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Enhanced MPPT Technique For DC-DC Luo Converter Using Model Predictive Control For Photovoltaic Systems

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Abstract:- The present study explored an enhanced maximum power point tracking technique which ensures fast tracking in PV systems. This system represents a Model Predictive Control (MPC) MPPT technique. Extracting the maximum power from PV systems has been widely investigated. The main benefaction of this article is an improvement of the Perturb and Observe (P&O) method through a fixed step predictive control under measured fast solar radiation. The preferred predictive control to achieve Maximum Power Point (MPP) speeds up the control loop since it predicts error before the switching signal is applied to the DC-DC Luo converter. Comparing the improved technique to the conventional P&O method indicates significant improvement in PV system performance. The proposed MPC-MPPT technique for a Luo converter is implemented using the MAT LAB SIMULINK

Keywords:- Maximum Power Point Tracking, Perturb and Observe, Model Predictive Control, super lift Luo converter

I. INTRODUCTION

According to numerous use of the fossil fuel, the reserves of petroleum substantially and rapidly reduced and will be depleted in a few decades. Since the crisis of energy depletion won't happen in a short period of time, however, researchers and scientists have done a lot of researches for the development of alternative energy sources. Solar energy is one of the alternative clean energy sources which are paid close attention by humans. India is located in the subtropical region, and possesses excellent sunshine conditions. It is very suitable for India to develop photovoltaic power generation. The reduction in the cost of photovoltaic cells has further increased the interest in renewable energy source, which continues to gain popularity with 60% annual growth in the installed capacity of photovoltaic (PV) systems from 2004 to 2009 and 80% in 2011 [1]. However the low conversion efficiency of PV cells is a significant obstacle to their widespread use. Therefore Maximum Power Point Tracking (MPPT) is needed to secure the maximum available solar energy is harnessed from the solar panel. A lot of MPPT algorithms have been developed by researchers and industry delegates all over the world. They are voltage feedback method, perturbation and observation method, linear approximation method, incremental conductance method, hill climbing method, actual measurement method, fuzzy control method and so on. The PV array can feed power to the system through a DC/DC converter boosting the output voltage [2, 3]. A Maximum Power Point Tracking (MPPT) control technique is required for the PV system to operate at the maximum power point. Many MPPT methods have been suggested over the past few decades; the relative merits of these various approaches are discussed. The critical operating regime is low insolation. Capturing all of the available solar power during low insolation periods can substantially improve system performance. An effective MPPT controller and converter can use available energy to significantly reduce the amount of installed PV system. Considering the MPPT methods candidate techniques[4] includes Incremental Conductance[5], Perturb-and-Observe (P&O) [6], fractional Open-Circuit Voltage (Voc) [7], and Best Fixed Voltage (BFV)[8]. Each approach has certain advantages and disadvantages of the present application. INC is a well-known technique with relatively good performance; however, INC method cannot always converge to the true maximum power point. P&O is a well-known technique with relatively good performance; however, P&O method cannot always converge to the true maximum power point. Also, P&O is relatively slow, which limits its ability to track transient insolation conditions. The main contribution of this paper is to improve the P&O method performance by predicting the error one step ahead in the horizon through model predictive control technique. The proposed method has faster response than conventional P&O under rapidly changing atmospheric conditions.

II. MODEL OF A SOLAR PHOTO VOLTAIC MODULE

PV systems convert sunlight into electrical energy without posing any environmental issues. Various equivalent models are available in the literature, for better understanding of the PV array. It is considered good as far as compromise between accuracy and user friendliness is desired. For the constant weather conditions the curve has only one unique point of MP and the V-I characteristic of an irradiated cell is not linear. It depends on several factors including the temperature and irradiance. With a varying irradiance the short circuit current varies, however, the open circuit voltage changes significantly with changes in temperature. The varying atmospheric conditions make the MPP keep shifting around the PV cure. In the PV simulation results shows the cumulative effect of the non homogenous weather conditions on MPP. A model which is electrically equivalent to that of a solar cell is shown in fig. 1 From the equivalent circuit it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor. So we can mathematically express the current produced by the solar cell as

$$I = I_L - I_D - I_{SH}, \quad (1)$$

Where, I= output current (A), I_L=source current (A), I_D= diode current (A), I_{SH}= shunt current (A)

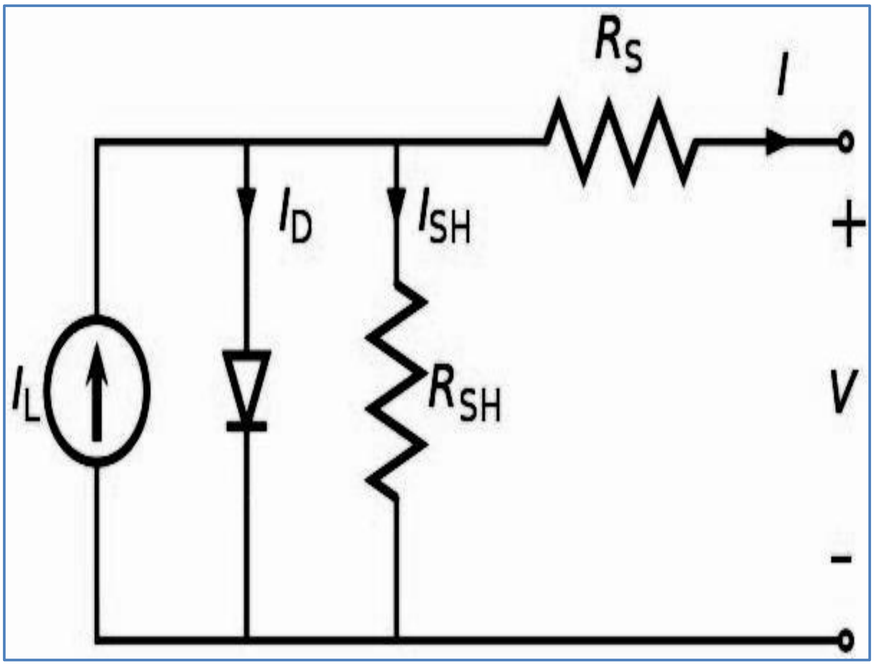

Fig.1 Equivalent circuit of PV system

III. MODEL PREDICTIVE CONTROL

The main characteristic of MPC is predicting the future behaviour of the desired control variables until a predefined step ahead in horizon of time. The predicted variables will be used to obtain the optimal switching state by minimizing a cost function. The model used for prediction is a discrete-time model which can be presented as a state space model [10]. The MPC for power electronics converters can be designed using the following steps: [9]

- Modelling of the power converter identifying all possible switching states and its relation to the input or output voltages or currents.
- Defining a cost function that represents the desired behaviour of the system.
- Obtaining discrete-time models that allow one to predict the future behaviour of the variables to be controlled.

The designed controller should consider the following tasks:

- Predict the behaviour of the controlled variables for all possible switching states.
- Evaluate the cost function for each prediction.
- Select the switching state that minimizes the cost function.

The general scheme of MPC for power electronics converters is illustrated in Fig. 2 [9]. In this scheme measured variables, X (K) are used in the model to calculate predictions, X (K+1) of the controlled variables for each one of the n possible actuations, that is, switching states, voltages, or currents. Then these predictions are evaluated using a cost function which considers the reference values, X (K+1) design constraints, and the optimal actuation, S, is selected and applied in the converter.

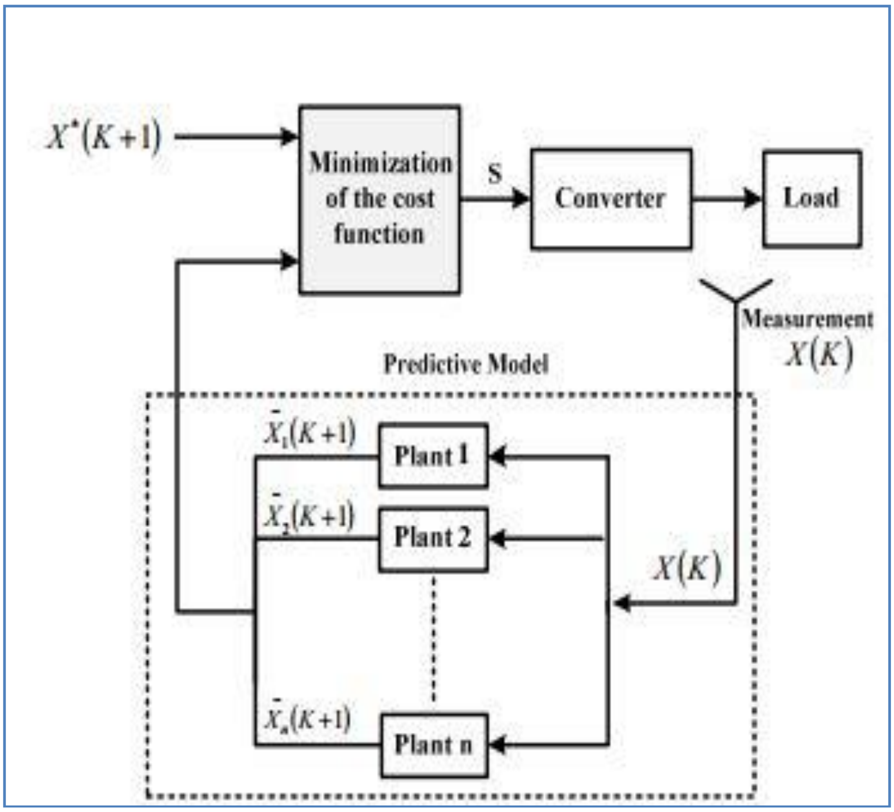

Fig.2 MPC general schematic for power electronic converters

The general form of the cost function, g, subject to minimization can be formulated as

$$\boldsymbol{g} = [\overline{X_1}(K+1) - X^*_1(K+1)] + \lambda_1 [\overline{X_2}(K+1) - X^*_2(K+1)] + ... + \lambda_n [\overline{X_n}(K+1) - X^*_n(K+1)] \quad \textbf{(2)}$$

Where, λ is the weighting factor. To select the switching state which minimizes the cost function g, all possible states are evaluated and the optimal value is stored to be applied next. The power converter can be from any topology and number of phases, while the generic load. It can represent an electrical machine, the grid, or any other active or passive load.

IV. MAXIMUM POWER POINT TRACKING USING MODEL PREDICTIVE CONTROL

The low conversion efficiency of PV systems is a significant obstacle to their growth; therefore Maximum Power Point Tracking (MPPT) is required to ensure the maximum available solar energy is harnessed from the solar panel. Many MPPT methods have been suggested over the past few decades; the relative merits of these various approaches are discussed. The critical operating regime is low insolation. Capturing all of the available solar power during low insolation periods can substantially improve system performance. An effective MPPT controller and converter can use available energy to significantly reduce the amount of installed PV. The main contribution of this section is to improve the P&O method performance by predicting the error one step ahead in the horizon through model predictive control technique. The proposed method has faster response than conventional P&O under rapidly changing atmospheric conditions. A super lift Luo converter is chosen as a DC/DC converter. P&O determines the reference current for the MPC which determines the next switching state. This technique predicts the error of the next sampling time and based on optimization of the cost function g, illustrated in Fig. 4, the switching state will be determined. The inputs to the predictive controller are the PV system current and voltage, and the reference current.

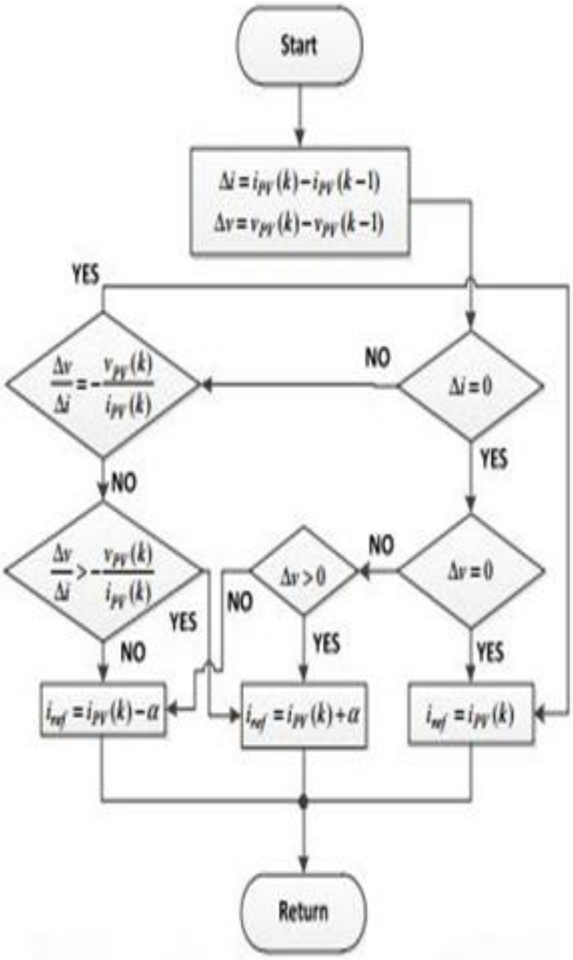

Fig. 3 Flow chart for MPC procedure to determine reference current using P & O

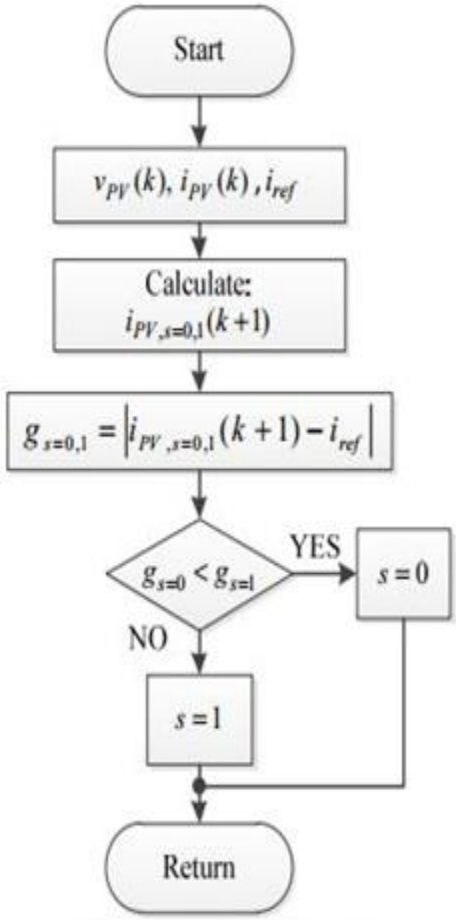

Fig. 4 Flow chart for MPC-MPPT procedure

Now after determination of the reference current using the procedure shown in Fig. 3, the cost function can be obtained as follows

$$g_{s=0,1} = \left| i_{pv\ s=0,1}(k+1) - i_{ref} \right| \tag{3}$$

The objective is to minimize the cost function g. The final switching state for MPPT can be determined using procedure illustrated in Fig. 4 However in this proposed system the MPC-MPPT is done for one step ahead in horizon, but the discrete time equation can be extended to n-step in horizon as following

$$\mathbf{i_{PV}}\,(\mathbf{k+n+1}) = \mathbf{i_{pv}}(\mathbf{k+n}) - \mathbf{S}\frac{\mathbf{T_s}}{\mathbf{L_n}}\mathbf{v_c}\,(\mathbf{k}) + (\mathbf{1-S})\frac{\mathbf{T_s}}{\mathbf{L_n}}\mathbf{v_c}\,(\mathbf{k+n}) \tag{4}$$

$$\mathbf{v_c}\,(\mathbf{k+n+1}) = \mathbf{S}\left[\mathbf{1} - \frac{\mathbf{T_s}}{\mathbf{RC}}\right]\mathbf{v_c}\,(\mathbf{k}) + (\mathbf{1-S})\,\frac{\mathbf{T_s}}{\mathbf{C_n}}\mathbf{i_{pv}}(\mathbf{k+n}) \tag{5}$$

Where, S is the switching state, T_s is the sampling time.
By increasing the number of steps to two or three, the computation time will be increased, but better control performance expected to be achieved.

The Limitations of P&O method can be summarized as follows:

The power tracked by the P&O method will oscillate and perturb up and down near the maximum power point. The magnitude of the oscillations is determined by the magnitude of variations of the output voltage. There is a misjudgment phenomenon for the P&O method when weather conditions change rapidly. The operating point is then farther away from the maximum power point. If the sun irradiance continuously increases, the distance between operating point and maximum power point will be farther. Consequently, the power loss of PV modules will increase, and the efficiency of the PV system will reduce. The value of generally varies between 0.64 and 0.85 can be calculated by analysing the PV system at a wide range of solar radiations and temperatures. Advantage of model predictive control, Improve the efficiency, Predetermination of future error prevents oscillations lesser than other methods, Tracks the maximum power faster.

V. LUO CONVERTER

The elementary LUO converter performs buck or boost operation in DC to DC conversion. The positive output LUO converter performs the conversion from positive input source voltage to positive output load voltage. Self-lift, Re lift, triple-lift, quadruple-lift and super-lift converters are the types of LUO converters which are derived from their appropriate elementary circuits with the help of voltage lift techniques. Reduction of value of duty ratio as well as the effect of parasitic elements can be easily acquired by the voltage lift technique. Luo converters have the characteristics of high voltage transfer gain, high power density, and reduced ripple in voltage and current in simple topology. The luo converter has low switching losses and the highest efficiency among non-isolated dc to dc converters and no negative polarity regulated output voltage compare with input voltage. It can also provide an improved output current characteristic due to the inductor on the output stage. Thus, the luo configuration is a proper converter to be employed in deceitful the MPPT. Voltage Lift (VL) Technique is a popular method widely used in electronic circuit design. It has been successfully employed in DC/DC converter applications in recent years and opened a way to design high voltage gain converters. Four series Luo Converters [11-14] are the examples of VL technique implementations However, the output voltage increases in stage by stage just along the arithmetic progression.

Positive Output Super lift Luo Converter

The fig. 5 shows a Super Lift Luo circuit with positive output

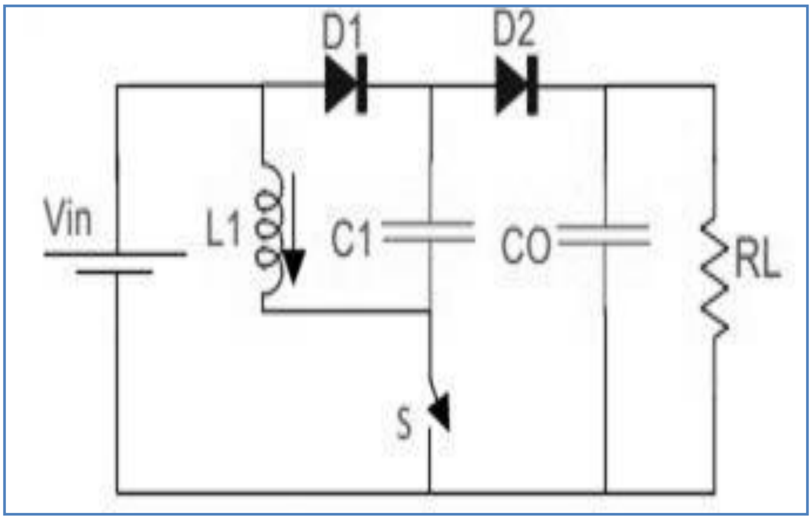

Fig 5. Super Lift Luo converter with positive output

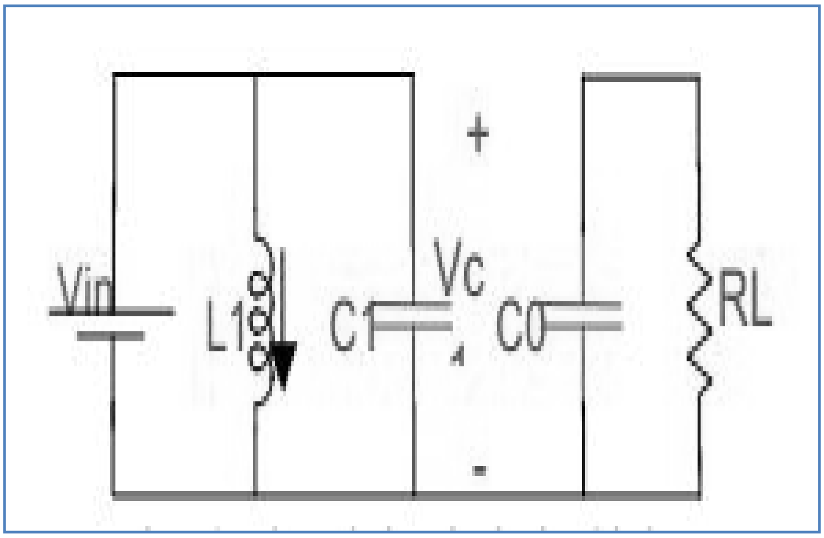

Fig. 6. The equivalent circuit when S is ON

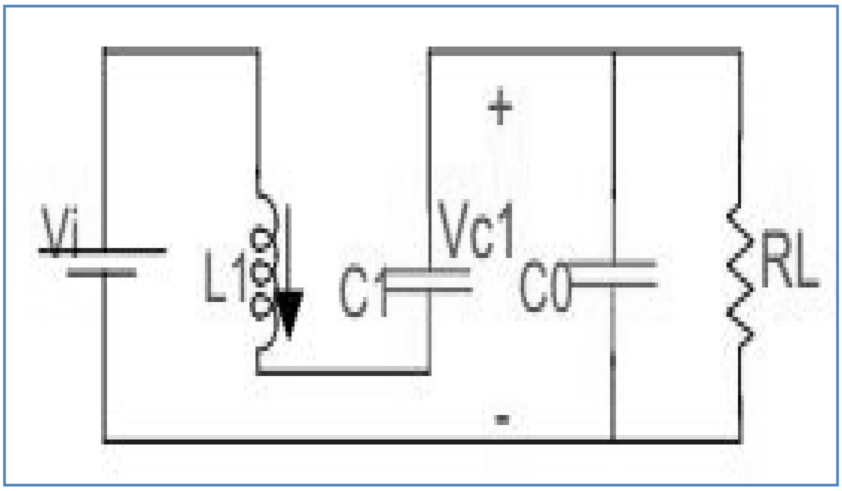

Fig.7.The equivalent circuit when S is OFF

This converter consists of Vin, capacitors Co and C_1, inductor L_1, power switch MOSFET and freewheel diodes D_1 and D_2. Also, it has a voltage lift circuit (VLC). VLC consists of diode D_1 and capacitor C_1. The equivalent circuits are shown in fig.6 To attention to equivalent circuits, when switch S is ON, the voltage across of C_1 (Vc_1) reach to Vin rapidly. At this time, the diode D_2 is OFF then its current is zero and the output current is $Io=V_0/R$. When switch S is OFF, according to fig.7, the inductor L_1 current flows to the capacitor C_1, diode D_2 and output port.

VI. SIMULATION RESULTS

To verify the tracking speed & performance of proposed Model predictive control and P & O method. Step change in the irradiance at time 0.5 s, when using the proposed MPC method the MPP is tracked at time 0.507 s, but when using the P&O method the MPP is tracked at time 0.515 s. The detail descriptive plots are illustrated in Fig. 7. Matlab/Simulink is used for the experimental results. The real time implementation of the MPC-MPPT is illustrated in Figs. 9 and 10.

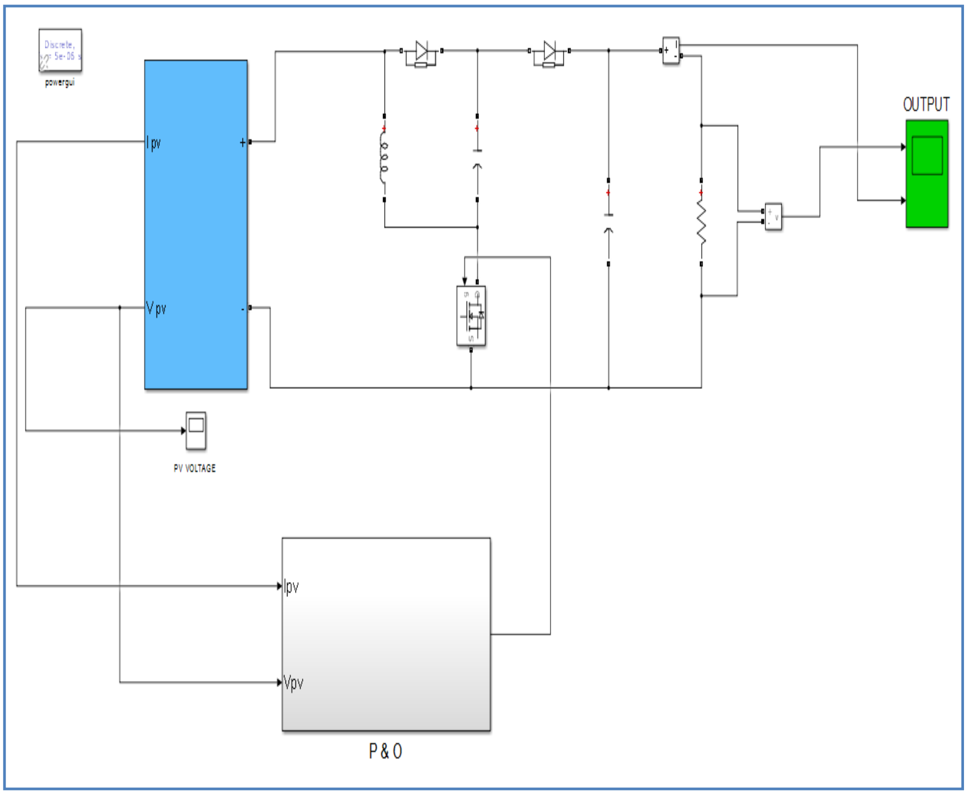

Fig.8. Simulation Diagram for P& O Method using Luo converter

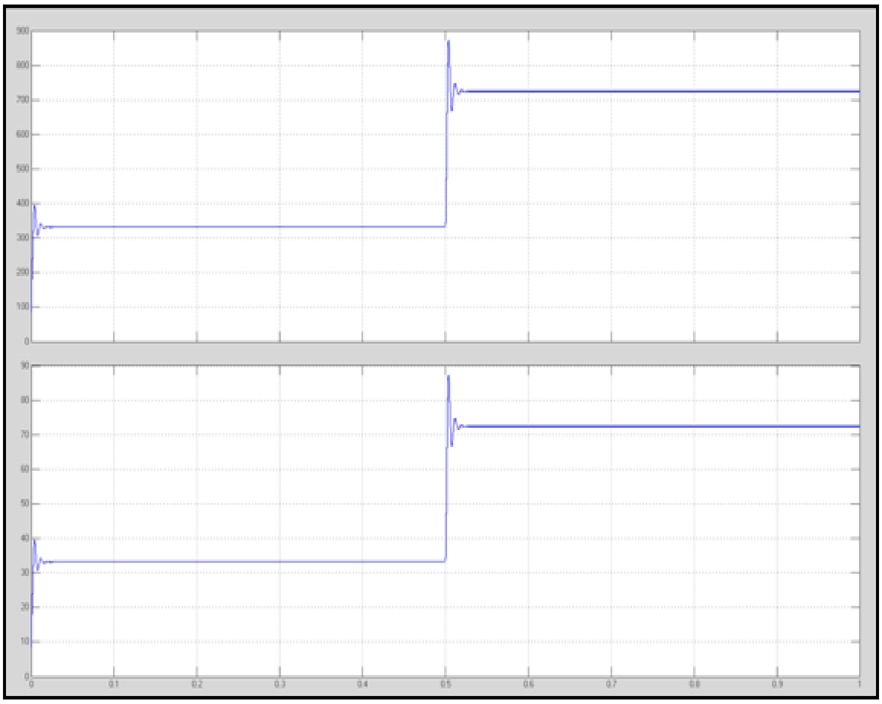

Fig.9. Simulation Output voltage & current waveform for P & O

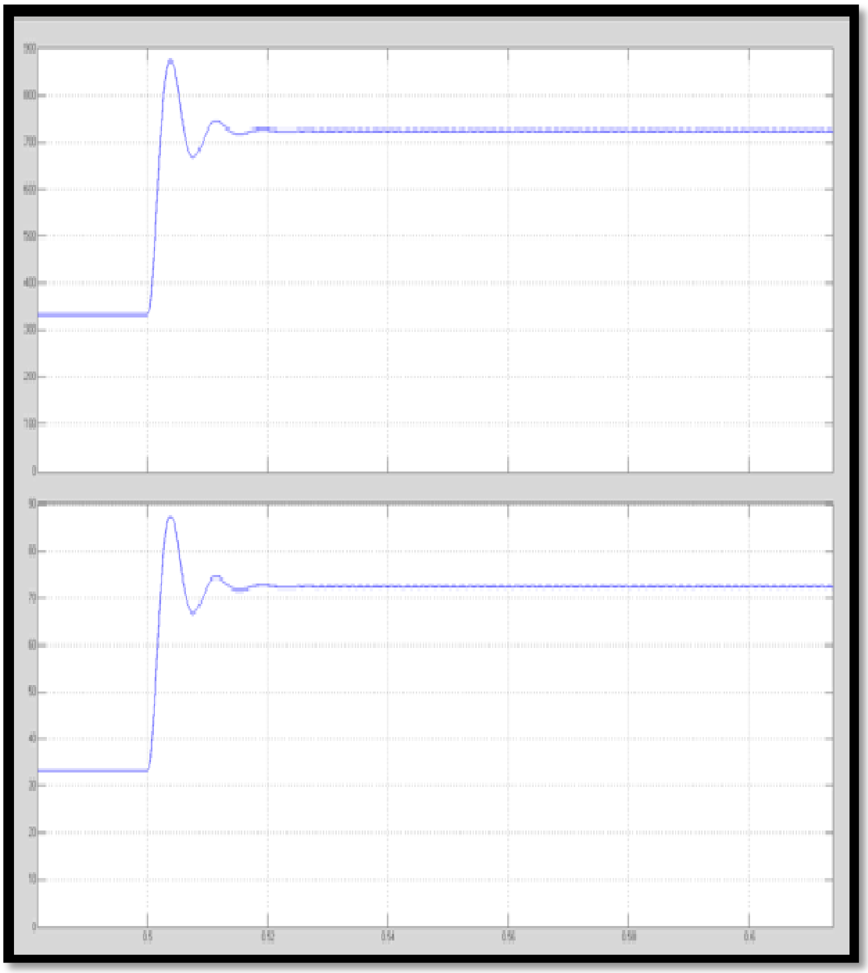

Fig.10. Simulation Output voltage & current waveform for P & O (full length variation)

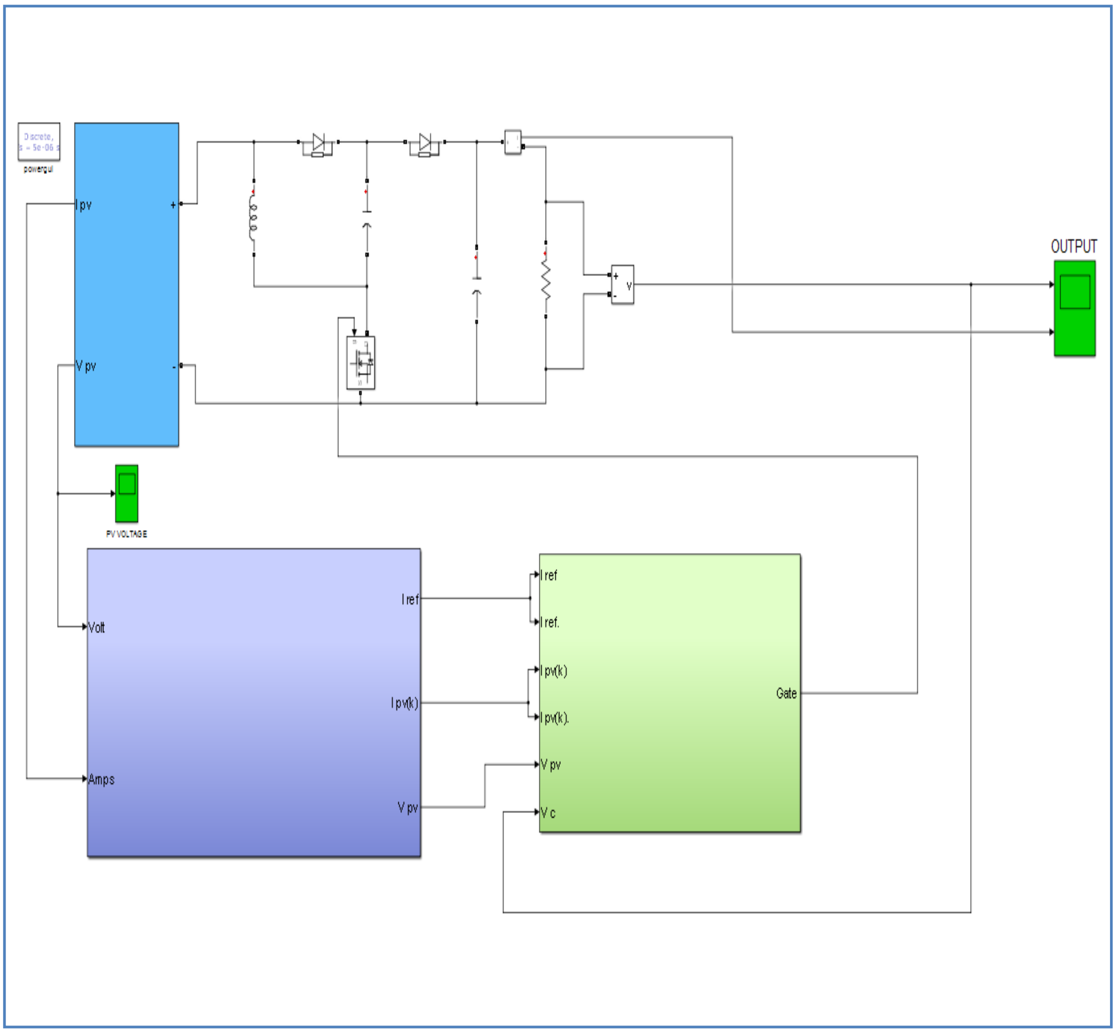

Fig.11 Design of MPC using Luo Converter

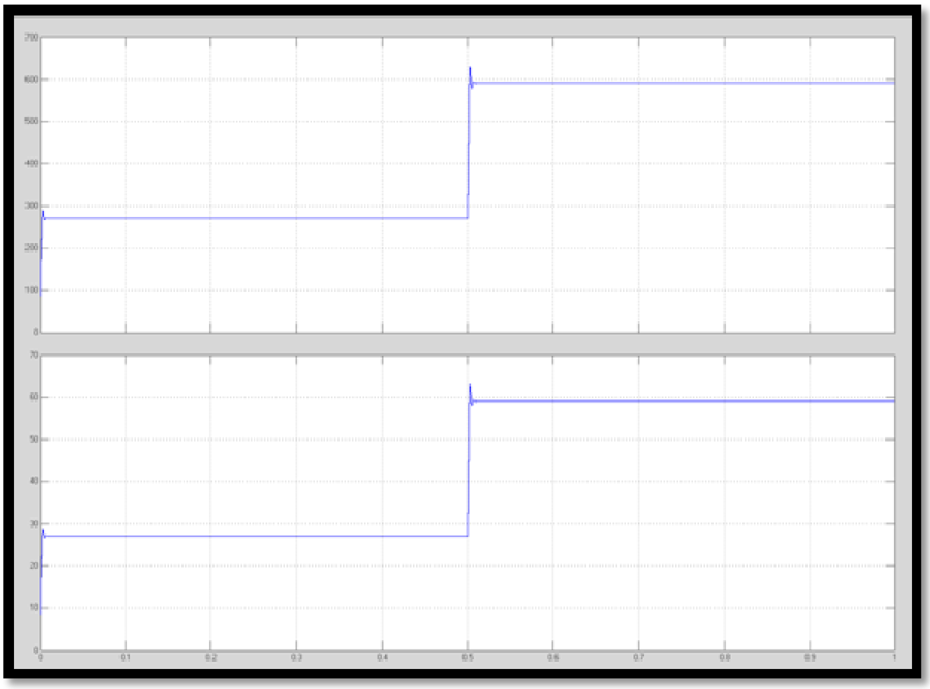

Fig.12. Simulation Output voltage & current Waveform for MPC

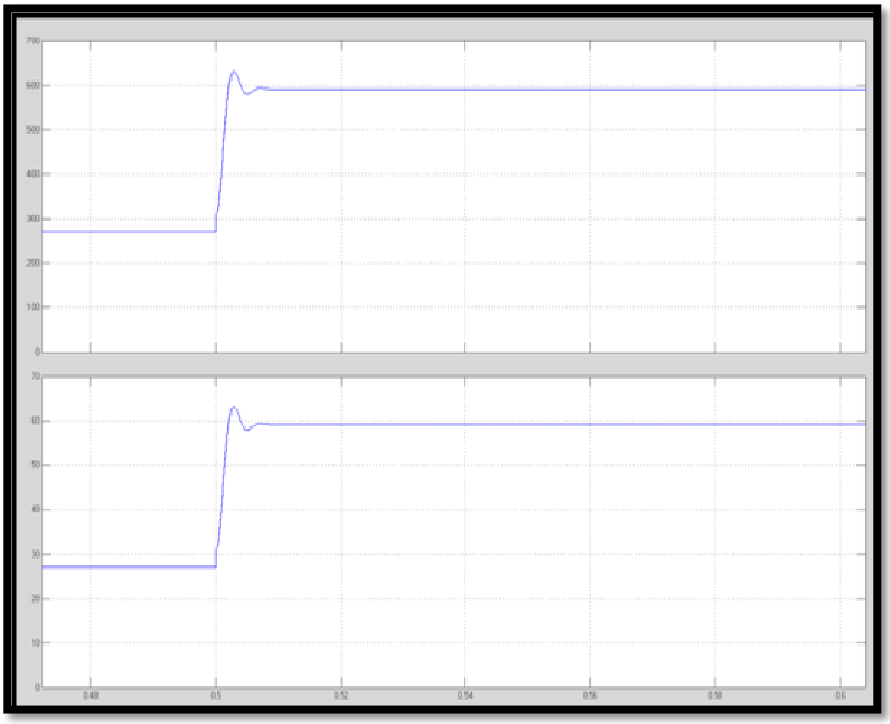

Fig.13. Simulation Output voltage & current Waveform for MPC (full length variation)

VI. CONCLUSION

This proposed system presents an improved MPPT technique by predicting the error at next sampling time before applying the switching signal using MPC. The proposed predictive MPPT technique is compared with commonly used P&O method to show the benefits and improvements in the speed and efficiency of the MPPT. The results show that the MPP is tracked much faster by using the MPC technique than P&O method. The MATLAB SIMULINK is used for implementing the control technique experimentally.

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