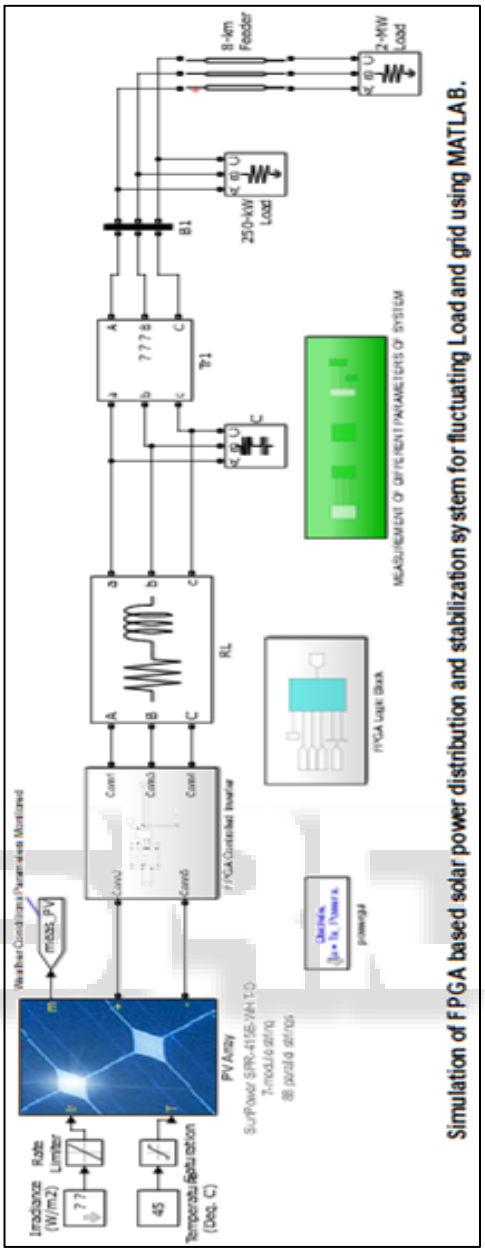


Fig. 4: Design of Inverter Logic

The main components of the FPFA Controlled Inverter are:

1) Maximum Power Point Tracker System (MPPT)
2) DC Voltage Regulator
3) Current Regulator
4) PWM Modulator

The inverter is controlled through parameters like solar irradiance, Solar PV voltage, PV current, temperature, shadowing etc. These parameters are used to determine new reference voltage (Vref). Vrefis fed to DC Voltage regulator where reference current is determined (Iref).

In order to maintain unity power factor, the current regulator keep on monitoring the grid's phase, voltage & frequency, (by feedback from the grid). This control signal from FPGA is passed through 3 level PWM Generator which is used to trigger 3-phase IGBT Bridge.

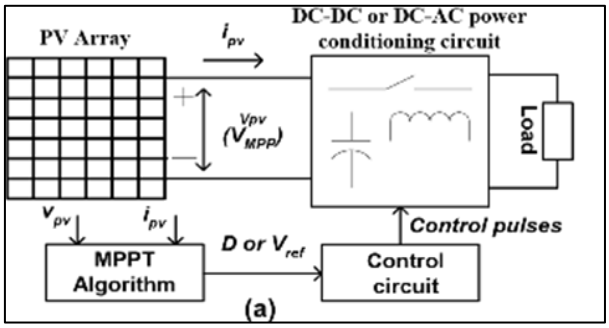


Fig. 5: Design of Inverter Logic

B. *FPGA MPPT Algorithm*

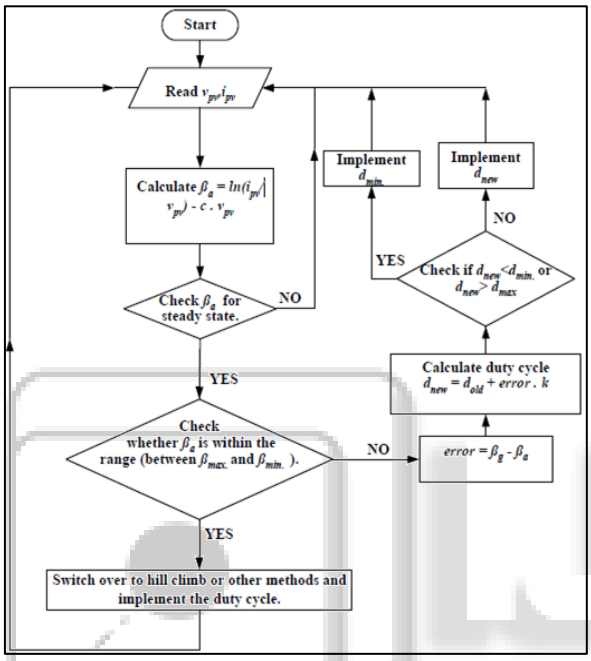
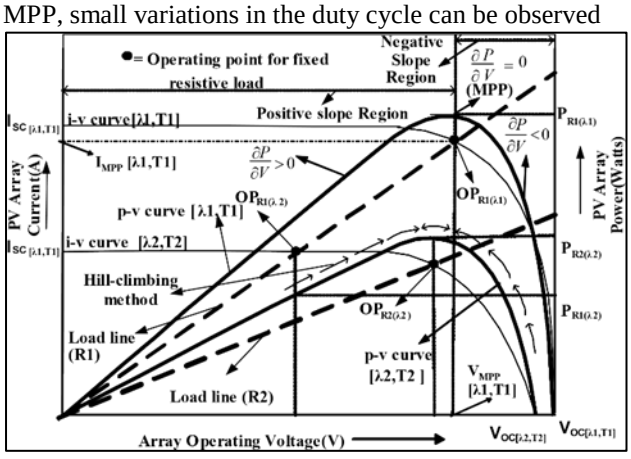


Fig.6.Flowchart Corresponding to Proposed MPPT Technique. [1]

The proposed algorithm is implemented on the PV boost converter system shown in Fig.5. The given system is simulated in MATLAB/SIMULINK. The energy storage element across the solar panel has an influence on the controller action during this transient condition, and this tends to disturb the βversus duty cycle relationship. Variable large steps in duty cycle for tracking MPP can be observed in the simulation during the start or sudden step change in the environmental conditions. As the PV power reaches near MPP, small variations in the duty cycle can be observed



C. *Design of PWM Generator*

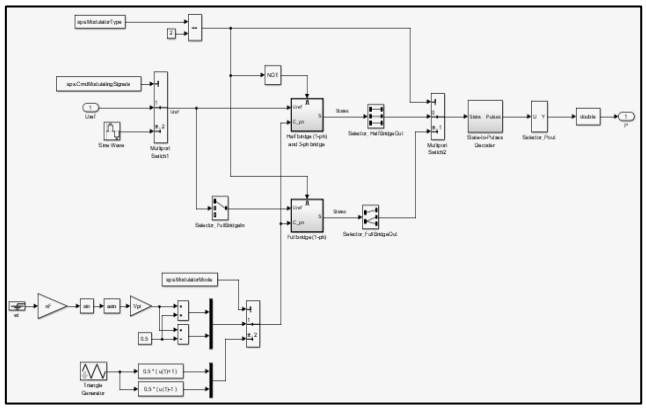


Fig. 7: PWM Generator

From the fig.7. The PWM Generator uses the carrier signal from the control logic. It uses triangular signal for the modulation of signal. This signal is used to trigger the base of the three- phase IGBT Bridge and converts the DC power into AC power keeping 50 Hz frequency and 230V Supply voltage.

IV. SIMULATION RESULTS & DISCUSSION

The experimental results and corresponding waveforms are shown in the following discussions.

A. *Standard Testing Condition*

In this testing condition all the parameters are taken in normal conditions.

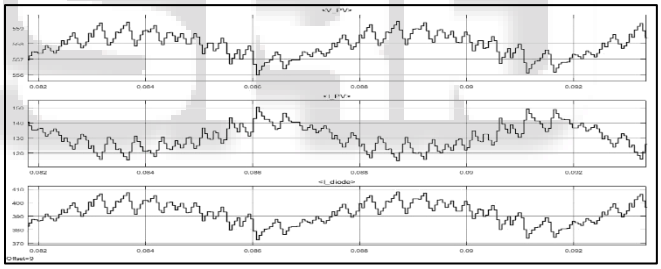


Fig. 8: PWM Generator (a) PV Voltage, (b) PV Current, (c) Diode voltage

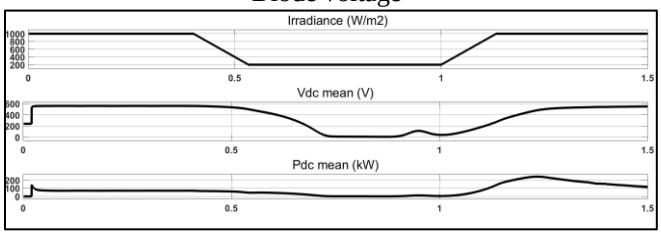


Fig. 9: Solar PV parameters: (a) PV Irradiance, (b) PV Voltage, (c) Mean PV Power

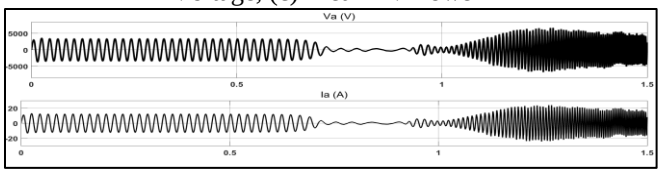


Fig. 10: Inverter Ouput parameters: (a) Output Voltage (Va), (b) Output Current(Ia)

B. *Change of Climatic Condition*

During sudden change in Soar irradiation due to cloud or shadow, the PV array may got affect the generation

significantly. So, the generation may unbalance the grid. Our proposed model stabilizes such fluctuation in few seconds delay as shown in Fig.9.

V. CONCLUSION

This paper presents an approach of modelling & controlling of a grid-connected PV- System through FPGA, to enhance the response time and power tracking. Due to high speed dedicated parallel processing channels of 100Khz, the chopping is faster. Hence, the output is pure sine wave & current maintains unity power factor. The simulation of the whole system has been done in MATLAB/SIMULINK & it shows an excellent performance of both power distribution stabilizations.

REFERENCES

[1] Anish NK, S. Moorthi, Murali Chakravarthi,M.P. Selvan,"FPGA Based Control Scheme for a Single-Stage Grid-Connected Solar Photovoltaic System" IEEE 2013.
[2] Bader N. Alajmi, Khaled H. Ahmed"Single-Phase Single-Stage Transformer less Grid-Connected PV System" IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 28, NO. 6, JUNE 2013.
[3] Sidharth Rajamohan, ChelladuraiVignesh"Modelling of Solar Array and Design of a Vector based Dual Band Hysterisis Current Control Technique for a 3 Phase Grid Connected PV System" 2012 IEEE.
[4] Fatima Zahra Amatoul Moulay Tahar Lamchich Abdelkader Outzourhit"Design Control of DC/AC Converter for a grid Connected PV Systems with Maximum Power Tracking using Matlab/Simulink" 2010 IEEE.
[5] Hamid R. Teymour, Danny Sutanto"Novel Modulation and Control Strategy for Five-level ANPC Converter with Unbalanced DC Voltage Applied to a Single-Phase Grid Connected PV System"2013 IEEE.
[6] Rupesh G. Wandhare and Vivek Agarwal"Novel Control Scheme to Reduce the Effect of Intermittent Solar Radiation on the Grid Connected PVSystem Power Output Without Losing MPPT"2012 IEEE.

