Design of an Improved Positive Output Super-Lift LUO Converter using Drift Free Technique for Photovoltaic Applications Integrated with Single Phase Grid Connected Photo Voltaic System (GCPS)

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Abstract— **It is a compact and simple circuitry which converts the DC output power of a PV Cell/Panel to the 6 times than the actual value using Improved positive output super-lift luo converter with drift-free technique with application of Perturb and Observe MPPT algorithm for maximum power point tracking- a drift free technique. It has integrated with Single Phase converter which converts improved output into AC signal which enable the system to be compatible with Grid System.**

Keywords— **Improved Super Lift Lup Converter, GCPS, PV Luo Converter**

I. Introduction

Renewable energy sources are considered an important source of energy in the twenty first century and are in use to fulfill our need and growing demands of electricity. In the last two decades the production cost of solar photovoltaic based system has decreased considerably. The per unit cost has also seen a decrease with the advancement in PV technology. These systems do not contribute to the global warning. The high penetration of solar PV system in electricity generation is evident from the fact that the PV system is expected to be the largest source of electricity generation among all the available renewable energy sources. They are considered feasible in residential applications and are suitable for roof top installations.

The PV modules are primarily a current source device and the current is produced when light falls on the surface of solar device. The characteristics curve of the PV module shows its non-linear behaviour. The nonlinear V-I curve of PV device has only one point of maximum power extraction. Therefore the energy harvesting at maximum efficiency is not simple enough. The existence of only one unique point of maximum power requires special techniques to operate the system at the point of maximum power. These techniques are called maximum power point tracking (MPPT) techniques. MPPT technique controls the power electronic interface such that the source impedance is matched with the load resistance and maximum power is transferred. In contrast of the nonlinear characteristics, MPPT techniques are vital for any solar PV system. Tens of methods have been reported in literature for tracking the maximum power point. Among the 20 distinct methods reported by following methods are widely uses by the researchers. Such as Perturb and observe, Incremental conductance, Fractional open circuit voltage, Fractional short circuit current, Fuzzy logic and Neural Network algorithm.

Among these method the factional open circuit voltage and short circuit current are considered offline MPPT techniques, because they track the MPP isolate the PV array and calculate the operating point for MPPT. These techniques adopt both analog and digital implementation. However, the periodic isolation of the PV array is actually a power loss, and the change in operating point depends on G, therefore in case the periodic power loss is to be avoided we need irradiance sensor that can measure the G and can isolate the PV array and when required. The other MPPT methods of perturb and observe, Incremental conductance, fuzzy logic control neural network are feedback control system. They can have analog as well as digital implementation. These techniques are considered as online MPPT techniques, because they track the MPP without disconnecting the panel from the system. The above mentioned techniques are medium complex in implementation but do not suffer from periodic power loss and during operating conditions need not isolate the PV array DC-DC converter plays a vital role in recent years due to its development in generation of electrical power by using renewable energy resources such as solar, wind etc. Fundamental DC-DC converter with Maximum Power Point Tracking (MPPT) technique in solar applications gives poor output power density due to the changeable sunlight and weather condition. Perturb and Observe (P&O) maximum power point tracking (MPPT) algorithm is a simple and efficient tracking technique. However, P&O tracking method suffers from drift in case of an increase in insolation (G) and this drift effect is severe in case of a rapid increase in insolation. In this work, Improved Positive Output Super-Lift Luo converter (IPOSLC) with Drift Avoidance P&O Maximum Power Point Technique (MPPT) has been implemented. In Positive Output Super-lift Luo Converter, the output is increased three times the input whereas in the proposed Improved Positive Output Super-Lift Luo converter, the output is increased six times of the input which is specified by adding an inductor and diode. Furthermore, connecting it to a GCPS system make it efficient to connect the enhanced output in AC, compatible to grid connectivity. The proposed system was modelled and simulated using MATLAB/Simulink and the prototype results were validated with the theoretical calculations.

II. PROPOSED SYSTEM

DC-DC converter with Maximum Power Point Tracking (MPPT) technique in solar applications gives poor output power density due to the changeable sunlight and weather condition. In this work, an Improved Positive Output Super - Lift Luo Converter (IPOSLLC) using drift free P&O MPPT technique has been designed and simulated using MATLAB/Simulink Software. Further, the proposed IPOSLLC has the ability to track maximum power even in fast changing weather conditions.

III. OBJECTIVE

To design and develop an efficient Improved Positive Output Super -Lift Luo Converter (IPOSLLC) using drift free MPPT technique. And to convert the DC output into AC in order to enable Grid Interactions.

IV. LITERATURE SURVEY

He and Luo (2005) [3] have analyzed four different types of Luo converters such as positive output self-lift Luo converter, positive output re-lift Luo converter, negative output self-lift Luo converter and the positive output super-lift Luo converter. Further, the authors have derived the voltage transfer gains and boundary conditions for both continuous and discontinuous modes of operation of all the four types of Luo converters.

Luo (2008) [8] has investigated the effect of capacitor voltage drops of Super-Lift Luo-Converters and modified the variations on output voltage. Further, the author has compared Super-Lift converters have very high voltage transfer gains than the fundamental converters.

Shan et al. (2012) [2] have designed a solar panel power system using the Super-Lift Luo Converter with a closed-loop control. Further, the authors have implemented a double closed-loop control to obtain the desired voltage.

Sunareswaran et al. (2016) [1] have integrated an ant colony optimization (ACO) and P&O method to yield faster and efficient convergence under partially shaded conditions. Further, the authors have found that the ant colony optimization with traditional P&O method tracks maximum power anD extracts more energy from the PV system.

Killi et al. (2015) [4] have proposed drift free Perturb and Observe (P&O) MPPT algorithm to track the maximum power in varying weather conditions. Further, the authors have observed that the drift free P&O MPPT algorithm tracks the maximum power more accurately and avoids the drift in fast changing weather conditions.

V. SYSTEM CONSTRUCTION

A. Block Diagram

Figure shows the block diagram of a proposed system. The system consists of a Photovoltaic panel (PV), Improved Positive Output Super-Lift Luo Converter along with single phase inverter connected to the Utility Grid.

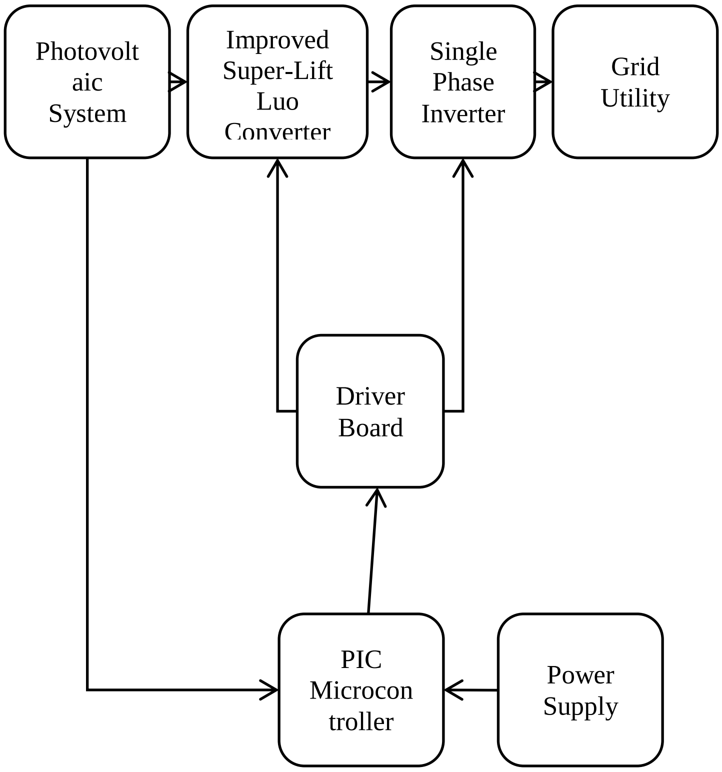


Fig. 1 Block Diagram of a proposed system

The Change in current in input of the IPOSLL converter is also taken as reference in the P&O MPPT loop to avoid drift phenomena. The current and voltage feedback from the panel is taken as reference and according to the MPPT algorithm the duty cycle of the IPOSLL converter is changed. The MPPT algorithm has been programmed into PIC 16F877A microcontroller. According to the feedback parameter such as panel voltage and current, the duty cycle of PIC microcontroller is varied. For appropriate duty cycle, the maximum power is tracked. The maximum power is tracked in terms of voltage and current. Further, it is applied to the grid under various weather conditions.

B. PV Panel

The output from a single photovoltaic cell is about 0.7 V. Many cells are stacked in series to get a higher voltage. The photovoltaic cell stack output can be boosted to the required level using a boost converter, but it induces current ripple which reduces the life of the photovoltaic cell stack. In addition, the photovoltaic cell voltage-current characteristics are non-linear. Hence, the interleaved boost converter is proposed in this paper as it reduces the source current ripple. This DC-DC converter serves the purpose of the interface between the photovoltaic module and the inverter for supply. This system can be used as a front-end converter for distributed supply system. Proper design of the boost converter is important for increasing the life of the photovoltaic cell as well as for improving the quality of the output power.

The output characteristics of PV module depends on insolation, the cell temperature and output voltage of PV module. Due to nonlinear characteristics of PV module, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications. For implementing the MPPT, there is a need to include the dc-dc converter into the system. There are different converter topologies are available. Among this, luo converter is selected in this project. The Improved Positive Output Super-Lift Luo converter is used as an interface between the panel and the load. From the elementary Positive Output Super-Lift Luo converter, the improved circuit is developed which increases the output value six times of input value.

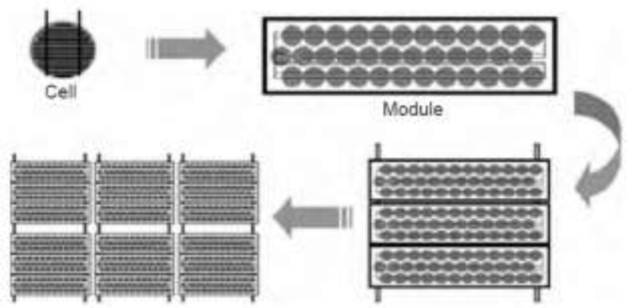


Fig. 2 Photovoltaic cells, modules, and arrays

C. Maximum Power Point Tracking

MPPT algorithms are necessary in PV applications to improve the efficiency of the system. MPPT is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors. When there is change in the load and environmental conditions such as temperature and insolation, the internal impedance of the panel varies thus leading to variation in the output power.

D. Types of MPPT Techniques

There are various MPPT techniques to track the maximum power such as follows.

- Perturb and Observe (P&O) method
- Incremental Conductance method
- Neural Networks
- Fuzzy Logic
- Particle Swarm Optimization etc.

Among these techniques, the P&O and the Incremental Conductance algorithms are the most common. These techniques have the advantage of an easy implementation. P&O method is used in this project.

The conventional P&O MPPT algorithm is developed based on the slope (dP/dV) variation on the P – V characteristics of the PV module. From the P −V characteristics, it can be visualized that the slope is positive on the left of MPP and negative on the right of MPP. Depending on the sign of the slope, the duty cycle has to be perturbed in order to track the peak power and flowchart of this conventional P&O MPPT algorithm is shown in Fig. 3.3. The duty cycle and the PV voltage (VPV) are inversely proportional to each other i.e., increase in duty cycle causes the VPV to decrease and vice versa.

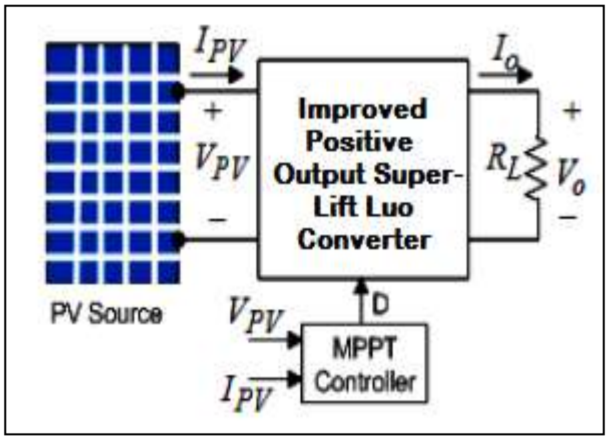


Fig. 3 Proposed IPOSLLC

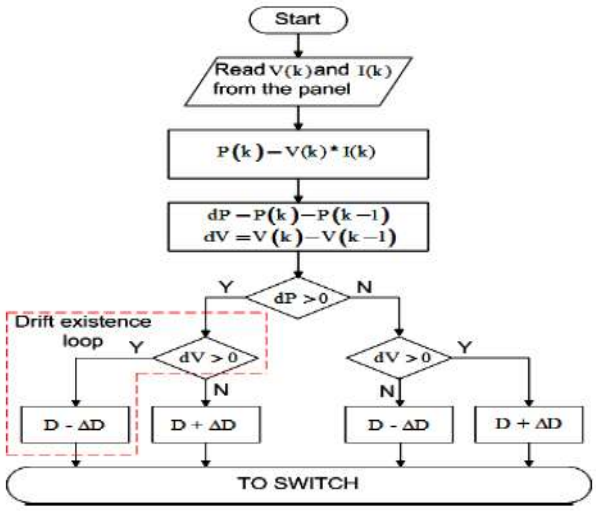


Fig. 4 Flowchart of P & O algorithm

The two vital parameters in any MPPT algorithm are perturbation time and perturbation step size and the criteria for choosing these two parameters are described below:

Selecting proper perturbation time (Ta): To make sure minimum number of oscillations with P&O algorithm (i.e., 3-Level operation), the perturbation time should be higher than the settling time of the system for a step change (ΔD) in duty cycle. The settling time is proportional to the perturbation step size (ΔD). In the view of adaptive technique, the perturbation time should be chosen such that it is greater than the settling time for a maximum step (ΔDmax) change in duty cycle.
Selecting proper perturbation step size (ΔD): The perturbation step size can be chosen by considering dynamic performance and steady state performance. The maximum value of step size (ΔDmax) improves the dynamic performance, whereas the minimum value of step size (ΔDmin) improves the steady state performance. The step size ΔDmin should be chosen based on the tracking accuracy in steady state and ADC resolution of the microcontroller used in the system. In general, as the switching converter intrinsically contains switching ripple on the PV voltage, an optimum value of ΔD should be chosen, such that the voltage variation due to perturbation of D (ΔD) should be greater than the amplitude of switching ripple of the PV voltage.

1) Steady state three level operation: Three level operation of the P&O technique in steady state is depicted in Fig. 3.5. Assume that the operating point has been moved from point 1 to point 2 and the decision has to be taken at point 2 by considering the values of dP and dV . As dP = (P2 − P1) > 0 and dV = (V2 − V1) > 0, the algorithm decreases the duty cycle and hence the operating point moves to the point 3. At point 3 as dP = (P3−P2) < 0 and dV = (V3−V2) > 0 the algorithm increases the duty cycle and thereby the operating point moves back to point 2. At point 2 as dP = (P2 − P3) > 0 and dV = (V2 − V3) < 0 the algorithm increases the duty cycle and hence the operating point moves to point 1. At point 1 as dP = (P1−P2) < 0 and dV = (V1−V2) < 0 the algorithm decreases the duty cycle and thereby the operating point moves back to point 2. In this pattern, the algorithm makes the operating point to oscillate in three points surrounding the MPP.

2) Drift Analysis: Drift problem occurs for an increase in insolation and it will be severe for a rapid increase in insolation which generally occurs in cloudy days. Drift can occur from any of the three steady state points depending on the instant of change in insolation in between the perturbation time (Ta) interval. Drift problem is due to the lack of knowledge in knowing whether the increase in power (dP > 0) is due to perturbation or due to increase in insolation. Suppose there is an increase in insolation while operating at point 1, then the operating point will be settled to a new point 4 in corresponding insolation curve during the same kTa perturbation interval. Now at point 4 as dP = P4 (kTa) − P2 ((k − 1)Ta) > 0 and dV = V4 (kTa) − V2 ((k − 1)Ta) > 0 the algorithm decreases the duty cycle and thereby moving to point 5 away from the MPP in the new curve which is called drift. Similarly for an increase in insolation at point 2 and point 3, the drift problem occurs due to confusion of this conventional P&O MPPT technique. This drift problem will be severe in case of a rapid increase in insolation and in case of adaptive P&O, as ΔD is large for a change in insolation which will results in the operating point to move in a wrong direction far away from the MPP as described below.

The relation between the IPV and VPV corresponding to the present operating point on the I −V characteristics of the PV module shown

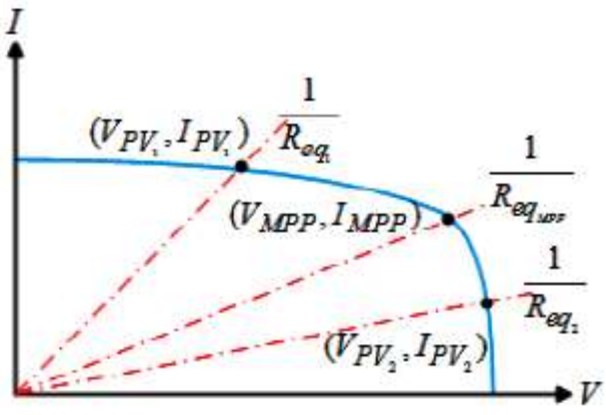


Fig. 5 I −V characteristics of the PV module

The I-V characteristics can be expressed in terms of slope of the load line as given below

$$I_{PV} = \frac{D^2}{\eta R_L (1-D)^2} V_{PV}$$

Similarly for an increase in insolation at point 1 and at point 2 the drift problem can be solved by incorporating dI into the algorithm and the movement of operating point with the proposed drift free modified P&O MPPT technique in case of a rapid increase in insolation is shown below:

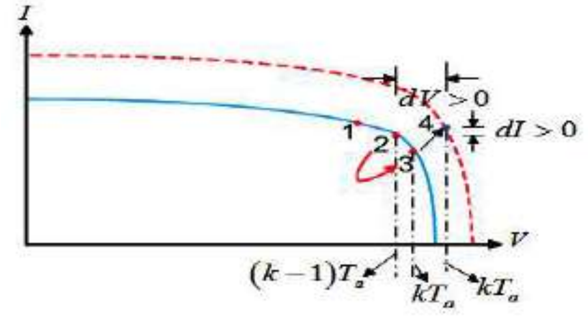


Fig. 6 (a)

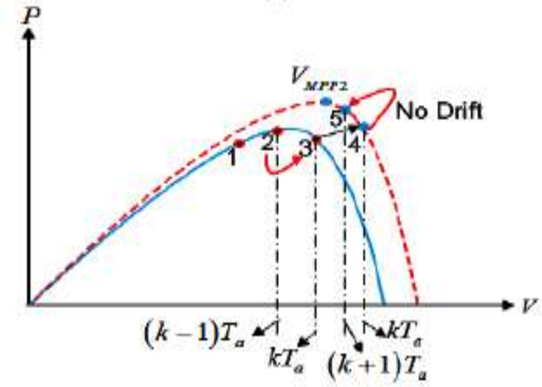


Fig. 6 (b)

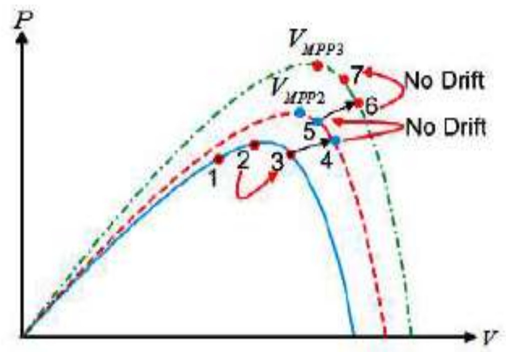


Fig. 6 (c)

Fig. 6 (a-c) I −V characteristics of the PV module and the change in operating point due to increase in insolation

The flowchart of this drift free modified P&O MPPT technique is shown below:

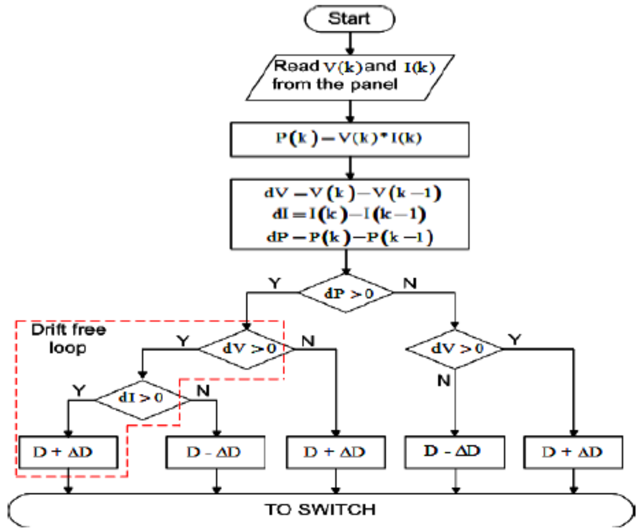


Fig. 7 Flowchart of drift free modified P & O MPPT Algorithm

E. Improved Positive Output Super-Lift Luo Converter

Luo converters were developed from the prototype using Voltage Lift (VL) technique. These converters perform DC-DC voltage increasing conversion with high power density, high efficiency, and cheap topology in simple structure. They are different from any other DC-DC step-up converters and possess many advantages including a high output voltage with small ripples. Therefore these converters are widely used in computer peripheral equipment and industrial applications, especially for high output voltage projects. This project introduces Improved Positive Output Super-Lift Luo Converter that implements the output voltage increasing in stage by stage along the geometric progression. With the Voltage Lift (VL) technique, the converter overcomes the effect of parasitic components that are present in the circuit that limits the output voltage. In this paper, the Improved Positive Output Super-Lift Luo converter (IPOSLC) incorporating the Super-Lift technique is introduced.

Although the Voltage Lift technique has been implemented successfully, they are able to increase the output voltage only in arithmetic progression. In order to increase the efficiency further Super-Lift technique is implemented which increases the output voltage in geometric progression. In this converter the main difference between the conventional circuit and IPOSLC is the presence of additional inductor and diode. Pls refer below figure:

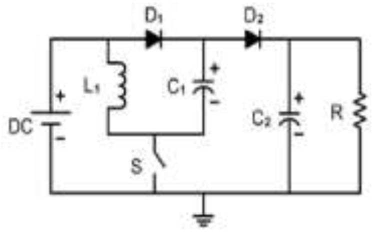


Fig. 7 Circuit Diagram of POSLC

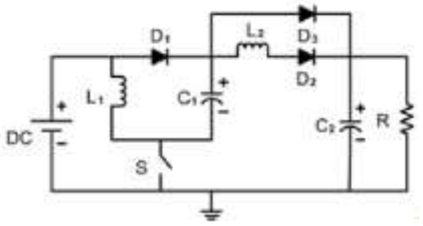


Fig. 8 Circuit Diagram of IPOSLC

VI. MODES OF OPERATIONS

A) MODE 1-Switch S ON

In this mode, the switch 'S' is turned ON during the period 0 to ΔT. When the switch is closed, the source voltage causes the current to flow through the inductor L1and capacitor C1. Since capacitor C1 has zero impedance to current, the capacitor C2 charges faster than inductor thus forward biasing the diode D1.

Thus charge gets stored in inductor L1 and Capacitor C1. Also during this period the load current is maintained constant by the discharging capacitor C2. Thus the energy stored in the capacitor C2 during the previous cycle is transferred to the load.

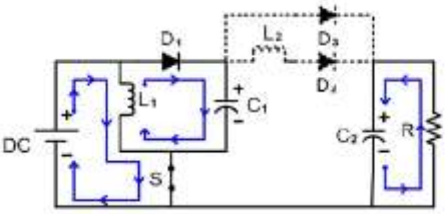


Fig.10 Equivalent Circuit of IPOSLC in mode 1

B) MODE 2- Switch S OFF

In this mode, the switch 'S' is turned off during the period ΔT to T. In this mode when the switch is open the energy that is stored in the inductor L1 and the capacitor C1 discharges across inductor L2 and the nodal points of the capacitor C2 thus boosting the output voltage. The load current is supplied by the inductor.

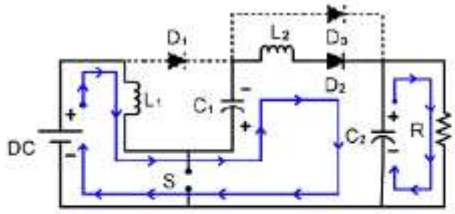


Fig.11 Equivalent Circuit of IPOSLC in mode 2

The specifications of the parameters used in the circuit are as follows:

TABLE I
CIRUIT PARAMETERS

Parameter's Name	Symbol	Value
Input Voltage	Vin	24V
Output Voltage	Vo	230.9V
Inductors	L1, L2	1mH,161.95uH
Capacitors	C1, C2	1.68uF,220uF
Nominal Switching Frequency	Fs	50KHz
Load Resistance	R	100Ω

VII. ADVANTAGES OF IPOSLC

- High output voltage with small ripples
- Cheap topology in Simple Structure
- Green Energy Generation System
- Almost negligible Systems

VIII. SIMULATION

Simulation has become a very powerful tool on the industry application as well as in academics, nowadays. It is now essential for an electrical engineer to understand the concept of simulation and learn its use in various applications. Simulation is one of the best ways to study the system or circuit behaviour without damaging it .The tools for doing the simulation in various fields are available in the market for engineering professionals.

Many industries are spending a considerable amount of time and money in doing simulation before manufacturing their product. In most of the research and development (R&D) work, the simulation plays a very important role. Without simulation it is quiet impossible to proceed further. It should be noted that in power electronics, computer simulation and a proof of concept hardware prototype in the laboratory are complimentary to each other. However computer simulation must not be considered as a substitute for hardware prototype.

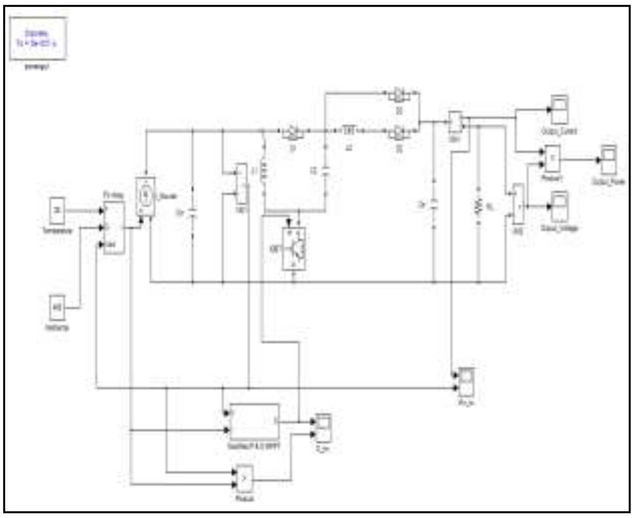
Sim Power Systems is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. Sim Power Systems uses the Simulink environment, allowing you to build a model using simple click and drag procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modelling library.

Since Simulink uses MATLAB as its computational engine, designers can also use MATLAB toolboxes and Simulink block sets. Sim Power Systems and Sim Mechanics share a special Physical Modelling block and connection line interface.

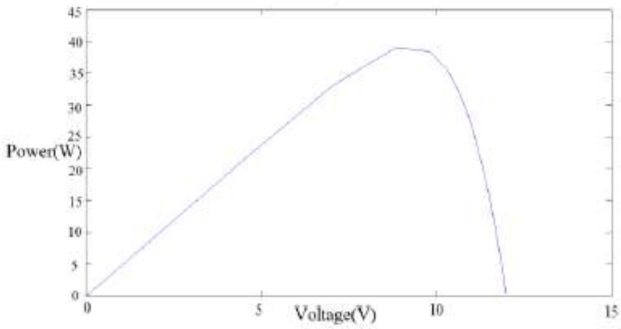
A) Features of Simulink:

- Graphical editor for building and managing hierarchical block diagrams.
- Libraries of predefined blocks for modelling continuous-time and discrete-time systems.
- Simulation engine with fixed-step and variable-step ODE solvers.
- Scopes and data displays for viewing simulation results.
- Project and data management tools for managing model files and data.
- Model analysis tools for refining model architecture and increasing simulation speed.
- MATLAB Function block for importing MATLAB algorithms into models. Legacy Code Tool for importing C and C++ code into model.

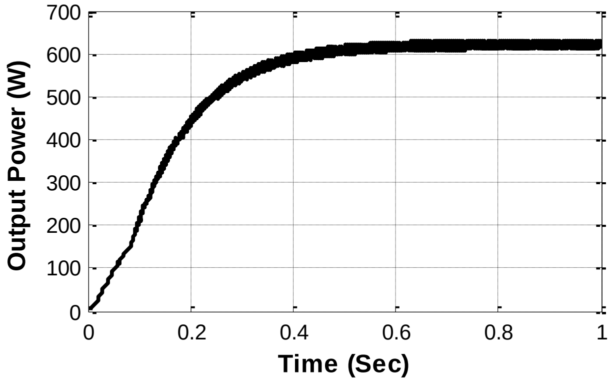
B) Simulink Circuit:



Fig, 12 Implementation of IPOSLC with Drift Avoidance MPPT Technique and PV Panel

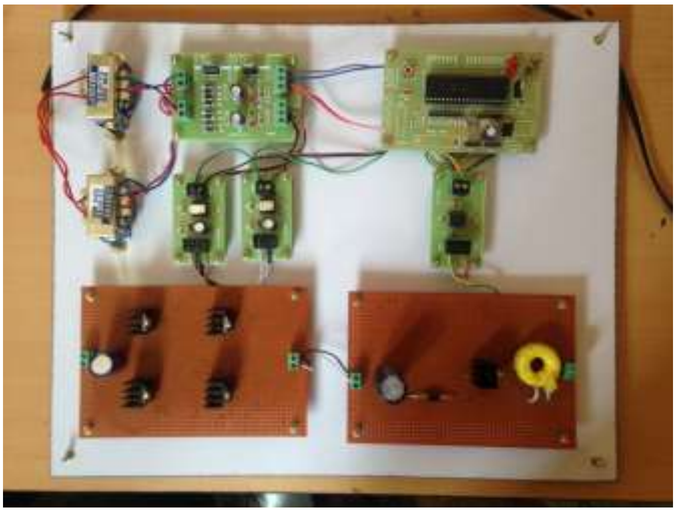


Fig, 13 P-V Characteristics of PV panel for 1000W/sqm

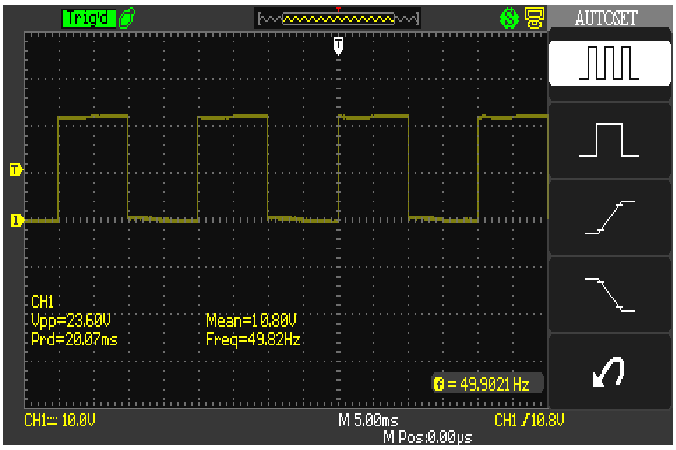


Fig, 14 The output power of converter

IX. HARDWARE MODEL



Fig, 15 The proposed Hardware Model



Fig, 16 Switching Waveform for alternate switches

X. CONCLUSION

The growing demand has led to increased use of renewable energy resources. Among all renewable energy resources, the photovoltaic (PV) power generation acts as a green source. To track the maximum power from the PV cell, Perturb and Observe (P&O) method is employed. However, P&O tracking method suffers from drift in case of an increase in insolation (G) and this drift effect is severe in case of a rapid increase in insolation. A modified P&O technique is proposed to avoid the drift problem by incorporating the information of change in current (ΔI) in the decision process in addition to change in power (ΔP) and change in voltage (ΔV). In this work, Improved Positive Output Super-Lift Luo converter (IPOSLC) with Drift Avoidance P&O Maximum Power Point Technique (MPPT) has been implemented. In Positive Output Super-lift Luo Converter, the output is increased three times the input whereas in the proposed Improved Positive Output Super-Lift Luo converter, the output is increased six times of the input which is specified by adding an inductor and diode. The proposed system was modelled and simulated using MATLAB/Simulink and the prototype results were validated with the theoretical calculations.

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