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# A review of novel control strategy for grid synergistic single-phase solar rooftop PV system using generalized integrated theory

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**ABSTRACT:**

A novel control strategy presents for rooftop PV system. Where boost converter iscontrolled by MPPT algorithm and single-phase inverter is controlled by unit templatewith second order generalized instigator. The Maximum Power Point Tracking Controller(MPPT) is an essential part of the photovoltaic (PV) system, it is used to extract themaximum power from the photovoltaic solar module and transfer that power to the load. Several MPPT techniques have been proposed in the literature. One of the mostcommonly used techniques is the perturb and observe algorithm (P&O), due to its lowcost and simple implementation, but it suffers from the slow tracking speed for small stepof perturbation and oscillations around themaximum power point (MPP) when it is subjected to a large step. In this thesis, the P&O algorithm with a variable step size (VS_P&O) is simulated by thePSIM software, analyzed and compared with the fixed step size P&O technique (FS_P&O). These two techniques are also simulated with and without proportionalintegrator corrector (PI corrector). The results show the good tracking, the high efficiencyand precision of the VS_P&O technique using the PI corrector.

## INTRODUCTION

### 1.1 Introduction

1.1.1 The need for Renewable EnergyRenewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturallyreplenished. Therefore, for all practical purposes, these resources can be considered to beinexhaustible, unlike dwindling conventional fossil fuels [1]. The global energy crunchhas provided a renewed impetus to the growth and development of Clean and RenewableEnergy sources. Clean Development Mechanisms (CDMs) [2] are being adopted byorganizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another majorfactor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produceenergy without the harmful effects of pollution unlike their conventional counterparts.

**1.1.2 Different sources of Renewable Energy**

**1.1.2.1 Wind power**

Wind turbines can be used to harness the energy [3] available in airflows. Current dayturbines range from around 600 kW to 5 MW [4] of rated power. Since the power outputis a function of the cube of the wind speed, it increases rapidly with an increase inavailable wind velocity? Recent advancements have led to aerofoil wind turbines, whichare more efficient due to a better aerodynamic structure.

**Fig. Wind turbine**

**1.1.2.2 Solar power**

The tapping of solar energy owes its origins to the British astronomer John Herschel [5]who famously used a solar thermal collector box to cook food during an expedition toAfrica. Solar energy can be utilized in two major ways. Firstly, the captured heat can beused as solar thermal energy, with applications in space heating. Another alternative isthe conversion of incident solar radiation to electrical energy, which is the most usableform of energy. This can be achieved with the help of solar photovoltaic cells [6] or withconcentrating solar power plants.

**1.1.2.3 Small hydropower**

Hydropower installations up to 10MW are considered as small hydropower and countedas renewable energy sources [7]. These involve converting the potential energy of waterstored in dams into usable electrical energy through the use of water turbines. Run-of-theriverhydroelectricity aims to utilize the kinetic energy of water without the need ofbuilding reservoirs or dams.

**1.1.2.4 Biomass**

Plants capture the energy of the sun through the process of photosynthesis. Oncombustion, these plants release the trapped energy. This way, biomass works as anatural battery to store the sun's energy [8] and yield it on requirement.

**1.1.2.5 Geothermal**

Geothermal energy is the thermal energy which is generated and stored [9] within the

layers of the Earth. The gradient thus developed gives rise to a continuous conduction ofheat from the core to the surface of the earth. This gradient can be utilized to heat waterto produce superheated steam and use it to run steam turbines to generate electricity. Themain disadvantage of geothermal energy is that it is usually limited to regions neartectonic plate boundaries, though recent advancements have led to the propagation of thistechnology [10].

**1.2 Solar Technology**

1**.2.1 Current Technologies**

1.2.1.1SolarPhotovoltaic (PV) TechnologiesOne of the key solar energy technologies is solar PV, where a semi-conductor material isused to convert sunlight to electricity directly. There are various photovoltaictechnologies developed to date, few are commercialized and others still remain at researchlevel. The solar PV market is currently dominated by crystalline silicon (c-Si) technology, ofwhich two types are used. The first is mono crystalline, produced by slicing wafers (up to150 mm diameter and 200 microns thick) from a high-purity single crystal boule. Thesecond is polycrystalline, made by sawing a cast block of silicon first into bars, and theninto wafers. The main trend in crystalline silicon cell manufacturing involves a movetoward polycrystalline technology. However, it may be note manufacturers are reducing the price for producing mono asidefrom crystalline silicon cells, other PV cell technologies including amorphous silicon (a-Si), thin Amorphous silicon solar cells require only 1% of the material (the silicon)needed for the production of crystalline silicon cells. It can be grown in any shape or size, and can be produced in an

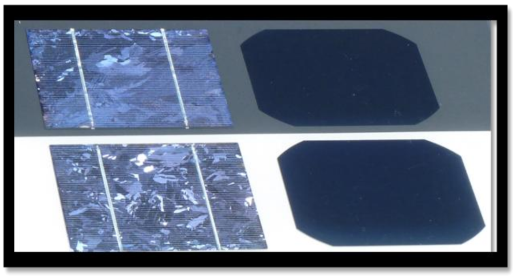

Figure:a) Poly-Si (left) b) Mono-Si (right)

Fig.1.1 Comparison of solar cells

economical way. Amorphous silicon cells were the first type of solar cells to be used in the application ofconsumer products such as watches, calculatoapplications; and given their low cost; they have been adopted by other larger scaleapplications. crystal boule. The second is polycrystalline, made by sawing a cast block ofsilicon first into bars, and then into wafers. Manufacturing involves a move toward polycrystalline technology. However, it may benote manufacturers are reducing the price for producing mono crystalline. Aside from crystalline silicon cells, other PV celland organic cells are commercially available. solar cells require only 1% of the material(the silicon) needed for the production of crystalline silicon cells. It can be grown in anyshape or size, and can be producedthe first type of solar cells be used in the application of consumer products such aswatches, calculators and other critical outdoor applications; and given their low cost; theyhave been adopted by other larger scale applications

**a) Mono crystalline**

calculators and other non-critical outdoorthe main trend in crystalline silicon celltechnologies including Si), thinin an economical way. Amorphous silicon cells were

applications.

a) Mono crystallinb) Polycrystalline c) Amorphous silicon

Fig 2. different type of PV cellthin-film

**1.2.1.2 Solar Thermal**

Technologies Solar thermal technologies extract heat energy transferred by solarradiation. The heat could be used for heating and cooling applications, or to drive a heat engine, in turn run a generator and produce electricity. Solar thermal collectors make useof a working fluid for energy transfer, such as water, oil, salts, air, and carbon dioxide. Concentrating solar collectors use mirrors to focus the sun's energy on a tube containing fluid. The mirrors follow the sun, heating the fluid to very high temperatures. Absorptionchillers operate by using this solar-heated fluid, to drive the refrigeration process. Usingsolar energy with absorption chillers reduces site-generated greenhouse gases as well asthe emissions created when fossil fuels are burned to create electricity.

**1.2.1.3 Low Temperature Solar Thermal Systems**

This type includes unglazed (flat plate) solar collectors and evacuated tube collectors.The operation of the system is reliant on the 'greenhouse effect'. Incident (high energy, short wavelength) solar radiation passes through the transparent or translucent surface ofthe solar collector. The metal or plastic surface and glazed panels reduce the heat radiatedback out, resulting in lower heat loss by the convection of heat from the hot absorbing surface. These types of systems are used for low temperature (up to 180°C), for example. TVPsolar, applications such as water and space heating, and swimming pools; where the lossof heat will not be as significant as with higher temperaturetypical picture of these types of solar thermal system

**a) Flat plate collectors**

**1.3 Trends and updates**

Renewable energy is the most efficient way to make a nationsufficient. Many industrialized nations have installedsupplement or provide an alternative to conventional energynumber of less developed nations have turned to solar to reduimported fuels. States are major markets for solar cells. With tax incentives, solarelectricity can often pay for itself in five to ten yearsCommercial concentrated solar power plants were first developed in the 1980s. The 392MW installation is the largest concentrating solar power plant in the world, located in theMojave Desert of California. Panels.

Fig.3 Evacuated tube collectors

**b) Evacuated tube collectors**

Fig 1.2 Rooftop PV systemindependent and selfinto their electrical grids tosources while an increasingreduce dependence on expensive years. Self intoceThe International Energy Agency projected in 2014 that under its "high renewable "scenario, by 2050, solar photovoltaic and concentrated solar power would contributeabout 16 and 11 percent, respectively, of the worldwide electricity consumption, andsolar would be the world's largest source of electricity.

Fig.4 Flat plate collectors

**1.4 Solar power in India**

In the developing countries like India, solar and power energy is a growing need for theprogress of the country. As power shortfalls continue, peak shortage is a critical problemthat has stifled industrial growth, and back-up generation is becoming increasinglyexpensive. Effective majors have been taken and now solar energy in India has becomethe fast-growing industry. International equipment suppliers are paying more attention tothe Indian market and are developing specific pricing and product strategies for India. India is ranked number one in solar electricity production per watt installed, with an insulation of 1700 to 1900 kilowatt hours per kilowatt peak (kWh/KWP). India's firstsolar power project (with a capacity of 5 MW) was registered under the CleanDevelopment Mechanism. The project is in Sivagangai Village, Sivaganga district, TamilNadu. India saw a sudden rise in use of solar electricity. Recent growth has been over3,000 MW per year and is set to increase yet further. The Charanka Solar Park, at 214MW the largest in the world, along with a total of 605 MW in Gujarat, representing 2/3of India's installed photovoltaic. Large solar parks have also been announced in the stateof Rajasthan the rapid growth in deployment of solar power is recorded and updatedmonthly on the Indian Government's Ministry of New and Renewable Energy website.Being a tropical country, India has about 300 clear and sunny days in a year. The solarenergy available in a year exceeds the possible energy output of all fossil fuel energyreserves in India.

**1.5 Future Scope of Solar Energy**

With reduced costs and improved technologies, the solar energy ensures the reducedelectricity bills, increases countries' energy security through reliance on an indigenous,inexhaustible resources, enhanced sustainability, reduced pollution, lower the costs ofmitigating global warming, and keeps fossil fuel prices lower than otherwise. It isenvironment friendly and any one can use it. The advantages are global. Hence theadditional costs of the incentives for early deployment should be considered learninginvestments; they must be wisely spent and need to be widely shared.

**1.6 Objectives and Contribution of the Thesis**

**1.6.1 Objectives**

The main objective of this study is to explore and analyze the effectiveness of solarenergy electrification in the rural community livelihood transformation and to understandthe people's sense of ownership, and acceptability of the photovoltaic solar technology.

1) To identify the social and economic opportunities in the community which have beencreated by the functioning of the PV solar electrification project in the village.

2) To examine the people's views and plans for the PV Solar project stability and thefuture maintenance of the project.

3) To achieve fast dynamic performance under wide source and load fluctuation.

4) Solar water pumps are used for irrigation of crops, water livestock and provideportable drinking water.

5) Solar water pump uses peak solar array output which frequently coincides with highwater demand during long, dry summer days.

6) In the event of cloudy weather solar water pump systems often use storage tanks to store excess water.

**1.6.2 Contribution of the Thesis**

The primary objective of this work is to model, control and analyze a standalone PVsystem. Some of the salient points of this thesis are:

1) Description of the components of solar water pumping PV system.

2) Modeling of PV module and efficient battery storage system.

3) Design of perturb and observe MPPT controller for boost DC-DC converter.

4) Implementation of close loop control strategy for single phase motor connected system.

**1.8 Summary**

This study comes up with a number of significances. First and foremost, the study showshow Photovoltaic Solar Energy Project installed in india village has so far benefited thepeople and the community at large. Also, the findings from this study shows the readiness,acceptance and a sense of ownership of the project installed in the village and moreimportantly show the acceptance of the people over the PV solar technology to theirsocieties to create a base and assurance on Photovoltaic Solar energy projects stability.

## LITERATURE SURVEY

**2.1 General**

This chapter provides a literature review of previous studies conducted on the followingtopics: Roof top solar, standalone water pumping systems, and PVWP systems. Energymanagement is defined as "the strategy of meeting energy demand when and where it isneeded, which can be achieved by adjusting and optimizing energy using systems andprocedures so as to reduce energy requirements per unit of output while holding constantor reducing total costs of producing the output from these systems" (Abdelaziz et al.,2011, p. 154). Recently, there has been a noticeable growth in energy demand around theworld. This growing demand posits challenges in the sustainability of traditional fossil fuels(e.g., coal, oil, natural gas) as non-renewable energy resources. These challenges includethe reduction of fossil fuels reserves, the negative environmental impact towards the climate change and air pollution, geopolitical and military disagreement, and the fuelprice increases (Asif & Muneer, 2007). Thus, it is advantageous to find better alternativesof energy resources and to adopt effective energy management strategies to meet currentand future electricity demand levels. Rooftop solar (RTS) systems are changing the dynamics and economics of the energysector across the world. Government of India's Ministry of New and RenewableEnergy (MNRE) has ambitious plans of adding 100 GW of solar power by 2022, ofwhich 40 GW is planned to be generated through Grid Connected RTS.A variety of policies and incentive schemes are being formulated to upscale the RTS inthe country. Mapping the RTS potentials of various regions of India can provide a soundbasis for creating a roadmap to achieve the goals set by the government. As per the MNRE, the current total installed capacity of solar power in India is at 16,611MW (as on 30/11/2017). Out of this capacity, about 864 MW comes from the RTSinstallations. Approvals of another 1,767 MW RTS projects have been issued. India'sprogress on the large-scale solar installation has been commendable with another 6,500MW to be added by March 2018. However, the country is still lagging behind on the RTSfront. Hence, to realise the target of 40 GW by 2022, there is a need for many urgentpolicy reforms. Fig 2 .1 prototype rooftop PV

**2.2 Research Background**

Among available RES systems, solar photovoltaic (PV) systems are the most widely adopted around the world, as indicated by Irena (2016): "PV power is already the mostwidely owned electricity source in the world inuptake is accelerating. In only five years, global installed capacity has grown from 40gigawatts (GW) to 227 GW. By comparison, the entire generation175 GW."A PV system is a power system thelectricity through a commutated/synchronous inverter. Even though there are someinitial costs of PV systems installation, the operation and maintenance costs areconsiderable low among other RES shave any moving parts (Boyle, 2012).system (Kanpur)terms of number of installations, and itscapacity of Africa isthat generates energy by directly convertingsystems as they do not require any fuel, and do notat sunlight into systemsThey are also considered thy have the lowest environmental impact among renewable andnon-renewable electricity production systems (Boyle, 2012). While PV systems can becategorized as grid-connected versus standalone systems, majority of PV systems aregrid-connected. There are different approaches towards PV systems and grid integration. A well-designedPV system can work efficiently with the electricity utility grid to strengthen thedistribution network by alleviating load shedding. It can also offset customer's electricitycosts when distribute extra generated energy back into the grid. However, becauseelectricity demand is not consistent where load profile varies based on different attributes(e.g., different types of users, temperature, season, time of the day, etc.). Optimal PV-grid integration requires the electricity suppliers to balance the electricitysupply by PV with local distribution network so that not only the electricity meets thedemand, but also not excessive supply at non-peak load. The first step of this optimization is to estimate the PV potentials, and in particular, rooftop PV systems. How to accurately estimate rooftop PV potential is considered asone of the deployment challenges in design RES-supported electricity grid, which isevident by the profligate literature in rooftop PV potential estimation. The objectives ofthis research are to provide a comprehensive review of related literature to synthesizeexisting approaches towards rooftop PV potential estimation and to provide guidelinesfor different applications of PV potential estimations.

**2.3 Literature Survey**

Studies show that a solar panel converts 30-40% of energy incident on it to electricalenergy. A Maximum Power Point tracking algorithm is necessary to increase theefficiency of the solar panel. There are different techniques for MPPT such as Perturband Observe (hill climbing method), Incremental conductance, Fractional Short CircuitCurrent, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance aremost commonly used because of their simple implementation, lesser time to track theMPP and several other economic reasons. Under abruptly changing weather conditions (irradiance level) as MPP changescontinuously, P&O takes it as a change in MPP due to perturbation rather than that ofirradiance and sometimes ends up in calculating wrong MPPT [11]. However, thisproblem gets avoided in Incremental Conductance method as the algorithm takes twosamples of voltage and current to calculate MPP. However, instead of higher efficiencythe complexity of the algorithm is very high compared to the previous one and hence thecost of implementation increases. So we have to mitigate with a trade-off betweencomplexity and efficiency. It is seen that the efficiency of the system also depends uponthe converter. Typically, it is maximum for a buck topology, then for buck-boost topology and minimumfor a boost topology. It is very simple to implement and has high efficiency both understationary and time varying atmospheric conditions [12]. When multiple solar modules are connected in parallel, another analog technique TEODIis also very effective which operates on the principle of equalization of output operatingpoints in correspondence to force displacement of input operating points of the identicaloperating system.

## 3 MAXIMUM POWER POINT TRACKING ALGORITHMS

**3.1Introduction**

An overview of Maximum Power Point Tracking A typical solar panel converts only 30to 40 percent of the incident solar irradiation into electrical energy. Maximum powerpoint tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit ismaximum when the Thevenin impedance of the circuit (source impedance) matches withthe load impedance. Hence our problem of tracking the maximum power point reduces toan impedance matching problem. In the source side we are using a boost convertor connected to a solar panel in order toenhance the output voltage so that it can be used for different applications like motorload. By changing the duty cycle of the boost converter appropriately we can match thesource impedance with that of the load impedance.

**3.2 Different MPPT techniques**

There are different techniques used to track the maximum power point. Few of the most
popular techniques are:

1) Perturb and observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
**6) Fuzzy logic**

The choice of the algorithm depends on the time complexity the algorithm takes to track
the MPP, implementation cost and the ease of implementation.

**3.2.1 Perturb & Observe**

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is
the voltage sensor, to sense the PV array voltage and so the cost of implementation is lessand hence easy to implement. The time complexity of this algorithm is very less but onreaching very close to the MPP it doesn’t stop at the MPP and keeps on perturbing onboth the directions. When this happens the algorithm has reached very close to the MPPand we can set an appropriate error limit or can use a wait function which ends upincreasing the time complexity of the algorithm. However, the method does not take account of the rapid change of irradiation level (due towhich MPPT changes) and considers it as a change in MPP due to perturbation and endsup calculating the wrong MPP. To avoid this problem, we can use incrementalconductance method.

**3.2.2 Incremental Conductance**

Incremental conductance method uses two voltage and current sensors to sense the outputvoltage and current of the PV array.

At MPP the slope of the PV curve is 0.

$(dP/dV)_{MPP}=d(VI)/dV$ 3.1

0=I+VdI/dVMPP 3.2

dI/dVMPP = - I/V 3.3

The left-hand side is the instantaneous conductance of the solar panel. When thisinstantaneous conductance equals the conductance of the solar then MPP is reached.

Here we are sensing both the voltage and current simultaneously. Hence the error due tochange in irradiance is eliminated. However, the complexity and the cost ofimplementation increase. As we go down the list of algorithms the complexity and thecost of implementation goes on increasing which may be suitable for a highlycomplicated system. This is the reason that Perturb and Observe and IncrementalConductance method are the most widely used algorithms. Owing to its simplicity of implementation we have chosen the Perturb & Observealgorithm for our study among the two.

**3.2.3 Fractional open circuit voltage**

The near linear relationship between VMPP and VOC of the PV array, under varyingirradiance and temperature levels, has given rise to the fractional VOC method.

VMPP = k1 Voc 3.4

where k1 is a constant of proportionality. Since k1 is dependent on the characteristics ofthe PV array being used, it usually has to be computed beforehand by empiricallydetermining VMPP and VOC for the specific PV array at different irradiance andtemperature levels. The factor k1 has been reported to be between 0.71 and 0.78. Once k1 is known, VMPPcan be computed with VOC measured periodically by momentarily shutting down thepower converter. However, this incurs some disadvantages, including temporary loss ofpower. [15].

**3.2.4 Fractional short circuit current**

Fractional ISC results from the fact that, under varying atmospheric conditions,IMPP is approximately linearly related to the ISC of the PV array.

IMPP =k2 Isc 3.5

where k2 is a proportionality constant. Just like in the fractional VOC technique, k2 hasto be determined according to the PV array in use. The constant k2 is generally found tobe between 0.78 and 0.92. Measuring ISC during operation is problematic. An additionalswitch usually has to be added to the power converter to periodically short the PV arrayso that ISC can be measured using a current sensor[15].

**3.2.5 Fuzzy Logic Control**

Microcontrollers have made using fuzzy logic control popular for MPPT over lastdecade. Fuzzy logic controllers have the advantages of working with imprecise inputs,not needing an accurate mathematical model, and handling nonlinearity [15].

**3.2.6 Neural Network**

Another technique of implementing MPPT which are also well adapted formicrocontrollers is neural networks. Neural networks commonly have three layers: input,hidden, and output layers. The number nodes in each layer vary and are user-dependent. The input variables can bePV array parameters like VOC and ISC, atmospheric data like irradiance andtemperature, or any combination of these. The output is usually one or several referencesignals like a duty cycle signal used to drive the power converter to operate at or close tothe MPP [15].Table 3.1 Characteristics of different MPPT techniques [15]

## 4MODELLING AND CONTROL STRATEGY

**4.1 Overview**

Water resources are essential for satisfying human needs, protecting health, and ensuringfood production, energy and the restoration of ecosystems, as well as for social andeconomic development and for sustainable development [1]. PV module is the basic power conversion unit of solar power generator system. The output characteristic of the PV module basically depends on the solar illumination andtemperature of the PV module. In this thesis, the PV cells are designed which are connected into a no. of series andparallel combinations to form the PV module and PV array. These PV array thenconnected with the DCDC buck-boost converter for the purpose of providing appropriatepower for the pumping [2]-[8].

**4.2 System Modeling and Design**

**4.2.1 Photovoltaic cell**

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light toelectrical energy by photovoltaic effect. If the energy of photon of light is greater than theband gap then the electron is emitted and the flow of electrons creates current. However, a photovoltaic cell is different from a photodiode. In a photodiode light falls onn channel of the semiconductor junction and gets converted into current or voltage signalbut a photovoltaic cell is always forward biased.

**4.2.2 PV module**

Usually a number of PV modules are arranged in series and parallel to meet the energyrequirements. PV modules of different sizes are commercially available (generally sizedfrom 1000W for example, a typical small-scale desalination plant requires a few thousandwatts of power.

**4.2.3 PV Modelling**

A PV array consists of several photovoltaic cells in series and parallel connections. Seriesconnections are responsible for increasing the voltage of the module whereas the parallelconnection is responsible for increasing the current in the array. Typically, a solar cellcan bemodelled by a current source and an inverted diode connected in parallel to it. Ithas its own series and parallel resistance. Series resistance is due to hindrance ino

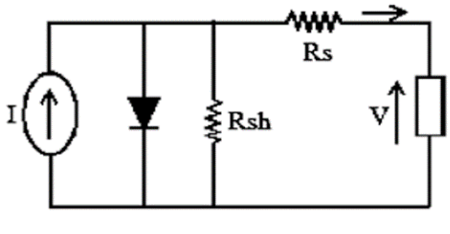

**Figure 4**: Single diode model of a PV cell

resistance is due to the leakage current.Figure 4.1: Single diode model of a PV cell Typically a solar cell can be modelled by a current source and an inverted diodeconnected in parallel to it. It has its own series and parallel resistance. Series resistance isdue to hindrance in the path of flow of electrons from n top junction and pararesistance is due to the leakage current. In this model we consider a current source (I) along with a diode and series resistance(Rs). The shunt resistance (RSH) in parallel is very high, has a negligible output current from the photovoltaic

I = Is

Id= Io (eqVd/kT

photovoltaic array is

– Id (4.1)

- 1) (4.2

the pathparallelnegligible effect. The4.2)where Io is the reverse saturation current of the diode,

q is the electron charge,Vd is thevoltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junctiontemperature in Kelvin (K)

From eq. 4.1 and 4.2

I = Isc – Io (eqVd/kT - 1) 4.3

Using suitable approximations,

I = Isc – Io (eq((V+IRs)/nkT) - 1) 4.4

where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (inKelvin) and n is the diode ideality factor in order to model the solar panel accurately wecan use two diode model but in our project our scope of study is limited to the singlediode model. Also, the shunt resistance is very high and can be neglected during thecourse of our study. Figure 4.2: TheI-V characteristics of a typical solar cell are as shown in the Figure 4.2. When thevoltage and the current characteristics are multipoint indicated as MPP is the po- V characteristics curve of photovoltaic cell multiplied we get the shown in Figure 4.3. Thepoint at which maximum.Figure 4.3 P4.3 Control strategy for boost converterAs stated in the introduction, the maximum power point tracking is basically a loadmatching problem. In order to change the input resistance of the panel to match the loadresistance (by varying the duty cycle), a DC to DC converter is required. It has been studied that the efficiency of the DC to DC converter is maximum for a buckconverter, then for a buck boost converter buttying to a grid or for a water pumping system which requires 230 V at the output enwe use a boost converter-V characteristics curve of photovoltaic cellas we intend to use our system either forend, soFig. 4.4: The circuit topology of Boost converterMode 1 operation of the Boost ConverterWhen the switch is closed the inductor gets charged through the battery and stores theenergy. In this mode inductor current rises (exponentially) but for simplicity we assumethat the charging and the discharging of the inductor are linear. The diode bloccurrent flowing and so the load current remains constant which is being supplied due tothe discharging of the capacitor.

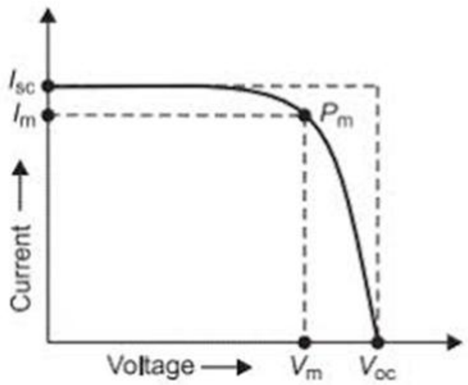


Figure 4.5v

Mode 1 operation of Boost Converter

blocks theMode 2 operation of the Boost ConverterIn mode 2 the switch is open and sin the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation. The waveforms for a boostconverter are shown in Figure4.7.Figure 4.6so the diode becomes short circuited. The energy stored4.7.Mode 2 operation of Boost ConverterFigure 4.7

**4.4 single phase Inverter**

The model of a single-phase inverter can be divided into two categories: category isbased on a synchronous frame system (dqanother category is built upon a stationary frame system (αβproportional-resonant (PR) regulatorWaveforms for a Boost Converterdq-frame) that usually adopt a PIαβ-frame)regulator.regulator;employs the system also employs a PI controller. The task of the MPPT algorithm is just tocalculate the reference voltage Vmove next for obtaining maximum power output. This processwith a 10 samples per second. The external control loop is the PI controller, whichcontrols the input voltage of the converter.Fig.4.8Single phase inverter matlab model.

ref towards which the PV operating voltage shouldis repeated periodically

**4.5 MPPT Algorithms**

Two of the most widely used methods for maximum power point racking are studiedhere. The methods are

1. Perturb & Observe Method.
2. Incremental Conductance Method.

4.5.1 Perturb & Observe Algorithm

The Perturb & Observe algorithm states thatis perturbed by a small increment, if the resulting change in powerare going in the direction of MPP and we keep on perturbing in the same direction. Ifis negative, we are going away fsupplied has to be changed.Figure 4.9: Solar panel characteristics showing MPP and operatingwhen the operating voltage of the PV panelΔP is positive,then wefrom the direction of MPP and the sign of perturbationpoints A and BΔProm pointsFigure 4.9 shows the plot of module output power versus module voltage for a solar panelat a given irradiation. The point marked as MPP is the Maximum Power Point, thetheoretical maximum output obtainable from the PVas two operating points. As shown inthe figure above, the point A is on the left-hand side of the MPP.Therefore, we can move towards the MPP by providing a positive perturbation to the

voltage. On the other hand, point B is on the right-hand side of theperturbation, the value of imperative to change the direction of perturbation to achieveMPP. The flowchart for the P&O algorithm is shown in Figure 4.2

MPP. Whenart a positiveIn a situation where the irradiance changes rapidly, the MPP also moves on the right handside of the curve. The algorithm takes it as a change due to perturbation and in the nextiteration it changes the direction of perturbation and hence goes awayshown in the figure.However, in this algorithm we use only one sensor, that is the voltage sensor, to sense thePV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching v

it doesnt stop at the MPP and keeps on perturbing in both the directions. When thishappens the algorithm has reached very close to the MPP and we can set an appropriatefrom thevery close to the MPPMPP asery

error limit or can use a wait function which ends up increasingalgorithm.

**4.5.3 Implementation of MPPT using a boost converter**

The system uses a boost converter to obtain more practical uses out of the solar panel.The initially low voltage output is stepped up to a higher level using the

though the use of the converter does tend to introduce switching losses. The blockdiagram shown in Figure 4.4 gives an overview of the required implementation. Figure4.12: the time complexity of theboost converter,Requisite implementation

## RESULT AND DISCUSSION

**5.1 General**

Section 5 incorporates framework reproduction results and talk about it. gives a short thought regarding recreation of independent PV framework and itsparameter esteems. The consequence of the proposed framework in Section 5.3 has beenportrayed, this segment is separated into four sub-areas, the main segment demonstratesthe aftereffects of PV board under sun-oriented radiation and diminishes sun poweredradiation. Subdivision demonstrates the aftereffect of the second battery vitalitystockpiling framework. Subsection demonstrates the consequence of third load and I likewise has sub-plot under two conditions, there is a stable direct weight and anotherstraight and non-straight weight. Also, the latter is a converter side outcome.

**5.2 Simulink Model of Single Phase PV System**

In a standalone PV system, battery is used as backup source to provide stable voltage andcurrent to the load. Stable voltage and current at the load can be achieved when the PVgenerated power should be balanced with the load demand power. That means wheneverPV power generation is less than the load demand of consumer, battery needs to providethe extra power and whenever PV power generation is more than the power demand of

the consumer, battery store the surplus power.Battery is bidirectional devices which can store as well as deliver the power duringstorage power it is in charging mode and when delivers the power work at dischargingmode. For Simulation of this standalone PV system a 1000 W PV generation is taken, whereseries connected PV modules are Ns=17 and parallel connected PV modules are Np=9

are considered during PV modelling. Series connection of PV module increases thevoltage rating while parallel connection of PV module increases the current rating. In

proposed research work are taken seventeen modules in one row having nine rows total.

**5.3 Simulation result and discussion**

The proposed Standalone PV system is modelled in Simulink of MATLAB R2015a withdiscreet solver at 10μS the developed model is tested under different conditions such aschange in change in solar irradiation, and different load condition. Performance isevaluated in terms of solar irradiation G(t) in w/m2 ,PV voltage (VPV ) , PV current

(IPV), boost converter output current (Idc), power developed by PV module is (Ppv), DCvoltage (Vdc), state of charging (SOC) of battery in percentage, battery voltage (Vbt)Battery current (Ibt) Battery power, motor terminal voltage (Vm) , motor current (Im)motor power demand active (Pm), battery voltage (Vb) current ( Ib).

**5.3.1 Performance of rooftop PV system**

Performance is evaluated in terms of solar irradiation G(t) in w/m2 , PV voltage (VPV ) ,PV current (IPV ), boost converter output current (Idc),is (Ppv), DC voltage (Vdc), proposed1000 w/m2 which is shown in tor power developed by PV modulesystem perform under constant solar irradiation

**5.4 Conclusion**

This chapter provides the simulation model of PV system-based Grid with boostconverter to extract maximum power from nature and perfAnd to invert dc power into ac power ItMATLAB 2015a under discreet mode.performance of P&O and Gridperformance is shown in tableIts result is satisfactory obtained using

Electronic and Electric Engineering. , 2014, Vol. 4, N. 2, pp. 213-224.erefore, we can move towards the MPP by providing a positive perturbation to thevoltage. On the other hand, point B is on the right-hand side of theperturbation, the value of imperative to change the direction of perturbation to achieveMPP. The flowchart for the P&O algorithm is shown in Figure 4.2. Figure 4.10: Flowchart of Perturb & Observe algorithm MPP. When art a positive4.5.2 Limitations of Perturb & Observe algorithmFigure 4.11: Curve showing wrong tracking of MPP by P&O algorithm underIn a situation where the irradiance changes rapidly, the MPP also moves on the right handside of the curve. The algorithm takes it as a change due to perturbation and in the nextiteration it changes the direction of perturbation and hence goes awayshown in the figure.However, in this algorithm we use only one sensor, that is the voltage sensor, to sense the

PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching vit doesn't stop at the MPP and keeps on perturbing in both the directions. When thishappens, the algorithm has reached very close to the MPP and we can set an appropriatefrom thevery close to the MPPT asenergy error limit or can use a wait function which ends up increasingalgorithm.

**4.5.3 Implementation of MPPT using a boost converter**

The system uses a boost converter to obtain more practical uses out of the solar panel. The initially low voltage output is stepped up to a higher level using thethough the use of the converter does tend to introduce switching losses. The blockdiagram shown in Figure 4.4 gives an overview of the required implementation.Figure 4.12:

the time complexity of theboost converter, Requisite implementation for MPPT systemModelling of rooftop PV systemSolar panelThe entire system has been modelled on MATLAB™ 2009a and Simulink™. The blockdiagram of the solar PV panel is shown in Figure 5.1 and Figure 5.2. The inputs to thesolar PV panel are temperature, solar irradiation, number of rows ofFigure 4.13: Masked block diagram of the modelled solar PV panel

**4.6 PI Controller**

The system also employs a PI controller. The task of the MPPT algorithm is just tocalculate the reference voltage Vref towards which the PVnext for obtaining maximum power output. This process is repeated periodically with the solar PV panel are temperature, solar irradiation, number of solar cells in series and

number of rows of solar cells in parallel.slower solar cells in parallel.: operating voltage should moverate of around 1-10 samples per second. The external control loop is the PI controller, which controls the input voltage of theconverter. The pulse width modulation is carried in the PWM block at a considerably fasterswitching frequency of 100 KHz. In our simulation, KP is taken to be 0.006 and KI istaken to be 7. A relatively high KI value ensures that the system stabilizes at a faster rate.The PI controller works towards minimizing the error between Vref and the measuredvoltage by varying the duty cycle through the switch. The switch is physically realized byusing a MOSFET with the gate voltage controlled by the duty cycle.

**4.7 Model for Perturb & Observe Algorithm**

The MPPT unit for this method utilizes the power and the the current and voltage valuesas in incremental conductance method. Rest every unit is similar to the previous modelunits. The repeating sequence being utilized in the model has an operating frequency of

## 5 RESULT AND DISCUSSION

**5.1 General**

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**5.3.1 Performance of rooftop PV system**

Performance is evaluated in terms of solar irradiation G(t) in w/m2 , PV voltage (VPV ) ,PV current (IPV ), boost converter output current (Idc),is (Ppv), DC voltage (Vdc), proposed1000 w/m2 which is shown in fig 5.1.Fig. 5.1 (A) Performance of PV systemtor power developed by PV modulesystem perform under constant solar irradiationofFig. 5.1 (B) Performance of Grid

**5.3.2 Performance of rooftop pv system rising irradiation**

The performance of of PV system its plots is divided into four part first one is voltage atpump terminal generation by PV system so battery is in charging mode which is shown inFig. 5.2Fig. 5.2 (A) Performance of grid under rising irradiationsFig 5.2 (B) Performance of PV system under rising irradiations

**5.3.3 Performance of PV System decreasing irradiation**

The performance of battery energy storagesystem of single phase PV system bassystem is shown in Fig. 5.3, its plots is divided into three part first one is battery voltagelevel second one is battery current when current is negative it work is in charging modewhile current is positive battery work is in discharging mode. Third one is state ofcharging of battery.Fig. 5.3 (A) Performance of PV pumping System under decreasing irradiation

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