Design and Implementation of Photo Voltaic source to the Microgrids in Islanded Mode through Matrix converter

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Abstract— *A microgrid is an electrical system which includes load and distributed generation that can be operated in parallel to the utility grid or as an electrical island. So the microgrids are capable of operating in two modes namely grid-connected mode or Islanded mode. Islanding condition describes the state of a microgrid when it is isolated from that of the utility grid. However the islanded operation of microgrid seeks a self generation and other essential converters and controllers for interfacing with the loads. This paper proposes building up of a Photovoltaic system for its Distributed Generation , Matrix converter and other control elements for the grid-connected and islanded operation*

Index Terms—Distributed generation (DG), Photo voltaic (PV), Grid connected operation and Islanding operation

I. INTRODUCTION

Microgrids represent an electrical network of a small community which includes load and distributed energy system or energy resource. This so contained microgrid can be operated in parallel with that of the broader utility grid or as an electrical island. Thereby we say that the microgrids are capable of operating in two modes namely Grid-connected and islanded mode.

Grid-Connected operation defines where the microgrid is connected to utility grid for its energy source. As in the case of islanding, the microgrid is cut-off or isolated from that of the utility grid. When that is so the case, for the continued operation of microgrids, it must have its own generating system i.e., the distributed generating system. This distributed generating system employs converters, filters and other control elements for the switching and controlled operation between the grid-connected and intentional islanding modes.

In older stages there was disconnection of DG's once the system is islanded was used. But nowadays in this competitive power environment, there are increased competition among the power companies to secure more and more consumers with higher degree of service, quality and reliability of power supply.

Here, it is a pressure to maintain higher degree of uninterrupted power supply. So in this scenario, the disconnection of DG's following the disturbances or faults will not be a feasible solution.

So practical solution will be the microgrids with their own DG's and their continued operation even at islanded or isolated situation. So as soon as the microgrid with load connected to the utility grid and Photovoltaic based DG system must detect the absence of power supply from that of the main grid. Then immediately it must cut-off the load from utility grid and connect it to the photovoltaic distributed generated system present within the microgrid. And hereby the PV designed supplies the worst case load in the grid.

Thus our proposed system includes a photovoltaic system with a data sheet comprising input data of temperature and irradiation. Also a matrix converter is employed to convert so produced DC voltage to 3-phase AC voltage and other filters, controllers and breakers are designed using MATLAB/SIMULINK.

II. MODELING OF PV SYSTEM

A photovoltaic system is one which converts the light energy into electrical energy. The basic or foremost device of a photovoltaic system is photovoltaic cells which converts the incident photons to electron or hole pairs.

Multiple photovoltaic cells are grouped in order to form the panels and PV modules. Also again the panels are arranged in series and parallel combinations to form large photovoltaic arrays.

A. Ideal photovoltaic cell

The design procedure of a photovoltaic cell enables to understand the building up of photovoltaic system (PV) using photovoltaic arrays. Thus Fig.1 shows the equivalent circuit of an ideal photovoltaic cell.

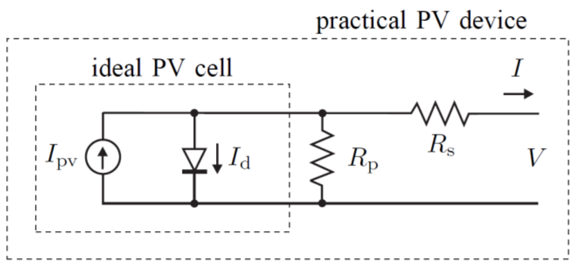


Fig.1. Single-diode model of the theoretical photovoltaic cell and equivalent circuit of a practical photovoltaic device including series and parallel resistances.

Also the fore given equation (1) describes the I-V characteristic of an ideal photovoltaic cell.

$$I = I_{pv,\,cell} - I_{0,\,cell}\left[exp\left(\frac{qV}{akT}\right) - 1\right] \quad (1)$$

Where

$I_{pv,\,cell}$ – is the current generated by incident light

$I_{0,\,cell}$ – reverse saturation or leakage current of diode

k – Boltzmann constant

T – Temperature of p-n junction

a – ideality constant of diode

Also Fig. 2 shows the I-V curve of a photovoltaic cell with light generated current I_{pv} and diode current $I_{d.}$

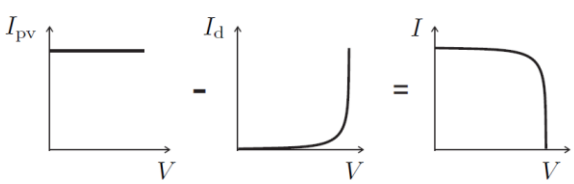


Fig.2. Characteristic I-V curve of a photovoltaic cell

B. Modeling of photovoltaic array

As the equation (1) represents the elementary photovoltaic cell which do not show the I-V characteristic of a practical PV array. As already discussed the PV array consists of many photovoltaic cells in series and parallel arrangements.

Let N_s be number of cells in series and N_p denote number of cells in parallel arrangement. The c7sells connected in series provide greater voltage outputs and similarly the cells connected in parallel provide greater current outputs.

Primarily the electrical generators are classified into two types namely current and voltage sources. But the practical photovoltaic device represents the hybrid behavior thus by achieving two properties ideally as current or voltage sourceis purely depending on the operating point as shown in Fig.2.

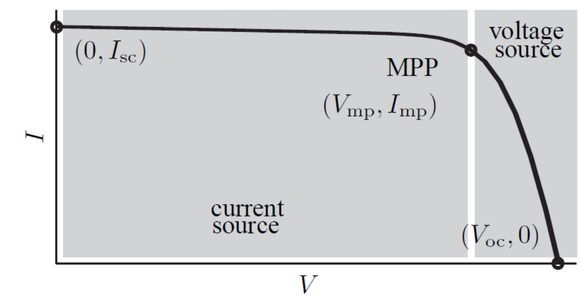


Fig.3 I-V characteristic of practical PV device

The PV device has series resistance R_s whose influence is stronger when the device operates in voltage-source region and similarly the parallel resistance R_p influence is stronger in the current source region. Whereas R_s is the sum of structural resistances and R_p is the resistance due to leakage current of p-n junction.

Obtaining to the conclusion, we say that I-V characteristic of PV device not only depends on the internal characteristic but also with external influences such as the temperature and irradiation which is influenced by equation (2).

$$I_{pv}=\left(I_{pv,n} + k_1\Delta_T\right)\frac{G}{G_n} \quad (2)$$

Where G is irradiation on surface and G_n is nominal irradiation.

C. Simulation of PV array

The simulation of photovoltaic array is done with photovoltaic model's equivalent circuit as in Fig.1. There are two possible methods of simulation strategies.

First model using one current source (I_m) and two resistors (R_s and R_p) as shown in Fig.4, where this circuit may be implemented using any circuit simulator and values are calculated by computational block. The second model comprising of only one current source is obtained by numerically solving I-V equation is given in Fig.5

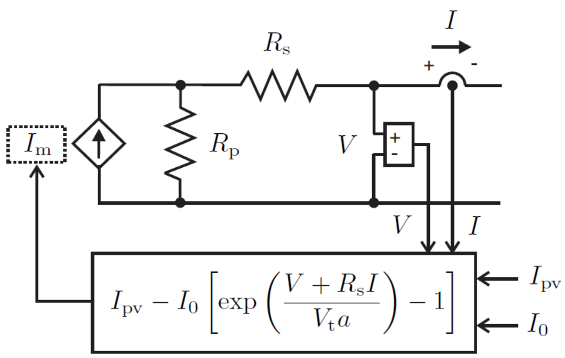


Fig.4. Photovoltaic array model circuit with a controlled current source, equivalent resistors and the equation of model current (I_m)

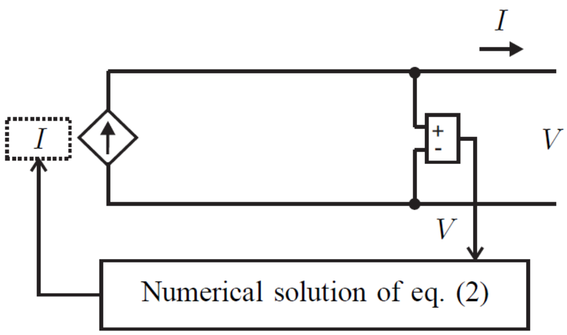
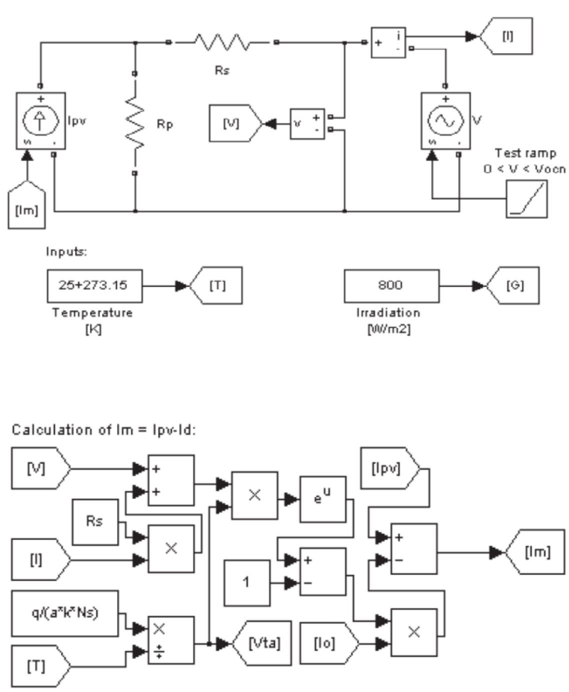


Fig.5. Photovoltaic array model circuit with a controlled current source and a computational block that solves I-V equation

And the Fig.6. shows the PV model implemented using MATLAB/Simulink using SimPowerSystems blockset.



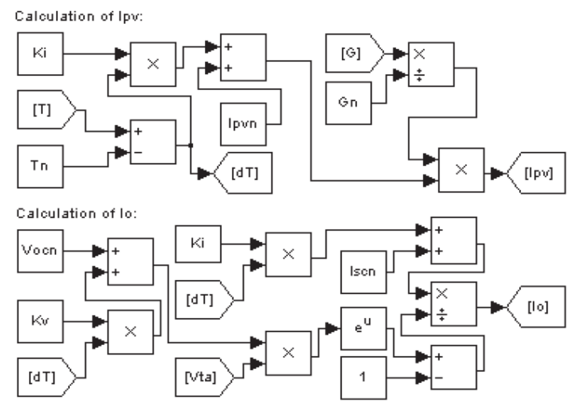


Fig.6. Photovoltaic circuit model built with MATLAb/SIMULINK

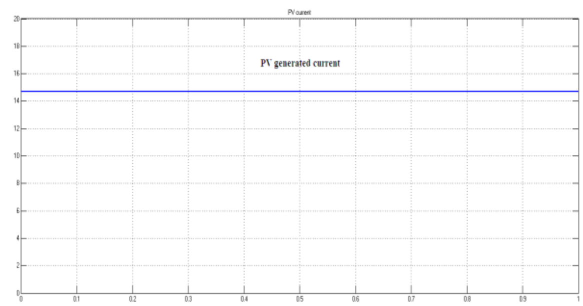


Fig.7. Generated current of PV modeled in MATLAB/SIMULINK

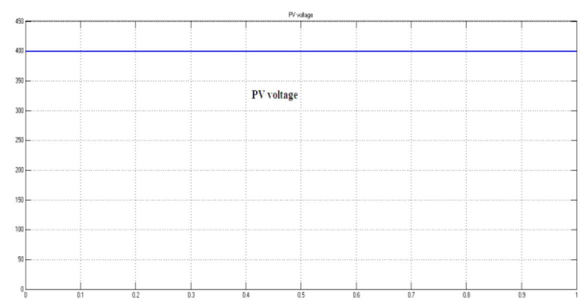


Fig.8. Generated voltage of PV modeled in MATLAB/SIMULINK

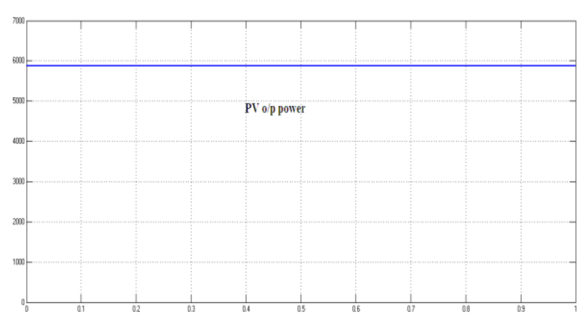


Fig.9. Output power of PV modeled in MATLAB/SIMULINK

Thus MATLAB/SIMULINK model of PV and their corresponding results are shown in figures 6,7,8 and 9. And the modeled PV derives necessary output power for the continued operation of microgrid.

III. Converters

A. Introduction

As our proposed system involves the photovoltaic system for its back-up generation i.e., distributed generation, dc-ac converters are essential for synchronizing with that of 3-phase grid. Thus here we employ a DC-AC Matrix converter which adopts pulse density modulation which primarily involves Space Vector Modulation method.

B. Circuit Configuration

The main circuit configuration of the proposed DC-AC matrix converter is shown in Fig.10. This circuit involves full bridge inverter by phase shift control on the primary side and matrix converter with pulse density modulation based space vector modulation on the secondary side. Here in this case both are circuit configurations are integrated.

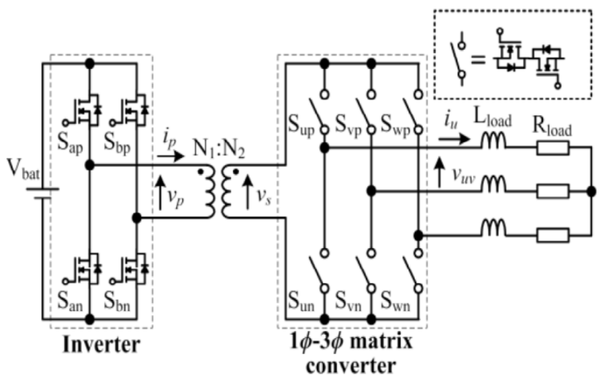


Fig.10.Circuit diagram of DC-AC converter with matrix converter

The proposed matrix converter promises to achieve reduction of bulkiness of existing DC-AC converter and also ensure long lifetime. The next ultimate task is to reduce switching losses that occur when PDM is used in matrix converter. So therefore ZVS (Zero Voltage Switching) is used where output of matrix converter is generated by PDM at zero voltage period.

C .Control Strategies

1. Phase shift control:

The Fig.11 shows the control block diagram of the inverter operation by the method of phase shift control. 3-level output voltage is derived out and thus the matrix converter turns out at zero voltage period provided by the inverter.

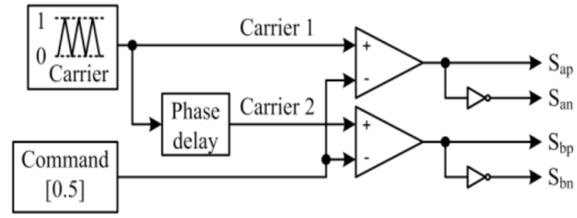


Fig.11. Control block diagram of inverter operation

2. PDM based SVM technique:

The control block diagram and operating waveforms with PDM is shown in Fig.12 and Fig.13. This above mentioned figures ensure zero voltage switching (ZVS) of the matrix converter. The PDM controls the pole and density of constant width pulse. Also these pulse signals are used as minimal unit of the output voltage waveform.

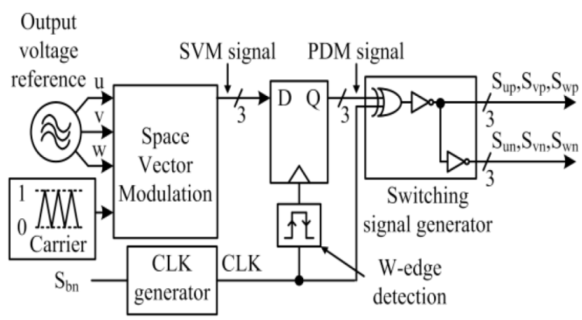


Fig.12. Control block diagram of the matrix converter

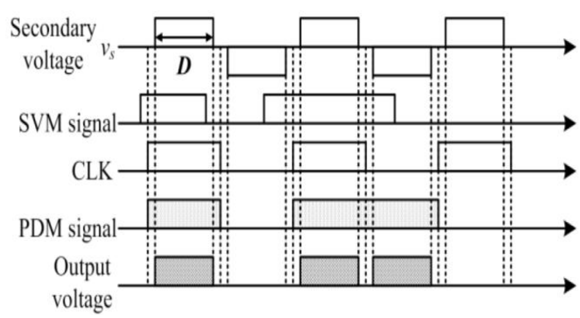


Fig.13. Operation principle of the PDM for matrix converter

The input of matrix converter is a square waveform with phase shift controls which so involves a D-flip flop. In order to yield gate signals the control block includes D-flip flop to quantize the duty references generated by SVM. The clock (CLK) is to operate D-flip flop. As a result Pulse Density Modulation (PDM) based Space Vector Method (SVM) and Zero Voltage Switching (ZVS) of the matrix converter is implemented where we achieve 3-level AC output.

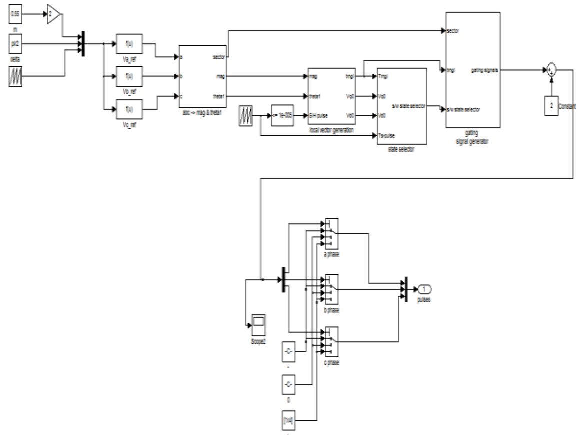


Fig.14. Simulated PDM based SVM of Matrix converter

IV. FILTERS

The usage of power converters such as matrix converter play a major role in power transfer from renewable energy source i.e., PV system to the utility or load. Hence LCL filter is often used to interface these converters or inverters with the grid. It filters out the harmonics produced by the matrix converter and also used to convert square wave to sine wave.

Commonly higher order LCL filter has been used instead of L-filter for removing the ripples out from the output of the matrix converter. The LCL filter achieves higher attenuation with reduction in size and weight and thus providing economy.

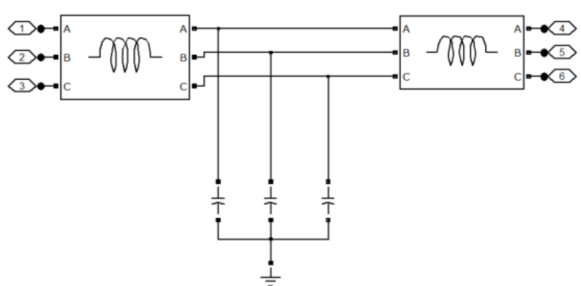


Fig.15. Circuit representation of an ordinary LCL Filter

LCL filters are mostly employed in grid-connected inverters and PWM or PDM based converters because of their minimization of amount of current distortion injected into the grid. Thus the proposed LCL filter performs the functions such as removal of ripples, reducing the switching frequency, reduction of size and weight and coupling current like performance to the utility grid.

V. OTHER COMPONENTS

The other components used other than which mentioned are breakers, measurement blocks, utility grid and three-phase RLC load.

A 3-phase RLC load and its supplier say utility grid is designed using MATLAB/SIMULINK. Finally the left out devices are Breaker switches which is the most important parameter block of our simulation. The breakers used here are 3-phase breakers which are used on the both sides of the worst case load. 3-phase breakers decide the connection of load to either the utility grid or the distributed generation of photovoltaic source.

VI. SIMULATION AND RESULTS

As completed with all the blocks of building the simulation in this paper is done with providing transition time to the breaker switches for when the load should be connected to the grid or to the PV source. Also during the absence of power in the grid, Islanding situation occurs and here the breakers act fast for the continued operation of loads thus providing uninterrupted power supply. The simulated system as whole is shown in Fig.16. The corresponding output of the system at Grid-connected mode and Islanded mode is shown in Fig.17 and Fig.18. The entire simulation is done using MATLAB/SIMULINK.

VII. CONCLUSION

Thus the paper proposes a control strategy and design of PV based back up generation for a microgrid is designed. Matrix converter is designed as a coupling between the load and the source for the purpose of conversion of DC-AC voltage and to provide a constant voltage to the load. The filters are designed to filter out the harmonics and ripples with the breakers performing Grid-connected and islanded mode operation of the grid and their corresponding outputs are provided. Our future focuses on the islanded operation of system using islanding detection algorithm. Also we plan to provide voltage support to load at grid-connected mode under low voltage periods without islanding the system.

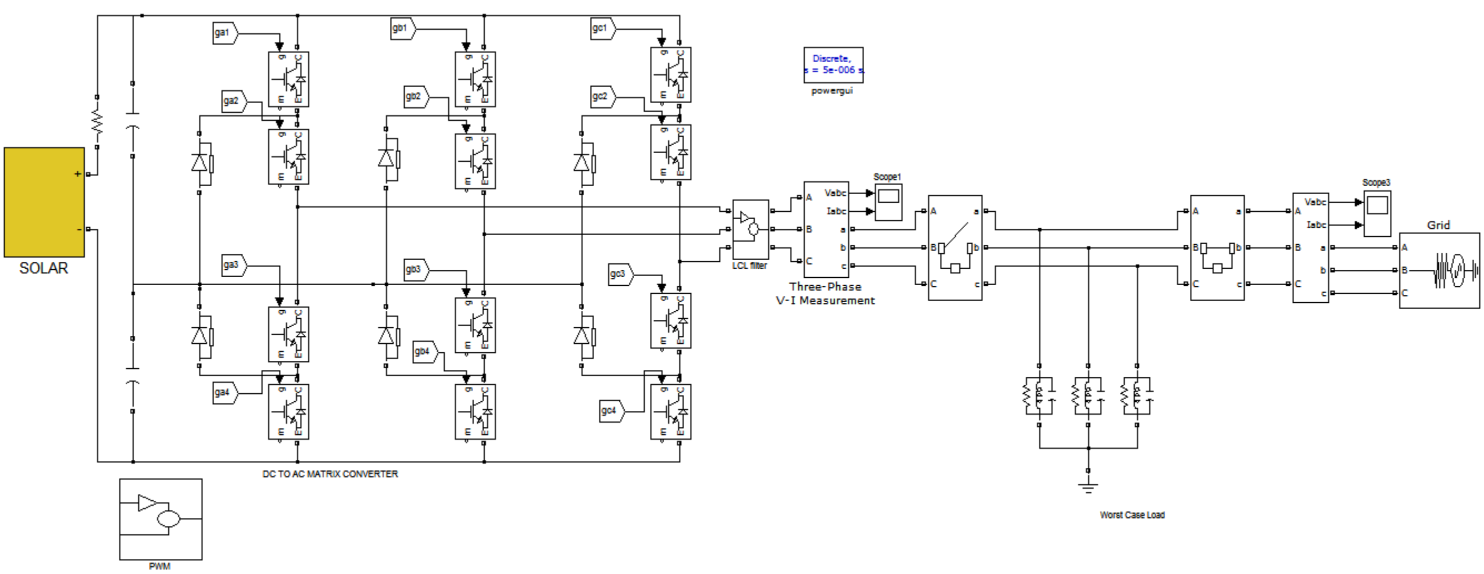


Fig.l6. Entire Simulated system as whole designed using MATLAB/SIMULINK

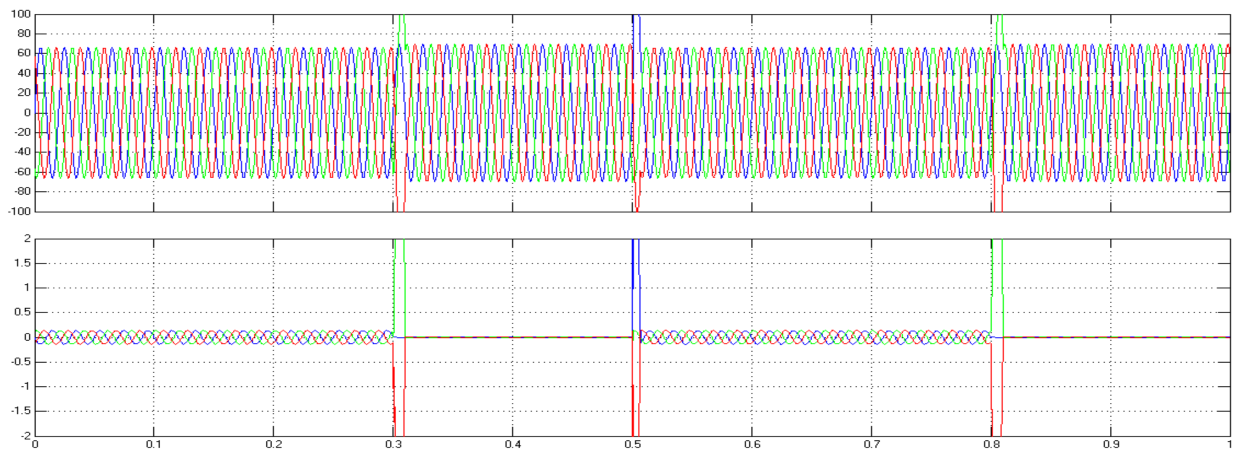


Fig.17. Output of simulated system in Grid-connected mode

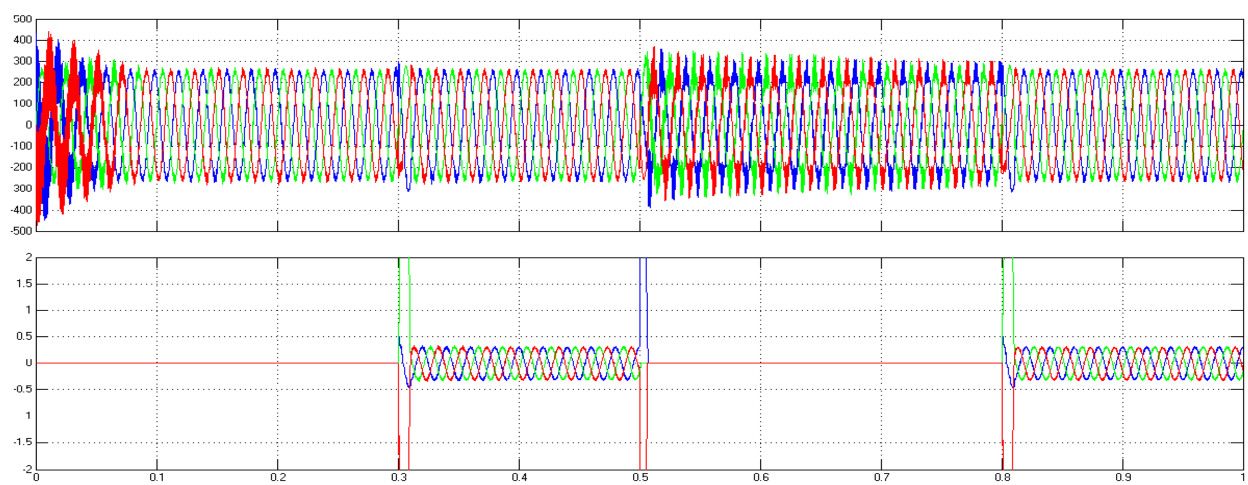


Fig.18. Output of simulated system in Islanded mode

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