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Implementation of Photovoltaic Cell and Analysis of Different Grid Connection

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Abstract:- This paper focuses on best modelling of a photovoltaic cell by making it closed loop. This model is based on mathematical equations and is described through an equivalent circuit including a photocurrent source, a diode, a series resistor and a shunt resistor. The developed model allows the prediction of PV cell behaviour under different physical and environmental parameters. The model can also be used to extract the physical parameters for a given solar PV cell as a function of temperature and solar radiation. In addition, this study outlines the working principle of PV module as well as PV array. In order to validate the developed model. The PV model is connected into different grid systems and analysed the performance of different systems. The comparative study also made in accordance with ripple output voltage by using the result analysis dc grid connection and two stage ac grid connection is made closed loop for the best performance.

Keywords:- Photovoltaic, voltage ripple, PI controller, maximum power point tracking (MPPT), voltage regulation, inverter.

I. INTRODUCTION

Over the past few decades, the demand for renewable energy has increased significantly due to the disadvantages of fossil fuels and greenhouse effect .Among various renewable energy sources the most popular one is solar energy. Standalone PV system is the popular way of utilizing solar energy. PV panels are used to convert the solar energy into electrical energy without pollution. In the past few years, solar energy sources demand has grown consistently due to the following factors: 1) increasing efficiency of solar cells; 2) manufacturing technology improvement; and 3) economies of scale [1]. A major application of PV is in the area of distributed or dispersed generation (DG). DG facilitates injection of locally generated power into the grid. While DG has several advantages, it also poses several challenges. As the capacity of PV system growing significantly, the impact of PV modules on power grid cannot be ignored. DG penetrates deep into the existing power systems, problems such as voltage variation, instability, interference, flicker, increase of harmonics and frequency drift etc. become more pronounced. Practical problems associated with the interaction of the PV system with the grid are the quality of power delivered to grid i.e. the power quality problems. Among these problems harmonics is found to be most important issue for grid interconnected PV system [2]. The output power produced by photovoltaic modules is influenced by the intensity of solar cell radiation, temperature of the solar cells and so on. When the quantity of this kind of power output is large enough, voltage pulsation on transmission lines will be obvious and difficult to control. Most of the renewable energy sources are connected to the grid by means of inverter. It is reported that the inverter supplies power of low quality at low level of solar radiation [3]. Under such conditions the PV array power and the corresponding inverter input power are low. The inverter when operating under such low input power exhibits large nonlinearity, hence output power with more harmonics. For reducing harmonics in grid connected PV system several methods have been analysed.

In this paper, firstly a PV module is designed with MPPT for the maximum working efficiency under any irradiance changes and temperature variations [4]. The PV model made is connected to DC grid for the using of DC application and PV model also connected in single stage and two stages embedded with an inverter for the AC applications [5]. Comparative study between all the grid connections is done and best results are analysed in case of closed loop implementation of DC grid and two stage AC grid connection. The complete system is simulated using MATLAB- SIMULINK and the results are presented.

II. MODELLING OF PV

The equivalent circuit of the PV cell is shown in figure 1. The PV model is a The PV module is a nonlinear device and can be represented as a current source model, as shown in figure 1.The traditional I − V characteristics of a PV module, neglecting the internal series resistance, is given by the equation (1)

$$I_o = N_p I_g - N_p I_{sat} \left\{ exp\left(\frac{qV_o}{AKT}\right) - 1 \right\} - I_{rsh} (1)$$

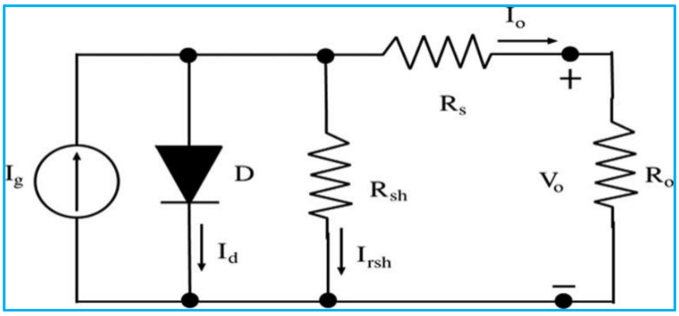


Fig. 1. Equivalent circuit of a PV module.

Where Io and Vo are the output current and output voltage of the PV module, respectively, Ig is the generated current under a given insolation, Isat is the reverse saturation current, q is the charge of an electron, K is the Boltzmann's constant, A is the ideality factor, T is the temperature (K) of the PV module, Np is the number of cells in parallel, and Irsh is the current due to intrinsic shunt resistance of the PV module. The saturation current Isat of the PV module varies with temperature according to the following equation (2).

$$I_{sat} = I_{or}\left[\frac{T}{T_r}\right]^3 exp\left[\frac{qE_g}{KT}\left(\frac{1}{T_r}-\frac{1}{T}\right)\right](2)$$

$$I_g = I_{sc}\frac{S_i}{1000} + I_t(T - T_r)(3)$$

WhereIor is the saturation current at Tr , Tr is the reference temperature (K), Eg is the band-gap energy, It is the short circuit current temperature coefficient, and Isc is the short-circuit current of PV module. The current due to the shunt resistance is given by (4)

$$I_{rsh} = \frac{V_{oc}}{N_s R_{sh}}(4)$$

Where Ns is the number of cells in series and Rsh is the internal shunt resistance of the solar module. For the solar MATLAB/SIMULINK based computer simulations.

III. MPPT DESIGN

The utilization of solar PV cell is hampered by the fact that the power Vs voltage curve in solar cell has a unique maximum power at a particular operating voltage (called as Vmpp) [5]. MPPT is used to deliver the maximum power at all varying input conditions. MPPT is designed by Perturb and Observe Algorithm hence it's effective and popular. The following equation is followed to locate the voltage at which the MPPT is reached.

Vmpp(*k*)=*Vmpp*(*k*-1) + *M**sign(*dp/dv*)

where, M is steep voltage and k is the iteration and dp/dv is change in PV power with respect to PV voltage.

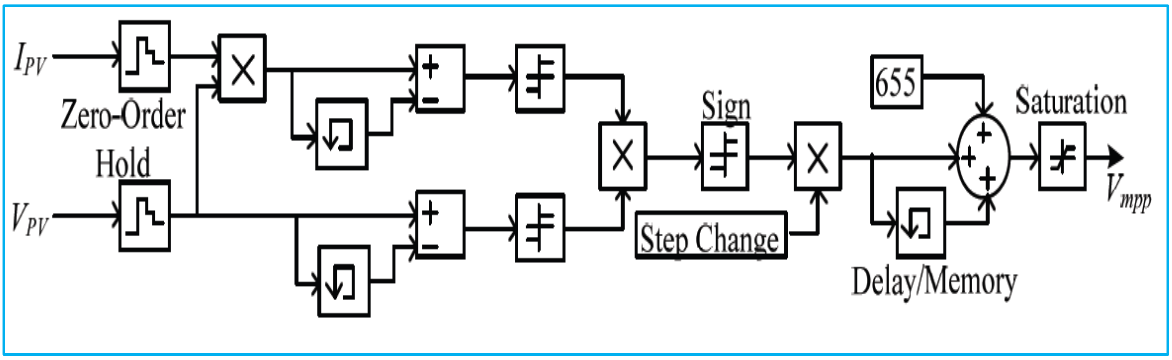


Fig. 2: P&O algorithm

IV. DIFFERENT GRID CONNECTION TOPOLOGY

A. DC grid connection

PV model is a non – linear system that means the ratio between current and voltage changes with when either current or voltage changes. PV model connected with boost dc – dc converter gives the linear output of continuous input current and a discontinues output current. Dc- dc conversion makes the output voltage 3 to 4 times the input voltage according to duty ratio.

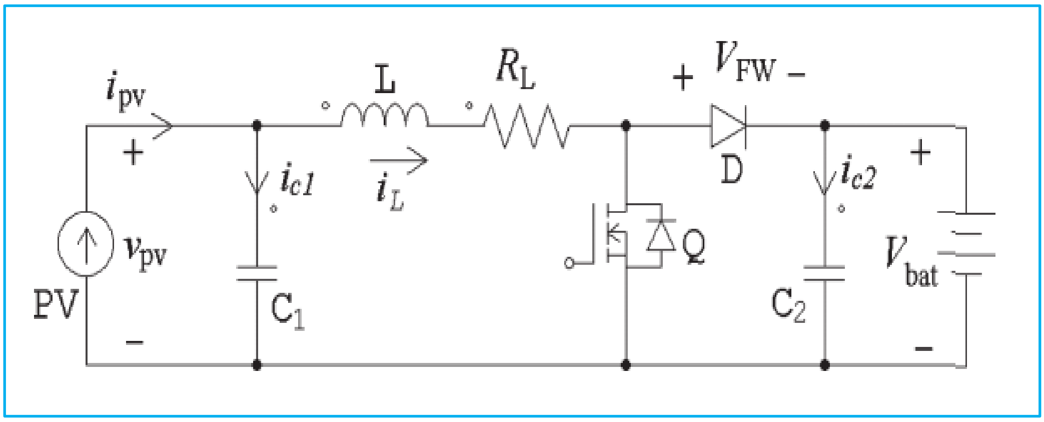


Fig. 3: dc grid connection

B. DC closed loop grid connection

PV model output is passed through a boost converter an increase in output voltage occur but due to that the voltage ripple increases as well as control of output voltage to a constant value is necessary. Irradiance and temperature changes occur in the PV will not affect the output voltage. The closed loop is implemented using a PI controller.

C. Single stage AC grid connection

PV output is obtained as DC output so we need to convert it to an AC output for the usage of AC appliances.

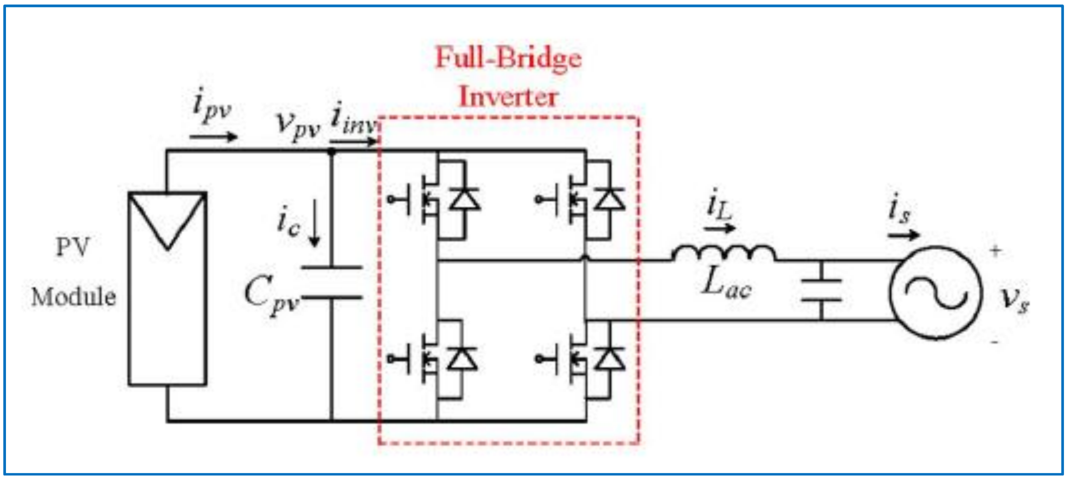


Fig. 4: Single stage grid connection

D. Two stage grid connection

PV output is DC in nature so the output is passed through dc-dc converter for the regulated output. The output can be changed in order to get the required output for the ac appliances.

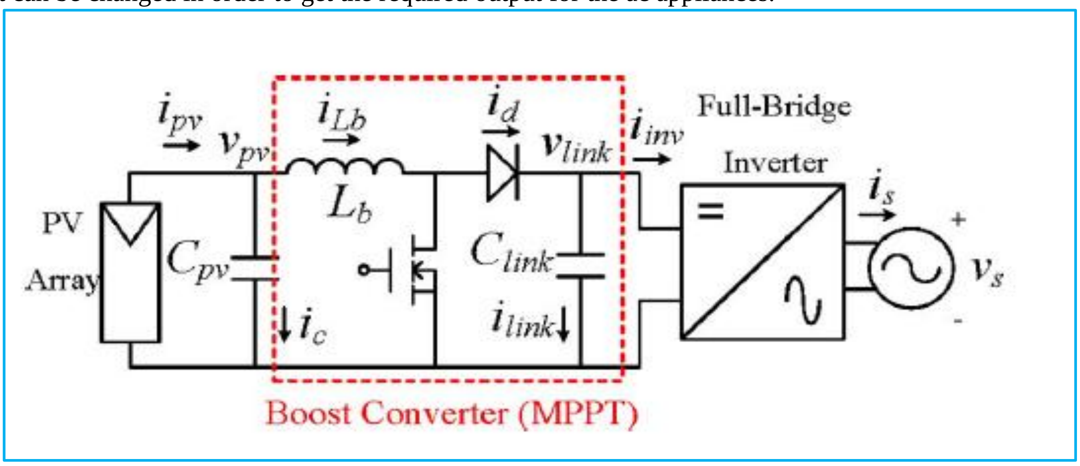


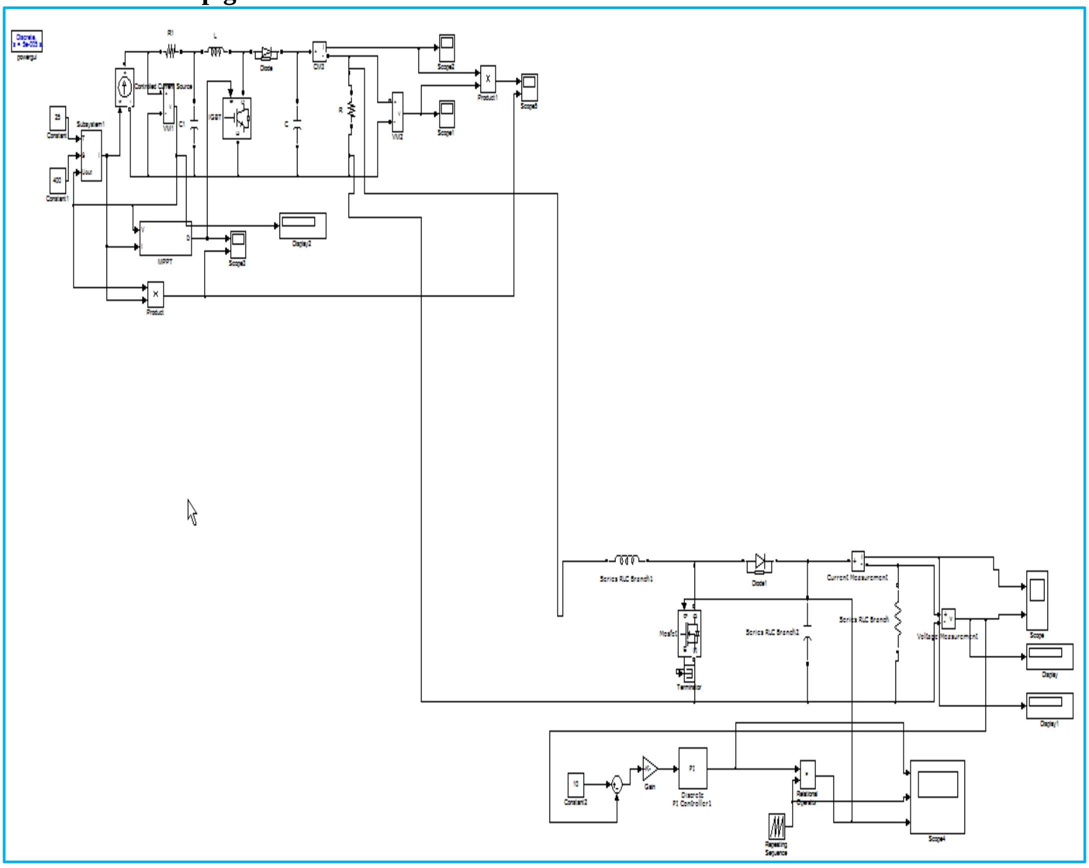
Fig. 5: Two stage grid connection

E. Two stage closed loop

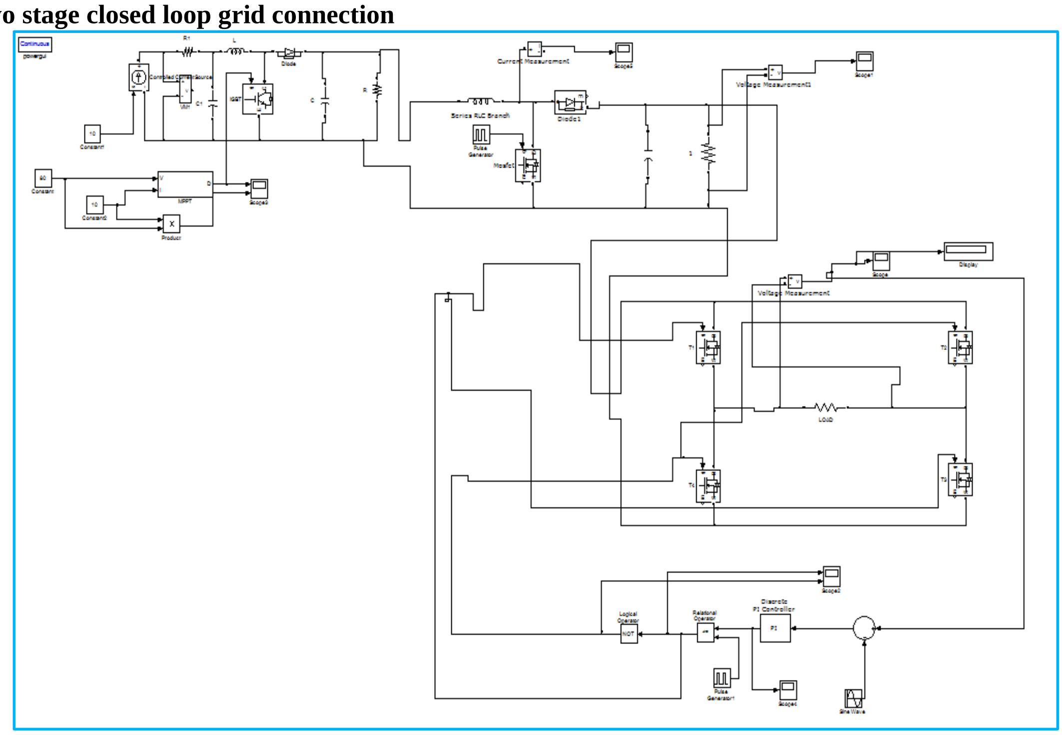
PV output voltage is of large ripple components so in order to avoid the ripple and make it a steady ac implementation of closed loop is necessary. PI controller is used to make it closed loop.

V. SIMULATION OF IMPLEMENTED GRID SYSTEMS

A. DC closed loop grid connection



B. Two stage closed loop grid connection



VI. SIMULATIONRESULTS

A. Closed loop DC grid

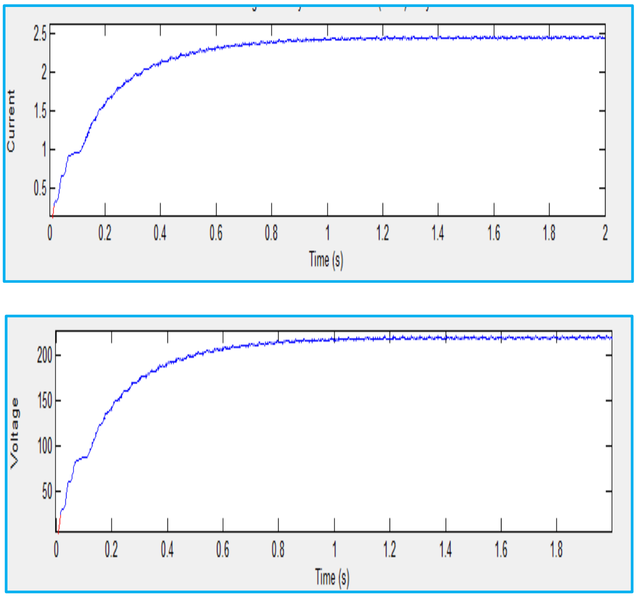


Fig. 6: Closed loop DC grid connection

Closed loop two stage grid connection

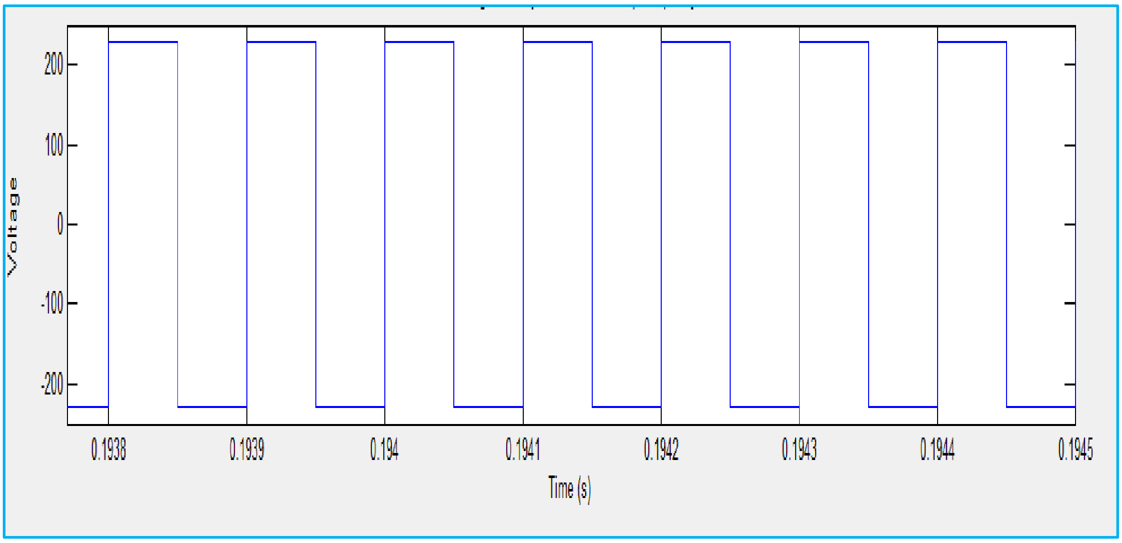
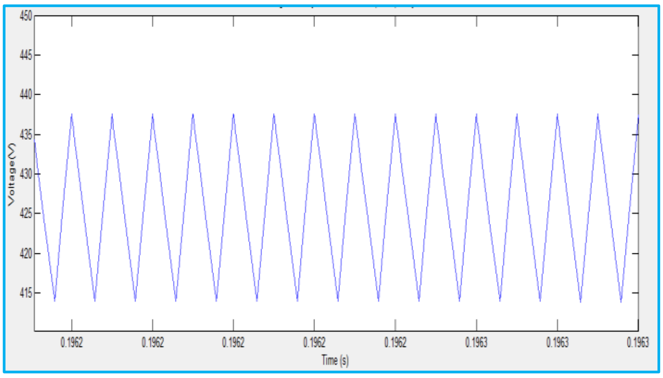


Fig. 7: Closed loop Two stage grid connection

VII. COMPARISON BETWEEN DIFFERENT GRID CONNECTION VOLTAGE RIPPLE



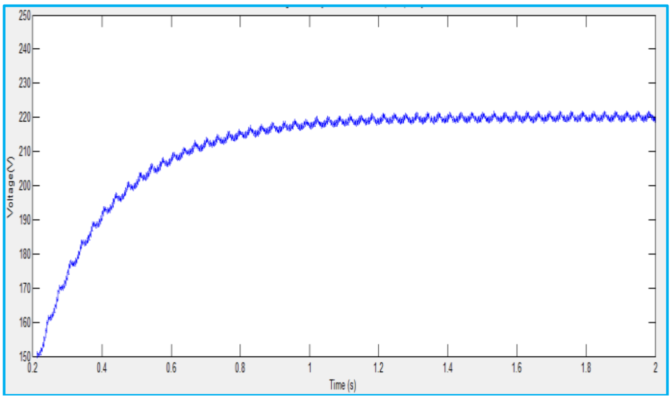
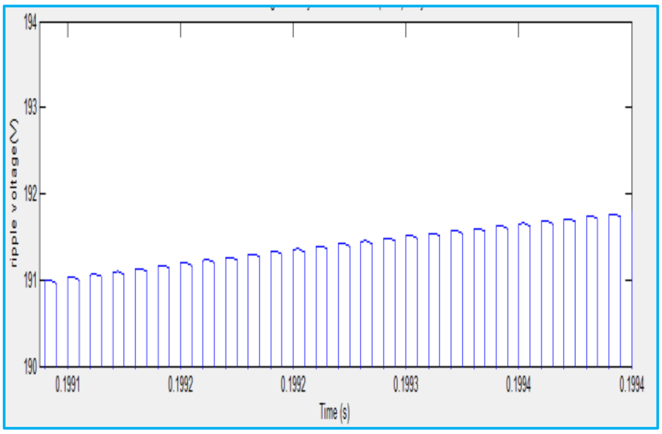


Fig. 8: Comparison between normal dc voltage ripple and closed loop ripple voltage



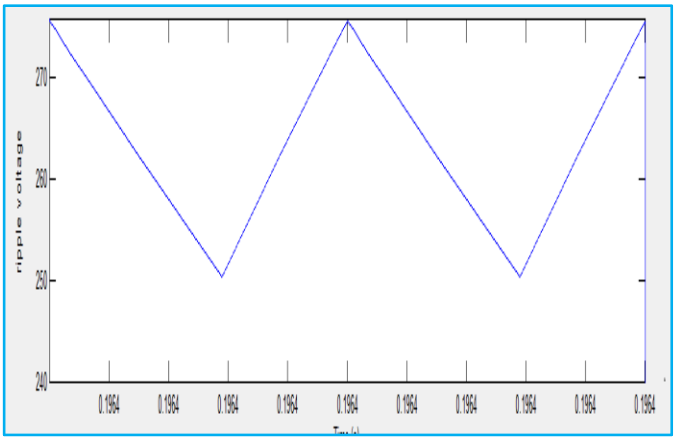
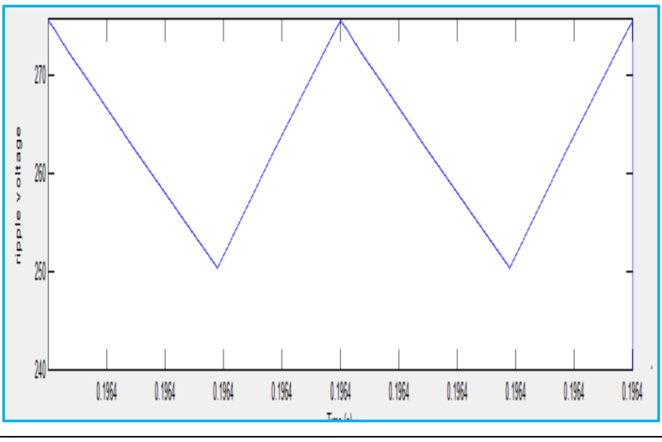


Fig. 9: Comparison between single stage ac voltage ripple and two stage ac voltage ripple



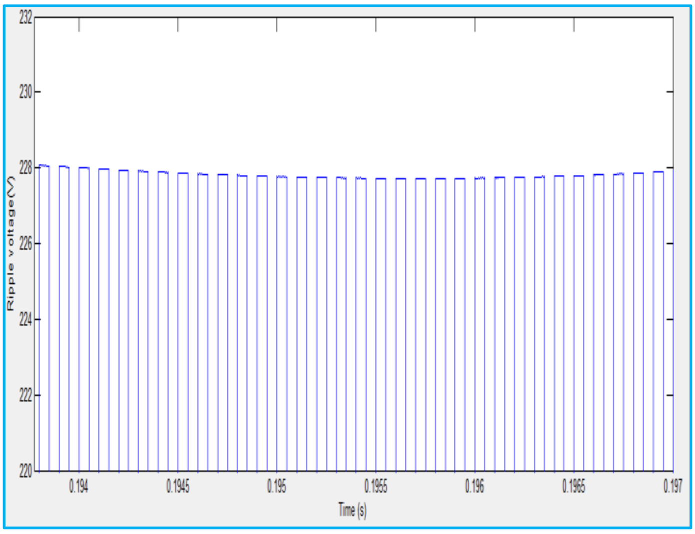


Fig. 10: Comparison between two stage voltage ripple and closed loop ripple voltage

Table 1 Power Loss Comparison In Different Grid Systems

POWER LOSS FACTORS (%)	DC PV GRID	DC CLOSED LOOP GRID	SINGLE STAGE AC GRID	TWO STAGE AC GRID	TWO STAGE CLOSED AC GRID
RIPPLE	7%	2%	1%	5%	≈ 0%
BOOST COVERTER	≈ 0%	≈ 0%	≈ 0%	2.5%	2.5%
INVERTER LOSS	≈ 0%	≈ 0%	2%	2%	2%
TOTAL POWER LOSS	7%	2%	3%	9.5%	4.5%

VIII. CONCLUSION

This paper has presented several grid connection basic topology with MATLAB analyzed the best power output occur in closed loop implementations. It shows that in closed loop models designed around 5% power loss can be saved and the different comparisons made here makes the user easy to select between the connection and type they used in hand with the quality analysis. Looking on the table , the DC closed loop has the minimum power loss where looking on the other hand it's clear that inverter losses create more loses in AC system so effective inverter topology can be implemented in future to reduce the 2% inverter loss. Finally, simulation results demonstrate the effectiveness of the presented analysis, design, implementation and comparison.

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