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Simulation and Analysis of SMC-MPPT Based Standalone Solar Tracking System

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ABSTRACT
The human need is increasing day by day due to rise in global human population which leads to rapid urbanization and industrialization which demands generation of huge amount of electrical energy. Due to the fast depletion of conventional sources of energy, environmental degradation and global warming, since decades mankind started using renewable sources energy such as solar energy, wind energy, geothermal energy, energy from biomass etc. Among these energy from solar photovoltaic (PV) is more promising as it is free of cost, green in nature and abundantly available. The generation of electricity from photovoltaic cells is rising fast across the globe. Governments of several countries give subsidies to encourage the generation of solar photovoltaic energy. These days witness a continuous rise in the use of energy from solar photovoltaic cells both in domestic and commercially. It is regrettable that as compared to the cost of conventional sources of energy, solar PV energy is costlier. Now days the cost has reduced due to its wide applications.

There is a lot of scope for research in implementing power electronics and control techniques to harness PV power with improved efficiencies and adequate use .An exact PV array model is necessary to examine the simulation and control of a solar PV power system.A PV system needs to operate at its maximum power point (MPP) to have the maximum efficiency. To operate the solar PV system at the MPP, a maximum power point tracker is highly essential. To obtain the maximum power points, there are numbers of techniques are reported such as Perturb and Observe (P&O), Hill Climbing (HC), Incremental Conductance (InC), Fuzzy logic control, Artificial Neural Network (ANN), Bio-inspired optimization techniques, Sliding Mode Control (SMC) etc.

The primary objective to improve the fundamental output voltage, current and reduce the Total Harmonic Distortion (THD), to improve the power quality has been systematically addressed. Various issues and challenges related to reduction of total harmonic distortion have been carefully studied through an exhaustive survey of literature and findings in each section like role of converters, role of maximum power extraction, role of stability and various control elements have been presented in organized manner. Based on these findings, the problem formulation has been researched. Various switching and pulse control schemes in the DC-DC boost converter and DC-AC conversion processes have been taken for investigation which include random pulse width modulation (RPWM) and Sliding Mode Control (SMC).

Keywords: Sliding Mode Control (SMC), Maximum Power Point Tracking, Solar Tracking System.

I. INTRODUCTION AND STATEMENT OF THE PROBLEM

1.1 Introduction

Energy is stimulating factor propelling all activities in rapidly developing the world.Many grounds of cost effective, prosperous growth with increasing urbanization thereby rising per capita energy consumption has widened the scope of energy extensively. Globally, anendless search for new energy sources is in demand. The conventional fossil fuels such as coal,oil and natural gas pose number of challenges: are costly, hazardous with no replenishment and boundary of getting disappear in future. A tremendous progress has been made in field of theRenewable Energy Technology (RET's) in last few decades to enhance research and development of energy systems such as solar, wind, ocean, geothermal, wave and bio energy systems furnished by the environment. Among these resources, solar energy is considered abundant, reliable, clean and green environment friendly renewable energy source. Solar Renewable resources are meeting demands of energy generation and distribution throughout the world specifically rural areas dominated by kerosene oil and fossil fuels.

The global PV (Photovoltaic) statistics across world has shown spectacular growth with India amongst top five nations using PV. Worldwide, India ranks fifth in power generation portfolio with a power generation capacity of 245 GW. As in 2014, the renewable energy contribution is 31.70 GW of the total installed capacity of 245 GW in India. By end of March2015, the installed grid connected solar power capacity is 3,744 MW, and it is expected to install an additional 10,000 MW by 2017 heading a total of 100,000 MW by 2022 [2]. India's dependence on expensive nonconventional sources can be minimized by tuning huge solar potential of about 300 clear, sunny days with solar power reception about 5,000 trillionkilowatt-hours (kWh). The daily average solar energy incident over India varies from 4 to 7kWh/m2 with about 1,500–2,000 sunshine hours per year greater than total energy consumption[1, 2].

The Application areas of SRET (Solar Renewable Energy Technology) not only serve as energy sources but also reduce environmental impacts associated with fossil fuels,greenhouse gas emissions, and nuclear energy; improving overall educational, employment and health opportunities. The Decade of Sustainable Energy for All (SE4ALL) is mobilizing towards universal access to renewable energy services, improving energy efficiency, and expanding the use of global energy mix by 2030. The interest in energy sustainability as documented in Renewable Global Status Report (GSR) demonstrates the need to accelerate grounding activities using solar PV installation for advancement of big projects together with small entrepreneurs [3].

The government is providing generation and fiscal-based incentives (GBI's) along with capital and interest subsidies to promote growth potential for the solar photovoltaic industry. The National Solar Mission targets development of SRET for power generation and other uses to compete with fossil-based energy options. The establishment of the Indian Renewable Energy Development Agency (IREDA) makes for renewed impetus on the R&D (Research and Development) projects for renewable energy and energy efficiency/conservation [4].

The uprising demands for new energy sources as alternatives to fossil fuels haveincreased interest in solar energy. Solar Photovoltaic's (PV) appear as inexhaustible,non-polluting and sustainable source of energy generation and promises boundless possibilitiesfor various applications. PV panel uses a number of solar cells that converts solar energy intoelectricity operating by the Photoelectric effect. The Photoelectric effect is property of certainmaterials (crystalline silicon, copper indium gallium selenide, cadmium telluride andamorphous silicon) to emit electron hole pairs on absorption and exposure to sunlight.

Available PV systems exist in three forms: Standalone or AC system, PV Generator orLarge stand-alone system, Grid-connected or Grid-tied, and Hybrid system. The stand-alone orac system is the replacement of individual requirements in power conditioning using PV array(series and the parallel combination of solar cells). The PV array is connected to the battery forcharging when the system is connected in daytime. A charge regulator terminates its operationwhen it fully charges the battery.

The PV Generator Combination system is a large stand-alone system that includes anadditional generator which is connected in periods of extended overcast. Sometimes, a smallerbattery bank is also used as a replacement of generator. The grid-connected type PV system includes connectivity of system with power grid eliminating batteries. It is also termed as utility intertie system. Other than using batteries and grid for power dependence, alternative sources can be used to create a PV system. This employs hybrid system combines PV system with nonconventional energy sources like wind, ocean, geothermal and small hydros. The advancement in solar PV systems has proposed new technological advances in power electronic industries,process microcontrollers, and digital simulations. These systems serve as a backup and serving as independent energy sources [5].

1.2 Solar Maximum Power Point

A single solar cell delivers 0.75W to 1.5W, therefore individual photovoltaic cells are connected in series or parallel or both configurations to deliver large wattage across load. This combination results in array of solar cells forming a PV panel/PV system. The photoelectric effect governs output from PV panel. The photons on absorption at panel surface jump into conduction band to release electron-hole pairs generating electricity after overcoming energyband gap. The DC equivalent of the solar cell is constructed using a current source in parallel with shunt and series resistance given in Fig. 1.1.

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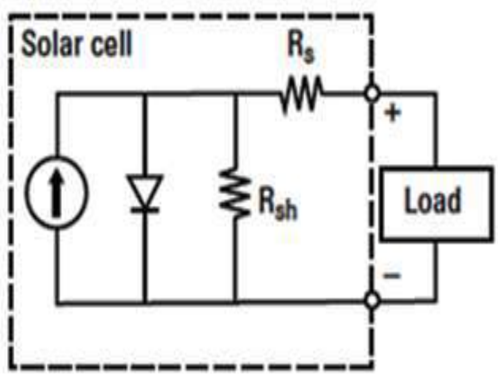

Fig. 1.1 Solar Cell DC equivalent model

The output of PV systems is determined by its I-V (Current Voltage) and P-V (PowerVoltage) characteristics. Solar cells possess nonlinear (inverse exponential) I-V and P-V characteristics. These characteristics vary differently for changing temperature and irradiance. The point that delivers maximum available energy output for a given array is known as Maximum Power Point (MPP). This point is located at Standard Test Conditions (STC) to deliver maximum output from the panel at temperature 25°C and an irradiance of 1000 W/m2.The Maximum Power Point Tracker (MPPT) system is used to obtain highest conversion efficiency of PV panel by maintaining continuous MPP [6].

The equivalent model can be used as the reference to work as solar cell simulator. PVpanel modelling is described for **Solarex MS-60W** panel that uses 36 solar cells for generating60W power output. But this energy is practically delivered in areas receiving plenty of sunlight and that too at STC. For isolated regions, more efficient systems need to be planted that track panel for STC and deliver output from a power grid.

To maximize power output and increase the efficiency of the system for distributedenvironment conditions, it is required to obtain continuous set point (desired output). This point is obtained when PV panel is operated at its optimum operating point i.e. Maximum PowerPoint. Unfortunately, it is difficult to maintain constant MPP due to change in atmospheric conditions and load variables. Thus, to achieve best performance from the system, it becomes necessary to force the system to operate at its optimum power point under all conditions. The explanation to such a problem is a Maximum Power Tracking system (MPPT) [8].MPPT consists of a solar panel, dc-dc converter, MPPT controller and an appropriate load at the output [6]. Block Diagram of MPPT System is given in Fig. 1.2.

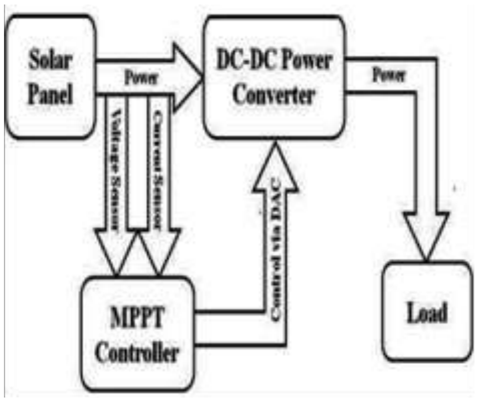

Fig. 1.2 Block Diagram of MPPT

The system is designed to meet voltage regulation, frequency regulation, power, and harmonics control with quick response time, reduced error and increased gain even underchanging environmental conditions. The power obtained at the output of PV is also determined by values of components used to produce the desired voltage and current.Solar panel acts as a simulator in MPPT system receiving sunlight and thereby giving power output. The changes observed in panel output with variable environmental conditions are dependent on a number of factors. These include the size of the panel, interface between paneland load (i.e. converter), device monitoring desired output or set point (i.e. controller). The output power of the panel is affected by the swing in temperature and irradiance variables thatis continuously changing throughout the day.

The change in temperature and irradiance produces the change in voltage and current,making the panel set point i.e. MPP unstable. Fig. 1.3 shows the slope of the curve obtained by intersection of source and load characteristics with varying loads. R2 corresponds to slope of MPP followed by current source region towards left i.e. R3 and voltage source region towards right i.e. R1.

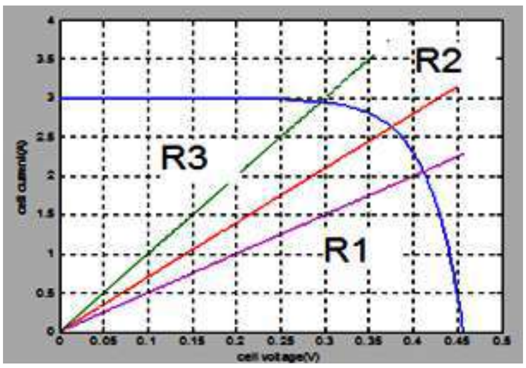

Fig. 1.3 MPP variations with Resistive Loads

To determine an expression for calculation of power output obtained from a PV system,dynamic impedance of the source is calculated in terms of static impedance. Delta (Δ) is used to describe a small change in power (ΔP), voltage (ΔV) and current (ΔI) due to temperature and irradiance variations.

$$P + \Delta P = (I + \Delta I).(V + \Delta V) \quad (1.1)$$

On expanding the equation (1.1) we get,

$$P + \Delta P = I.V + \Delta V.I + \Delta I.V + \Delta I.\Delta V \quad (1.2)$$

Simplifying equation by ignoring the constant values of P and product I.V together with small values of product ΔI.ΔV which is almost negligible, expression for dynamic impedance reduces to equation (1.3).

$$\Delta P = \Delta V.I + \Delta I.V \quad (1.3)$$

ΔP must be zero at the peak point. Therefore, at peak point the above expression in the limit becomes (1.4):

$$\frac{dV}{dI} = -\frac{V}{I} \quad (1.4)$$

This equation shows that dynamic impedance of the source equals to the negative of static impedance. The oscillating condition or change in dynamic impedance can be improved by using a suitable converter and controller.The output power characteristics vary across load with the change in temperature. Since direct connection of panel and load is expensive and undesirable, Converters are employed as an interface to transform the variable output from solar panels into the constant voltage.

Converters are power devices converting one form of voltage to other.Converters are mainly of two types AC and DC. AC converters convert sinusoidal input AC voltage into different magnitude AC voltage at output whereas DC converters transform input DC voltage at the output. The distinctive aspect of DC converters is that DC output cannot be easily step up or step down as AC. However, as compared to AC which has limited power supply, DC forms a large market sharing capability with reduced costs and improved performance. Additionally, DC converter components used in construction are also helpful in analysing harmonics or unwanted transients at the output. Therefore DC converters are preferred over AC converters. Many types of DC toDC converters are available commercially.These include

Buck converter : Step down voltage
Boost converter : Step up voltage
Buck Boost converter : Step up-down voltage
Cuk converter : Step up-down with reverse polarity
SEPIC : Step up-down or output equal to input

Amongst all other converter systems, Buck converter is the easiest implemented converter used to reduce the voltage at the output. The voltage step-down or voltage reduction is done by combining passive semiconductor devices to obtain voltage stabilization.The output current of PV panel is converted to voltage and thereafter, monitored to maintain MPP by feedback signal pulse from the controller.

II. REVIEW OF LITERATURE

Introduction:

The classic energy systems using fossil fuels confront with growing mission of energy expansion and application. An emerging alternative to occur as powerful standby is employing alternative RET's (Renewable Energy Technology) using energy sources like solar, wind,hydro, geothermal and biomass for electricity generation and distribution [1]. Solar energy has appeared as the best alternative for a number of application areas on account of many economic and environmental advantages. It is an abundant, free power source, economic, smooth operation requiring less maintenance, passive income source and reducing catastrophic climatic change by eradicating greenhouse effect [2].

A link between energy and poverty is developed by novel features of detachable PVmodules for cottage industrial applications. Many portable chargeable types of equipment in rural areas exempt use of crude kerosene oils used for lighting. PRADAN (ProfessionalAssistance for Development Action) assists in promoting SHG (Self Help Groups) for motorized cum solar paddle operated generator sets for both small scale and cottage packing industries [3]. A road map of solar India utilizing PV in avenues integrating solar power kits,solar charge controllers or regulators, inverters, solar lighted highways and roads is detailed [4].Solar building operating on solar temperature control with devices for refrigeration with various multitasking electronic appliances are analyzed [52, 60]

The kind of process monitoring for all above mentioned applications is quite complicated, to be modelled precisely [5]. Moreover, due to the prolonged development in automation systems and more imperative control desired in performance, digital modelling of parameters is highly demanded [10]. There is an emergent need for exacting practical control problems whose input-output relations of the system may be uncertain and can be changed byunknown disturbances [11]. For the appearance of such systems, conventional control methods are not always adequate [12-16]. New schemes are needed for indeterminate nonlinear, time varying systems integrated with features of optimization (self-tuning) and adaptability touncertainties [9, 17]

III. MAXIMUM POWER POINT TRACKING FOR PV SYSTEM

3.1 INTRODUCTION

Literature reports voluminous research to improve the PV powersystem efficiency through material development, enhancing strategies for theefficient power point tracking and the development of efficient of DC-DC powerconverter topologies. Today's material technology assures only low to mediumenergy conversion efficiency PV cell. Hence, it is important to design highperformance DC-DC converter and to propose efficient tracking algorithm. Inwhich challenges arise on account of non-linear nature of I-V characteristics ofPV system. The use of conventional power converters in PV system for MPPT,results in high ripple content in voltage and current. The problem gets worsebecause the output power of solar cells mainly depends on factors such astemperature and irradiance. Varying environmental conditions greatly affect thephotovoltaic array output power.

The nonlinear I–V characteristics of the PV source make the MPPT complex. To overcome this problem, number of MPPT methods have beendeveloped such as P&O, INC, ripple correlation control and lookup table method(Soon et al. 2013, Ishaque et al. 2014, Lin et al. 2011, Esram et al. 2006, Chunget al. 2003). Among these, the first two are the most commonly implementedmethods in the existing PV systems. These methods vary in complexity,accuracy, speed, oscillation around the MPP, hardware implementation, andsensor requirement.

The artificial intelligence methods such as fuzzy logic and neuralnetwork are well adopted for handling nonlinearity in many applications.Though these methods are good in dealing with the nonlinear characteristics ofthe I–V curves of PV panel, they require extensive computation and theversatility of these methods is limited (Messai et al. 2011, Femia et al. 2007,Faraji et al. 2013). The lookup table method needs a prior knowledge of the PVarray characteristics, so that, a clear mathematical function relating the outputcharacteristics has to be predetermined. However, PV array characteristicsdepend on many complex factors such as temperature, partial shading, aging anda possible breakdown of individual cells. So, it is difficult to predict and store allthe possible system conditions.

Modified algorithms have been introduced to improve the efficiencyof MPPT algorithm in different aspects (Liu et al. 2008, Emad & Masahito2010). INC algorithm with direct control method (Safari &Mekhile 2011, Liqunet al. 2013) eliminates additional control loop required for MPPT and shorten thecomputational time. In recent years implementation point of view, several MPPTalgorithms such as Hill Climbing/P&O method, INC technique and artificialintelligence methods have been implemented using FPGA based controllerbecause of its inherent features such as faster operation and optimized design ofhardware architecture etc (Mellit et al. 2011, Khaehintung et al. 2006).

Electricity is one of the greatest inventions man has ever made, due to its very important role in socio-economic and technological development [1]. The need for electrical energy is increasing every year and also an increase in the government's construction of power plants.

The power plant relies on a thermal generator that can produce a large amount of power. On the other hand, thermal generators have several drawbacks, including air pollution, noise, waste, exhausted fuel, and expensive initial investment. Therefore, we need the alternative way to overcome these problems by utilizing renewable energy. One sustainable renewable energy, solar energy, is converted into electrical energy using the Solar PV System.

Solar PV Systems generate DC from sunlight, which can be directly used for DC electrical equipment or to recharge batteries. Solar PV system based off-grid has several advantages, including suitable for electrification in remote areas and pollution-free. Solar PV Systems can be applied to public street lighting systems, electricity needs for boats, recreational vehicles, electric cars, camera detectors, and remote monitors.

Besides, Solar PV Systems are dependent on solar radiation. The current produced is direct current (DC). Thus the Solar PV System requires AC, a converter from DC to AC is needed, an inverter. The inverter converts the DC from the energy storage unit then supplied into the connected AC load.

There are square wave inverters, modified square wave inverters, and pure sine wave inverters. Among the three types of inverters, the most efficient and suitable for all loads is the pure sine wave inverter [2]. It is an inverter that has an output voltage with a pure sine waveform. This type of inverter can provide a voltage supply to inductor loads or electric motors with excellent power efficiency. This paper documents the design of an Arduino-based pure sine wave inverter, focusing on a small scale solar PV system. The inverter's various applications are solar electrical systems, Remote homes, Telecommunications, Computers, Tools, Security applications, Mobile power, Monitoring equipment, Emergency power, and lighting.

3.2 SINE WAVE INVERTER

Single-phase inverters are of three types i.e. square wave inverter, modified sine wave inverter, and pure sine inverter. The pure sine inverter is studied in this paper. The square wave or modified sine wave; these two types of inverters are cheaper and are not suitable for delicate electronic devices [3]. The output of pure sine wave inverter is a near-perfect sine wave. Pure sine wave inverters have fewer power losses and less heat generation [4]. The sine wave has minor harmonic distortion resulting in a very clean supply. It makes it most suitable for running electronic systems such as microwaves ovens, computers and motors and other sensitive equipment without causing problems or noise. Pulse Width Modulation (PWM) technique is best for sine wave generation.

A pure or true sine wave inverter changes or converts the DC supply into a near-perfect sine wave. The sine wave has minimal harmonic distortion, which results in a very clean supply [5]. It makes it suitable for working electronic systems such as computers, motors, and microwave ovens, and other sensitive equipment without causing problems like noise. Things like mains battery chargers also run better on pure sine wave converters. Ideally, the output waveforms of an inverter should be sinusoidal. However, the waveforms of efficient inverters are non-sinusoidal and contain specific harmonics [6]. Due to the availability of high-speed power semiconductor devices, the harmonic contents present in the output voltage can be minimized significantly by using switching techniques [7].

3.3 MAXIMUM POWER POINT TRACKING

The Power-Voltage or current-voltage curve of a solar panel, there is a peak operating point at which the Solar Panel delivers the maximum possible power to the load. This unique point is called the maximum power point (MPP) of solar panel. The photovoltaic nature of the solar panels makes the (Power-Voltage or current-voltage) curves depend on temperature and irradiance (the flux of radiant energy per unit area) levels. In other words depending on the amount of sunlight per unit area of the panels the curve will vary hence the peakpoint or MPP will vary accordingly in Fig.3.1. Therefore it can be deduced that the operating current and voltage which maximize power output will change with environmental conditions.

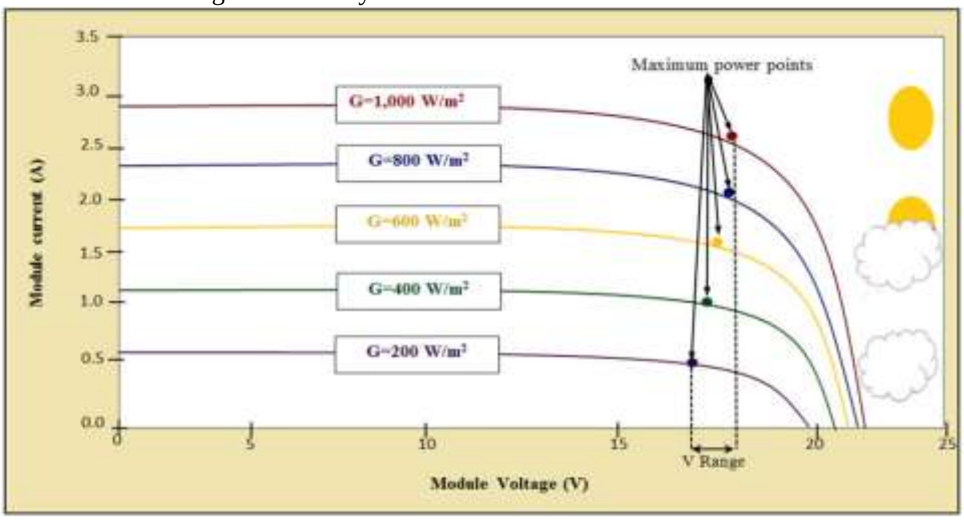

Fig.3.1: Variation of maximum Power Point (MPP) at different sunlight conditions

From the above Figure it can be seen that the MPP depends on certain conditions such as the irradiance for instance which is given by the symbol 'G'. At different values of G from the graph it can be seen how the values of MPP has slightly shifted. It is hence the work of charge controller using certain algorithm to calculate the MPP at every instance providing the maximum power hence making the system more efficient. In these applications, the load can demand more power than the PV system can deliver.

There are many different approaches to maximizing the power from a PV system, this

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range from using simple voltage relationships to more complexes multiple sample based analysis.

3.4 MPPT METHODS

There are some conventional methods for MPPT.
1. Constant Voltage method
2. Open Circuit Voltage method
3. Perturb and Observe method
4.Incremental Conductance method
5. Sliding Mode Control

3.4.1 Constant Voltage Method

The constant voltage method is quite a simple method but an inefficient method. This methods imply uses single voltage to represent the V_{mpp}. In some cases this value is set by an external resistor connected to a current source pin of the control IC. For the various different irradiance variations, As in Fig.3.2 method will collect about 80% of the available maximum power. The actual performance will be determined by the average level of irradiance. Since the maximum power point of a solar PVF module does not always lie between 70-80 percent of Voc, this is why the tracking efficiency is low in this case.

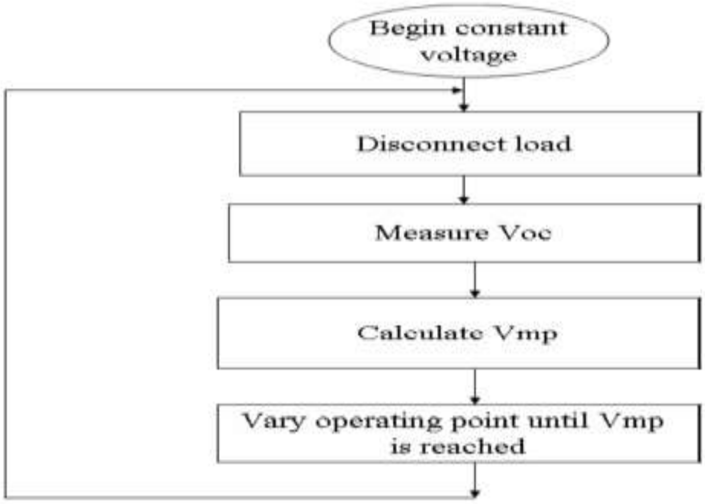

Fig.3.2: Flowchart of constant voltage method

3.4.2 Open Circuit Voltage Method

Another method which is similar to the constant voltage method but an improvement to it is the Open Circuit Voltage method which uses V_{oc} to calculate V_{mpp}. Once the system obtains the V_{oc} value, V_{mpp} is calculated by,

$$V_{mpp} = k^* V_{oc}$$

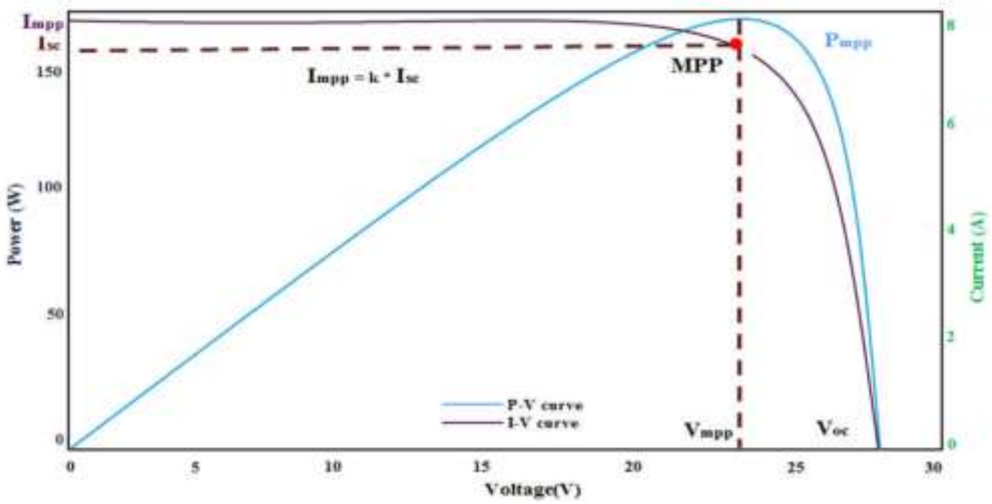

Fig.3.3: I-V and P-V characteristics of Open circuit voltage method

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The V_{oc} is the open circuit voltage of the PV Panel. The k value is typically between to 0.7 to 0.8as it is always less than unity (commonly used as 0.76). It is necessary to update V_{oc} occasionally to compensate for any temperature change. Sampling the V_{oc} value can also help correct for temperature changes and to some degree changes in irradiance. Monitoring the input current can indicate when the V_{oc} should be re-measured. The k value is a function of the logarithmic function of the irradiance, increasing in value as the irradiance increases as in Fig.3.3

3.4.3 Perturb and Observe Method

This method is a widely used approach to determine the MPP. In this method the controller adjusts the voltage by a small amount from the array and measures power, if the power increases,then there are further adjustments made in the direction until power no longer increases. This is called the Perturb and Observe Method. This method works by perturbing the system by increasing or decreasing the PV module operating voltage and observing its impact on the output power supplied by the module as in Fig.3.4.The voltage to a cell is increased initially, if the output power increase, the voltage is persistently increased till the point until the output power starts declining.

Once the output power starts decreasing, the voltage to the cell is decreased until the point when the maximum power is reached. This process is continued until the MPPT is attained. This results in an oscillation of the output power around the MPP. The PV module's output power curve is a function of the voltage(P-V curve), at the constant irradiance and the constant module temperature; it is also assumed that the PV module is operating at a point which is away from the maximum power point. Now if the operating voltage of the PV module is perturbed by a minute amount the resulting power P is then observed. If it is seen that the P is positive, then in that case it is supposed that it has moved the operating point closer to the MPP. Hence further voltage perturbations in the same direction will continue moving the operating point toward the MPP. If the P is negative, in that case the operating point will be moving away from the MPP and the path of perturbation should be inverted to move back toward the MPP.

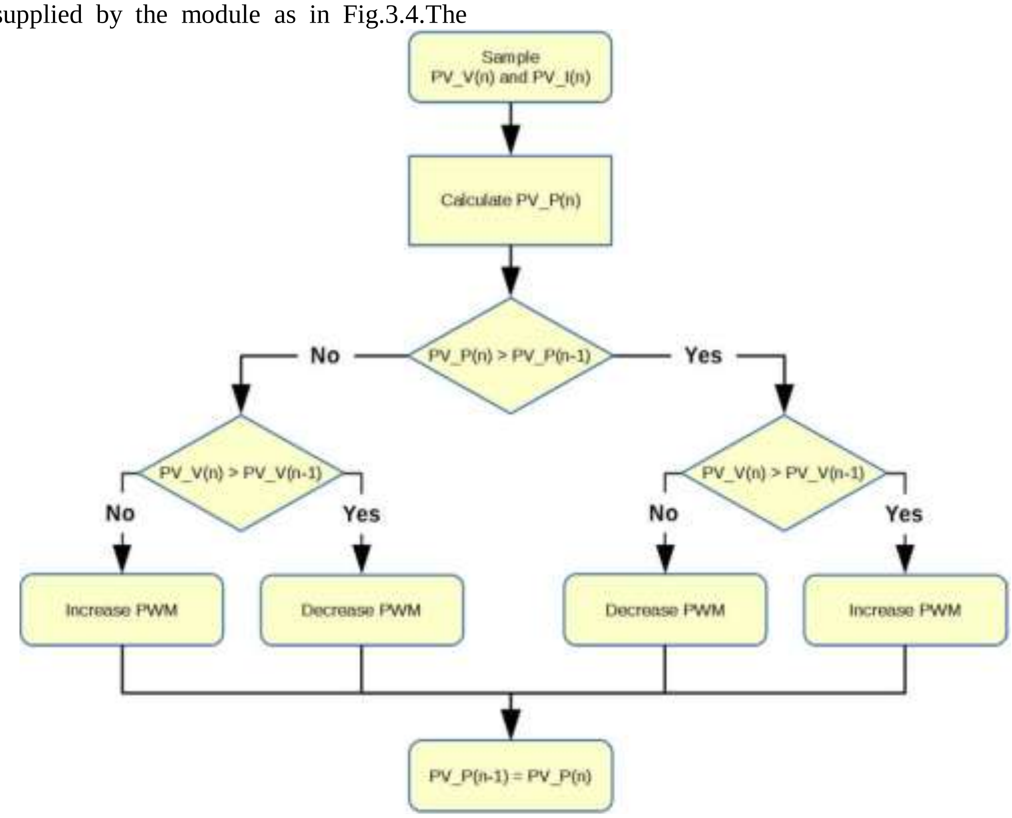

Fig.3.4: Shows the flowchart of P&O

3.4.4 Incremental Conductance Method

An observation based on a P-V characteristic curve the Incremental Conductance Method was planned. In 1993 when this algorithm was made it was intended to overcome some drawbacks of the P&O algorithm. The MPP can be calculated with the help of the relation between dI/dV and-I/V. The incremental conductance method is based on the fact that, the slope of the PV array ofthe power curve is zero at the MPP, positive on the left of the MPP and negative on the right on the MPP. This can be given by,

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV}$$

$$= I + V\frac{dI}{dV}$$

MPP is reached when dP/dV=0 and

$$\frac{dI}{dV} = -\frac{I}{V}$$

$$\frac{dP}{dV} > 0 \text{ then} V_p < V_{mpp}$$

$$\frac{dP}{dV} = 0 \text{ then} V_p = V_{mpp}$$

$$\frac{dP}{dV} < 0 \text{ then} V_p > V_{mpp}$$

So if the MPP lies on right side, dI/dV<-I/V and then the Photo Voltaic voltage must be reduced to reach the MPP. In order to find the MPP IC method can be used, it has been known to improve the PV efficiency, reduce power loss and also the system cost. When IC method is implemented in a microcontroller it is seen to produce a much more stable performance compared to P&O method.

The procedure starts with measuring the present values of PV module voltage and current. Then,it computes the incremental changes, dI (change in current) and dV (change in voltage), which uses the present and previous values of the voltage and current. With the help of the relationships in the equations mentioned above the main check is then done. If the condition satisfies the inequality equation shown above, it is assumed that the operating point is at the left side of the MPP thus must be moved to the right by increasing the module voltage. Similarly, if the condition satisfies the inequality equation, it is assumed that the operating point is at the rightside of the MPP, thus must be moved to the left by decreasing the module voltage.

3.4.4 Sliding Mode Control

The sliding mode control theory of the VSC system provides a method to design a system in such a way that the controlled system is to be insensitive to parameter variations and external load disturbances. The approach is realized by the use of a high speed switching control law which forces the trajectory of the system to move to a predetermined path in the state variable space (called Sliding or Switching Surface and it is a line in case of two dimensions) and to stay in that surface thereafter.

Before the system reaches the switching surface, there is a control directed towards the switching surface which is called reaching mode. The regime of a control system in the sliding surface is called Sliding Mode. In sliding mode a system's response remains insensitive to certain parameters variations and unknown disturbances.The Variable Structure System (VSS) theory has been applied to nonlinear systems. One of the main features of this method is that one only needs to drive the error to a switching surface, after which the system is in sliding mode and robust against modeling uncertainties and disturbances. A Sliding Mode Controller is a Variable Structure Controller (VSC).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1944-1957 www.ijaem.net ISSN: 2395-5252

Basically, a VSC includes several different continuous functions that map plant state to a control surface and the switching among different functions is determined by plant state that is represented by a switching function.

Consider the following state equation:

$$\dot{x}(t) = Ax(t) + Bu(t)$$

which can be rewritten as:

$$\dot{x}(t) = f(x, t, u)$$

where, x is the state vector of the system, u is the control input and f is a function vector. If the function vector f is discontinuous on a surface S(x)=0 called sliding surface in the sliding mode theory then:

$$f(x, t, u) = \begin{cases} f^{+}(x, t, u^{+}) & \text{if} \quad S>0 \\ f^{-}(x, t, u^{-}) & \text{if} \quad S<0 \end{cases}$$

The system is in sliding mode if its representative point moves on the sliding surface S(x)=0. The sliding surface is also called as switching function because the control action switches depending on its sign on the two sides of the sliding surface.

In sliding mode theory, the control problem is to find a control input u such that the state vector x tracks a desired trajectory x* in the presence of model uncertainties and external disturbance. The sliding surface may then be set to be of the form:

$$S(x) = x - x^{*}$$

If the initial condition S(0)=0 is not satisfied then the tracking can only be achieved after a transient phase called reaching mode.

Since the aim is to force the system states to the sliding surface, the adopted control strategy must guarantee the system trajectory move toward and stay on the sliding surface from any initial condition if the following condition meets,

$$S\dot{S} \leq -\eta|S|$$

where, η is a positive constant that guarantees the system trajectories hit the sliding surface in finite time[10]. The required sliding mode controller achieving finite time convergence to the sliding surface is given by:

$$u = \begin{cases} 1 & \text{for} \quad S>0 \\ 0 & \text{for} \quad S<0 \end{cases}$$

IV. SIMULATION RESULTS ANDDISCUSSION

The developed MATLAB Simulink model of the proposed system has PV module, the implementation of pure sine wave inverter, which can convert DC voltage to AC voltage at high efficiency and low cost. Solar-powered electricity generation is being favoured nowadays as the world increasingly focuses on environmental concerns. The designed inverter converted DC voltage into AC voltage for a small-scale off-grid solar PV system suitable for electrification in remote areas, pollution-free, and inexpensive.

Its inverter uses a random pulse width modulation technique and a simple circuit, consisting of only four MOSFET switches and one MOSFET driver. The H-bridge inverter's output is applied to a step-up transformer with a dual coil input and a single-coil output, and hence, we can create positive and negative sides of the wave.

Mitigate a voltage noise; a capacitor is parallelly installed at the secondary side of the transformer. Several simulations are performed to verify the effectiveness of the designed inverter using Proteus software, and continued hardware implementation. Based on some simulation, the designed inverter produces a 30V rms 50 Hz sine wave with very low harmonics distortion. The highest efficiency was obtained using 2200nF / 400V of the filter capacitor, The proposed system is economical, efficient and reliable and can be used for small scale power applications.

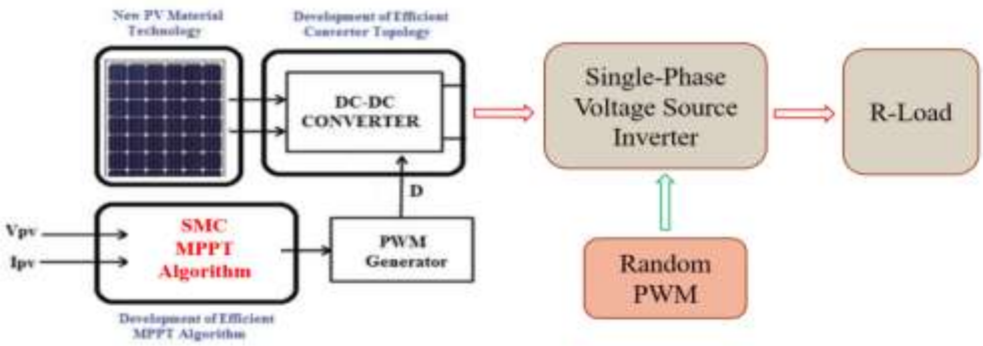

Fig.4.1:Block Diagram for Solar MPPT

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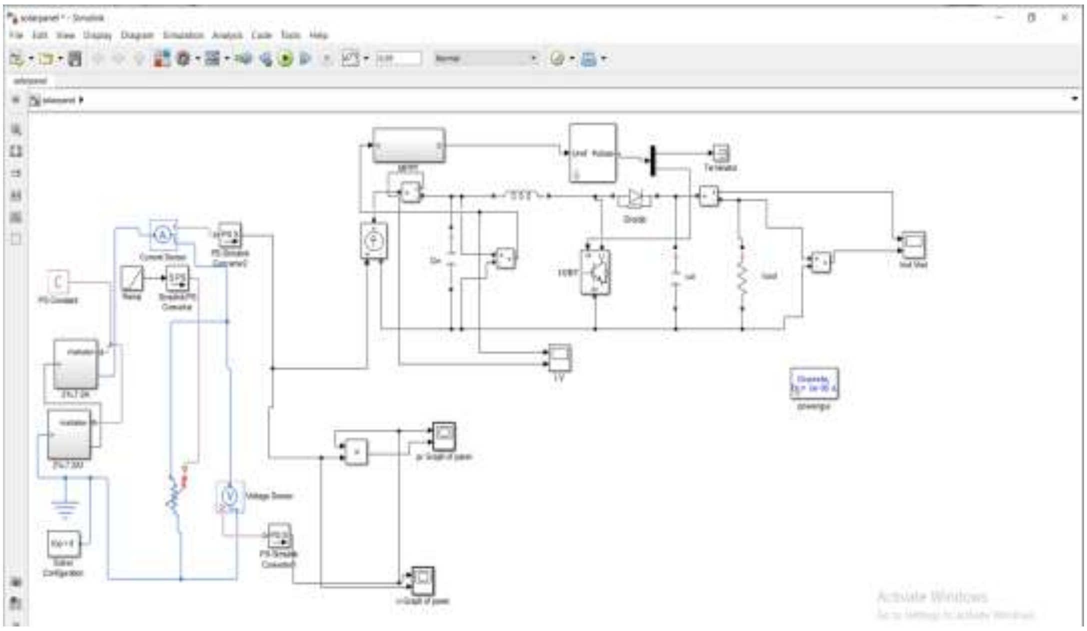

Fig.4.2:Simulation diagram of SMC MPPT

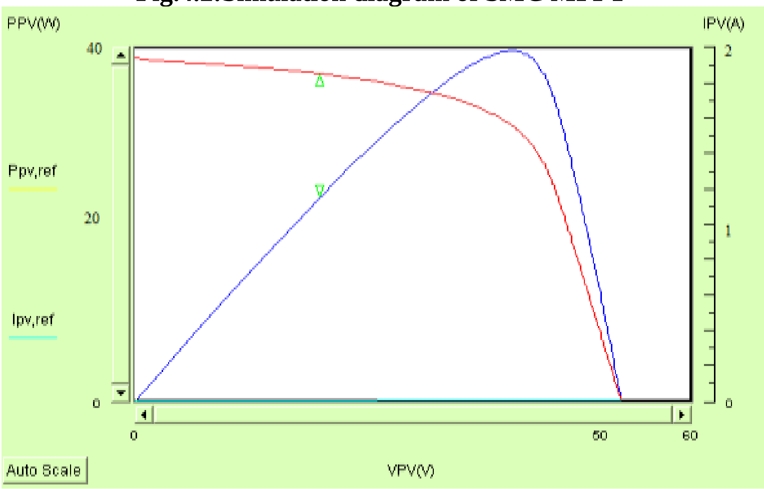

Fig.4.3: PV Simulation IV Characterizes of Solar MPPT

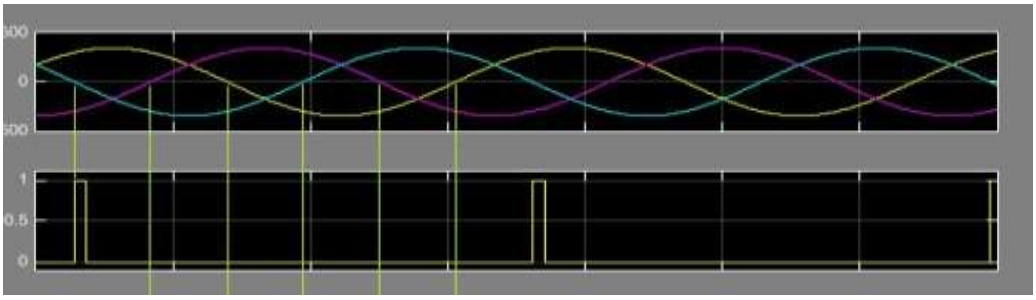

Fig.4.4:Pulse Generation using Random PWM

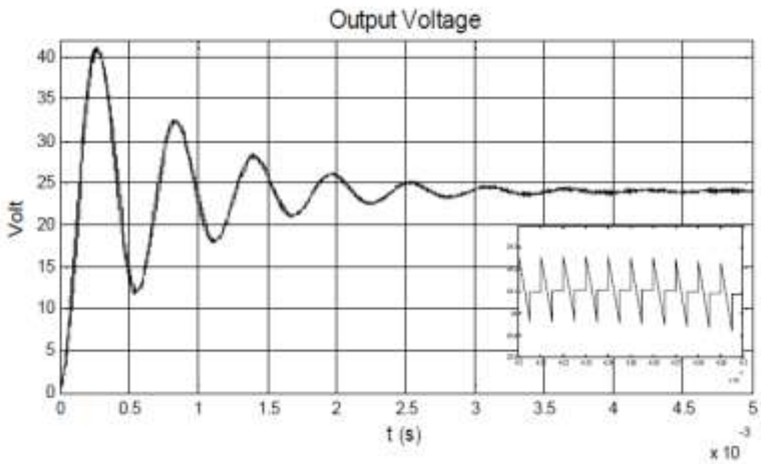

Fig.4.5: DC-DC Boost Converter Output Voltage

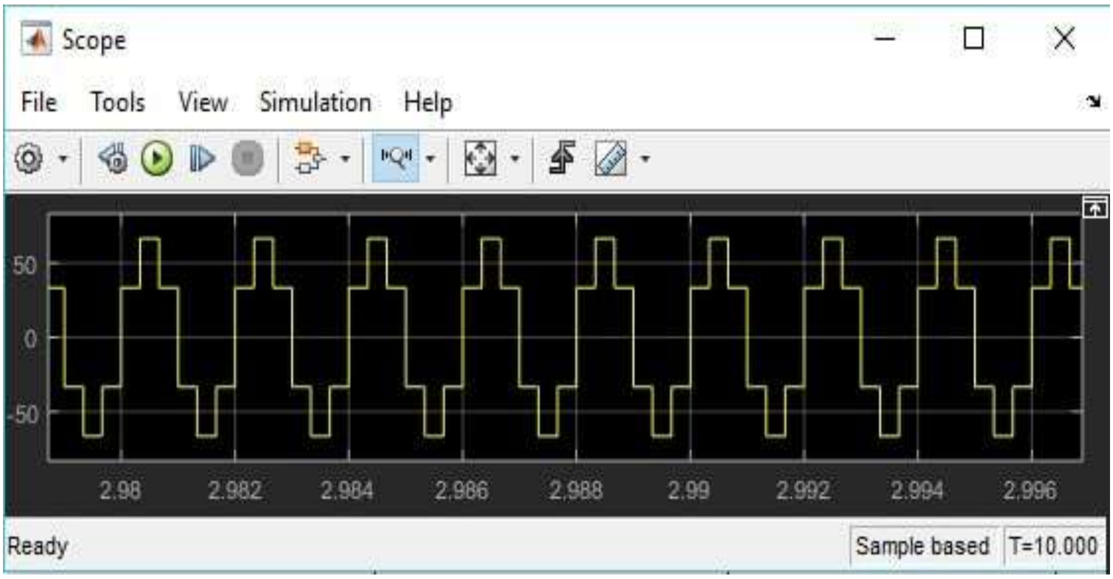

Fig.4.6:Output Line Voltage of Voltage Source Inverter(VSI)

V. CONCLUSIONS AND FUTURE WORK

This thesis has discussed the characteristics of solar PV module and various MPPT methods in the beginning. The Cuk converter based solar PV system was considered for the analysis in this research. Based on the electrical equations of the solar PV module, a MATLAB/Simulink model was designed to validate and study the effects of temperature and irradiation. The solar PV module of L1235-37Wp was used to analyse the DC-DC Boost converter based PV system. The Sliding Mode Controller MPPT was simulated from solar PV module. The effectiveness of the MPPT algorithm was tested for the change in loads and compared with others load conditions.

The input voltage (Output voltage of the solar PV module) of the boost converter-based solar PV system was regulated for the change indifferent load condition using a RPWM controller. Also the DC-DC Boost converter used in solar PV system was stable and the input voltage was kept within the specified range under disturbances at the source voltage and the change in irradiation.

5.1 SCOPE FOR FUTURE WORK

The investigation of non-linear dynamics such as chaos in solar PVpowered Boost DC-DC converter system was analyzed in this research. The non-linear dynamic analysis may be extended to grid connected solar PVsystem to avoid undesirable operation.

Future work includes the small signal modelling of current controller design for regulation of solar PV powered system and then regulation of PV array is to be carried out with both voltage and inner current loop for the change in irradiation.

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