A DISSERTATION

ON

Design and Modelling of Solar Photovoltaic system with Particle Swarm Optimization Technique

Submitted In Partial Fulfilment of the Requirement for the Award of the Degree in

MASTER OF TECHNOLOGY

In

Renewable Energy Technology

Submitted By

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Declaration

This is to certify that the M. Tech dissertation on **“Design and Modelling of Solar Photovoltaic System with Particle Swarm Optimization Technique”** is submitted by me(Talat Zahra) for the Partial Fulfilment of the requirement for the award of the degree of Master of Technology in Renewable Energy Technology in the Department of Electronics and Communication Engineering , Faculty of Engineering, in Integral University, Lucknow, UP (India) . This comprises original study based on the research articles and other authentic resources from the web and due acknowledgement have been made in the text to the materials used. I, hereby, further declare that in case of any legal dispute in relation to my research work, I will be solely responsible. Also, any part of this work has not been presented or published anywhere for the award of degree.

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CERTIFICATE

This is to certify that the project titled **“Design and Modelling of Solar Photovoltaic System with Particle Swarm Optimization Technique”** has been carried out by **Ms. Talat Zahra** under my supervision and guidance in partial fulfilment of the requirements for the award of degree of **“Master of Technology”** in Renewable Energy Technology at Department of Electronics and Communication Engineering, Integral University, Lucknow, India.

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ABSTRACT

The use of PV is very dependent on climate, temperature, and irradiation, therefore MPPT (Maximum Power Point Tracking) is needed to obtain optimal power. In this thesis MPPT for PV system based on PSO using input voltage and current of the boost converter is presented. The performance of Particle swarm optimization is validated by Simulink with irradiance variations. The use of PSO can achieve maximum power for various irradiance. MPPT based PSO was compared by a PV system without MPPT. Based on simulation results PSO provides the power improvement by 47.98 W. Simulation results show that the system designed can optimize power produced by PV.

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CERTIFICATE

Dated: _________

This is to certify that Talat Zahra has studied **'Design and Modelling of Solar Photovoltaic system with Particle Swarm Optimization Technique'**, taking references from the Solar Photovoltaic plant installed in Integral University". This study was a part of her field work as per M. Tech Syllabus.

The field work conducted successfully.

PROF. (DR.) T. USMANI

Director (Solar Project)

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SYMBOLS AND ABBREVIATIONS

a	Diode ideality factor
α_S	The slope of the change in the cell operating temperature due to a change in the solar irradiation level
D	Duty cycle
F_{sw}	Switching frequency
$pbest$	local best
$gbest$	global best.
T	module temperature (k).
I_{ph} or I_l	Light generated current of a PV cell
V_{CX} , I_{phx}	Light generated cell output voltage and current
I_D	Diode current
I_C & V_C	Are cell supplied current and terminal voltages respectively.
I_o	Diode reverse saturation current
i_{PV}	Output current of a PV cell
I_{sc}	Short-circuit current of a PV cell
J	Moment of inertia of the system in kg-m^2
K	Boltzmann's constant
L_a	Self inductance of the armature winding
Ns	Series connected module
Np	Number of module in parallel
P_{max}	Maximum power output of a PV panel
P_{Array}	Out-put power of the PV array
Q	Charge of an electron
R_a	Armature resistance
R_s	Module resistance
V_T	Thermal voltage

Chapter 1
INTRODUCTION

Modern society is heavily reliant on energy. Energy consumption is growing, consequently industrialization, urbanization, and population is also growing. The availability of energy resources has a significant impact on every country's economy and people's level of living. Traditional fossil energy sources such as coal, oil, and gas are rapidly depleting. These sources are expected to be exhausted during the next 100-150 years [1]. Nearly 80% of the world's current energy consumption is satisfied by fossil fuels. If these energy sources on which we rely become depleted, the world would face energy scarcity. Before such a disastrous situation occurred, industrial and emerging countries recognized the importance of creating alternative energy options.

Renewable energy resources such as hydro, biomass, wind, solar, etc. are attracting attention. The necessity of the hour is for a sustainable economic and environmentally favourable supply. India is a tropical country with plenty of solar energy. It's an appealing and practical choice. Solar energy harnessing efforts began in India a long time ago [2]. However, further R&D efforts by universities, scientific organizations, and corporations are required to make solar energy relatively competitive with conventional sources.

We are living in a time where the solar panel, windmill,the wind turbine has been invented and modified for the efficient generation of electrical power and Mechanical work. Availability of renewable energy and indefinite presence has been two major factors that have worked in support of the adoption of renewable energy. Renewable energy sources are transitioning from non-conventional sources of energy to conventional sources of energy.

In a country like India, renewable energy sources have a considerable number of advantages over fossil fuel-based energy sources as renewable energy sources do not harm the environment and do not emit harmful greenhouse gases. In many ways, renewable energy sources are an answer to India's exponentially growing power needs. As the depletion of fossil fuel-based energy sources continues renewable energy sources present themselves as a gateway to sustainable jobs for the youth of India.

India takes the second position on the list of most populated countries in the world and takes the first position in the fastest-growing population list. At the current rate, India will overtake China's population by the year 2025[3]. Credits are for the Government of India for keeping electrification as one of its top priorities since independence in 1947.

As of the year, 2020 India is the third-largest consumer of electrical power in the world however India has the lowest per capita electricity consumption when compared with similar developing countries and developed countries of the world.

Utilizing and promoting renewable energy electrical power sources becomes imperative to India's agenda on the global stage as India is a signatory to the Paris climate agreement. Through renewable energy electrical power sources, India aims to provide clean and green electrical power to its population and also contribute its chair in saving the environment following the Paris climate change agreement. The average age of Indian citizens is estimated and calculated to be 27 years of age. As of the year 2020 thermal energy has been contributing an alliance share of 61% to India's electrical power sector [4].

Thermal energy is a widely available source of electrical power and considering India's economic standing thermal energy is a very cost-effective means of producing electrical power.

The government of India has launched the Jawaharlal Nehru National solar mission and the faster adoption and manufacturing of hybrid and electric vehicles programs to help decrease the share of thermal energy in the electrical power generation sector of India, with the implementation and success of renewable energy programs initiated by the government of India and the private sector alike, India can secure its energy needs as it does not depend on one source of energy for electrical power generation.

The growing economy of India will be helped by the decreasing burden on our foreign reserves which are spent on importing fossil fuel-based sources of energy. India’s coastline of 7500 km serves as an ideal platform for wind turbine and windmill installation. Mother nature has gifted India with 300 days of direct sunlight for the utilization of solar power [5]. The emission of greenhouse gases and other harmful pollutants concerning the environment and ozone layer from automotive sources has been a concern all over the world. Indian perspective on harmful pollutants concerning environment and ozone layer from automotive sources has been mainly concentrated on faster adoption and manufacturing of electric vehicles a scheme launched by the government of India to promote manufacture design develop and improve the electric vehicle sector in India.

The inclusion of battery-operated vehicles remains the top priority of the Government of India to tackle harmful pollutants for the environment and ozone layer from automotive sources.

Faster adoption and manufacturing of electric vehicles in India is a dual objective program.

Its first objective is to decrease the effect of harmful pollutants on the environment and more ozone layer from automotive sources by replacing fossil fuel-based automotive sources with battery-operated vehicles. Secondly, it focuses on decreasing the Reliance of India on fossil fuel best sources. As mentioned earlier fossil fuel resources take up a major chunk of India's foreign reserves in addition to polluting the environment [6]. The need for energy for industries has been the constant factor and has never changed from the first Industrial Revolution to Industrial Revolution 4.0.

To focus on self-sustaining energy and to accelerate the economic growth of India the Government of India has launched an initiative termed make in India which focuses on the production and manufacturing of technological advancements and their research and development facilities in India itself. Tata Power solar system and Waaree solar are the major companies that are dominating the solar energy sector in India. Suzlon and Vestas India remain the companies that are introducing electrical power generated from wind turbines and windmills in India. Usage of biogas power plants for localized generation of electricity in the rural areas and semi-urban areas of India remains a very popular effective and cheap method of producing electrical power. The 1979 energy crisis acted as a catalyst to renewable energy as many countries began to look into renewable energy with increased enthusiasm. India set up the Commission on Additional Sources of Energy in 1981 and the Department of non-conventional energy sources in 1982. Indian Renewable Energy Development Agency was start with taking care of financial aspects and was founded in 1987 [7].

Energy resources, that are directly produced by the sun (thermal, photochemical, and photoelectric), indirectly produced by the sun (wind, hydropower, and photosynthetic energy stored in biomass), or produced by some other natural environmental processes and mechanisms that is spontaneously renewed over a short time frame (such as geothermal and tidal energy) all comes under the category of renewable energy. Further, Energy resources sourced from fossil fuels, waste products collected from fossil fuels, and waste products derived from inorganic sources are not included in renewable energy.

Types of renewable energy

- Solar Energy
- Biomass
- Geothermal Energy
- Wind Energy
- Hydropower

Benefits of Renewable Energy

- Does not emit any greenhouse gases.
- Highly sustainable.
- Highly cost-effective
- Less labor is required to perform the task.
- Economical benefitted to remote communities.
- Geothermal steam sources, for example, take up less space than bigger conventional power plants and may operate at any time of day or night.
- To produce more power at peak times, hydro electrical power can be easily controlled.
- Biomass energy helps cut down on the amount of rubbish that is transported to landfills.

Among all the types of renewable energy, Solar energy is an infinite source of energy that will play a significant role in the future. The density of solar radiation, however, varies from location to location, as does the utilization of solar energy. Major advantages of the usage of solar energy areas:

- It doesn't emit toxic substances or contaminants into the air.
- It doesn't produce waste.
- It causes less electricity loss.
- It can be used underutilized lands.
- It improves grid security.
- It is a free source of energy.
- It is completely environment friendly.

1.1 Solar Energy

The story of solar energy generation and transmission begins in the year 1839 by Alexandra Edmond Becquerel. Before Alexander Edmond Becquerel, MV Lomonosov theorized that lenses could be used for two amplifiers and extract the power of solar radiation efficiently, in the year 1767. Before the advent of rooftop solar generation and transmission through solar panels, the first household application of solar energy was the solar cooker. It was first used by J.Harshal, a South African in 1830 [8]. 1830 was also the year when the first greenhouse which was made of glass was constructed by H Repton in Europe a focal point in the history of solar energy generation and transmission came over a hundred years after Alexandra discovered the photovoltaic effect in the year 1941 when Russell Ohl invented the solar cell.

1.2 Solar Cell

Russell Ohl's invention would change the face of the electricity generation and transmission industry in the years to come. Today we can see that Russel Ohl's invention has helped in the generation and transmission of electricity for megacities and also assist in the smooth functioning of wristwatches and calculators by acting as a source of power for them. India has been blessed with 300 days of direct sunlight out of a potential 365 days of direct sunlight. The Thar Desert which lies in the Indian state of Rajasthan is a desert located in the western part of the country [9]. The Thar Desert presents itself as a massive opportunity for government sector electricity generation and transmission companies as well as the private sector. Electricity generation and transmission companies' setup massive solar power plants in the Thar Desert so that a massive amount of land can be available for the betterment of the country. Incentives for government sector electricity generation and transmission, companies and private sector electricity generation and transmit companies is that since they will be setting a solar power plant in the desert population is huge and expenditure on land for constructing the potential Solar Power Plant will be minuscule.

1.3 Solar Photo voltaic (SPV)

Solar photovoltaic (PV) is generally consumed as a renewable energy resource for electricity generation. The energy obtained from the sun's rays is converted into electricity by using a solar cell. Solar PV is expected to grow rapidly owing to its endless energy supply and zero pollution to the environment during production. PV energy conversion is the consistent conversion of solar radiation into electricity via the photovoltaic effect. The photovoltaic effect is the generation of a possible difference at the junction of two different materials [10].

PV solar energy is being developed as a new and ecologically friendly energy source to offer electricity for people's comfort on Earth. The power obtained from a PV system comprising one or more photovoltaic cells is determined by the irradiance, temperature, and current obtained from the solar cells.

PV systems are used to convert solar energy directly into electricity using the photovoltaic effect concept. When some materials are exposed to light, photons are attracted and free electrons are released. This is known as the photoelectric effect.

Photovoltaic systems need less maintenance and are fully recyclable. Photovoltaic modules are used to generate electricity in rural regions where the electric power grid does not exist, hence improving the quality of life in these places. Because PV cells are unstable, it is critical to change as much energy as possible whenever it is available [11].

The sun's rays are harvested by solar cells included in a semiconductor device, for converting solar energy into electricity. A solar cell is a component used to distribute a specific quantity of electric power that is distinguished by an output voltage and current. Solar energy transfer to practical equipment demands a specified voltage or current for their functioning.

PV power systems are usually categorized depending on their functional necessities, module configurations, type of connection made with other energy sources, and electrical loads. Photovoltaic systems are considered for offering DC and/or AC power service for operating interrelated with or self-governing of the utility grid. Association between other power sources and power storage systems are also made possible with PV systems [12]. The main categorizations are as follows:

- Grid-connected or utility-interactive systems
- Stand-alone systems
- Grid-connected or Utility-interactive Systems

Benefits of PV systems:

It offers substantial advantages over conventional power sources. Some of them are as follows:

- Most of the PV modules show no degradation even after ten years of use.
- Even in harsh conditions, PV systems have proven their reliability.
- PV users can cite energy independently from utilities as their primary motivation.

- PV systems are very safe and do not require combustible fuels.
- PV systems are more cost-effective as compared to bulky conventional systems.
- PV systems reduce sound pollution as they work silently.
- Because of the increased insulation at high altitudes, photovoltaic is favorable because power production is maximized. A diesel generator at higher altitudes, on the other hand, must be de-rated due to efficiency and power output losses.

1.4 Maximum Power Point Tracking (MPPT)

In practice, PV arrays do not simultaneously accept uniform insulations. Certain portions of the PV array get shaded by a heavy cloud, trees, or near constructions. This causes the shaded PV cells to attract the huge amount of electric power produced by other PV cells and generates high insulation which is transformed into heat. This condition is known as a hotspot issue that affects the PV cells with minimum insulation. To avoid these situations, Maximum PowerPoint Tracking (MPPT) is essential in PV systems [13].

MPPT is an electronic system that aids in the efficient support of photovoltaic modules, allowing the modules to generate maximum power. In other words, MPPT is a fully electronic system that modifies the electrical working point of PV modules to provide the maximum available power. The extra power saved by the module is made available as an increased battery charging current. Furthermore, MPPT is used in combination with an automated tracking approach.

Despite changes in load and weather conditions, the PV production is to be run with greater system power efficiency at the peak power point. In other words, maximum power is supplied to the load via source impedance equalization. An MPPT system is designed to aid maximum power throughout the operation of a solar array by tracking variations in maximum power caused by changes in atmospheric conditions. The MPPT system was simply an electrical device that was installed between the PV array and the load. When a solar panel generates power, its maximum power output varies with meteorological conditions, as do the electrical qualities of the load. To achieve optimal usage, PV-produced systems must operate at full power or near to it.

Maximum Power Point Tracking (MPPT) is used to get maximum power from PV systems. It is mostly used to aid applications inputting electricity on the grid, charging batteries, or operating an electric motor. Furthermore, there is no well-being requirement imposed by electric organizations or legislative bodies [14]. However, when PV becomes a more relevant on-screen character or a component in power systems, PV establishments have become a generally significant product of the electrical industry. The conditions and guidelines for the safe and dependable use of PV systems are being standardized. When it comes to planning, assembling, developing, and marketing a PV institution, two groups of requirements may be examined broadly. These two groups are the working or execution prerequisites and the legal guidelines that PV converters and PV establishments must follow.

The quantity of electricity produced by the PV system is determined by the DC voltage provided by the PV panels. The relationship between control input and output power is non-convex and has several local maxima. PV module output power is reduced due to a continual oscillation in the steady-state. Furthermore, due to the robust shifting of weather conditions, the PV module does not operate at its optimal output power. To get higher power for any given environmental circumstances, an MPPT system is required to the output of the solar cells and a suitable resistance is utilized.

Because of the higher initial cost of PV power generating systems with lower energy conversion efficiency, the PV system was pushed to extract the maximum power from the PV source. MPPT aided in reaching the maximum power produced by PV systems under dynamic conditions. In addition, several search techniques are used in the tracking of maximum power point (MPP) from PV systems.

To establish the MPP and improve system efficiency, various MPPT approaches for PV power systems were developed. MPPT algorithms are classified into two types:

- Indirect control or quasi tracking methods
- Direct control or true tracking methods.

Indirect Control Methods

MPP is estimated using either the voltage or current of a PV array, solar insolation, or mathematical functions derived from empirical data. These approaches are incapable of tracking the MPP in the face of inconsistent irradiation and temperature and are less useful nowadays. These methods include look-up table procedure, Fractional open-circuit voltage, and Fractional short-circuit current.

Direct Control Methods

True tracking systems can detect the proper operating point even while changing meteorological conditions. True tracking approaches are now being used in these methods and they are commonly used in the process. These are as follows:

1.4.1 Hill Climbing Algorithms

1.4.2 Perturbation and Observation (P&O) technique

1.4.3 Incremental Conductance technique

1.4.4 Constant Voltage Method

1.4.5 Sliding Mode Control

1.4.1 Hill Climbing Algorithms

The duty cycle is continually perturbed at regular intervals in the hill-climbing technique, and the resulting voltage, current, and power are obtained. After obtaining the power, the slope of the PV curve is examined. Based on the positive slope and negative slope, it is decided if the operating point is in the constant voltage region or the constant current region [15].

The algorithmic steps of the hill-climbing algorithm are given below.

Algorithmic steps:

Step 1. Measure the value of voltage and current of solar PV.

Step 2. Set the modulation index.

Step 3. Calculate the initial power.

Step 4. Increase the value of the modulation index.

Step 5. Since the voltage and current of solar PV.

Step 6. Calculate the modified power.

Step 7. If the change in power is positive, increase the modulation index, if it is negative decrease the value of the modulation index. If no change the value modulation index is maintained.

Step 8: Repeat step 5.

1.4.2 Perturbation and Observation (P&O) technique

The Perturb and Observe approach is a popular method for solar and wind energy conversion systems. In the case of a solar PV system, the PV output voltage and current are measured twice in a row. The power is computed for two consecutive periods. The power change required to alter the voltage is computed as dP/dV. The duty cycle is increased or decreased based on the positive and negative values of the slope dP/dV. As a result, the voltage and power are set to the maximum power point. If the slope dP/dV=0, the maximum power point for the current environmental circumstances have been attained. This is an ongoing effort. The measurements must be taken continually, and changes in power and voltage must be computed to conduct control measures. The MPP is achieved mostly by matching the impedance of the solar PV with the impedance of the load side. To match the impedance, the duty cycle is regulated [16]. The algorithmic steps are as follows.

Algorithmic steps

Step 1. Measure the two consecutive values of voltages and currents of solar PV.

Step 2. Calculate the powers P(n) and P(n-1).

Step 3: If the powers are increasing, then decrease the duty cycle.

Step 4: If the powers are decreasing, then increase the duty cycle.

Step 5: Go to step 1.

1.4.3 Incremental Conductance technique

The incremental conductance technique is used to calculate the PV module's terminal voltage by measuring and comparing the incremental conductance to the instantaneous conductance. When the incremental conductance equals the instantaneous conductance, the maximum power is obtained. The PV module's terminal voltage is altered at regular intervals until the incremental conductance equals the instantaneous conductance [17]. The algorithmic steps are given below:

Algorithmic steps:

Step 1. Investigate the two consecutive voltages (V) and current (I) of solar PV

Step 2. Calculate the dI/dV.

Step 3. If dI/dV>0, the operating point is on the left of MPP. Increment the voltage.

Step 4. If dI/dV<0, the operating point is in the right of MPP. Decrement the voltage.

Step 5. Go to step 1.

1.4.4 Constant Voltage Method

The constant voltage approach makes use of the fact that the ratio of the array voltage (VMPP) to MPP and the open-circuit voltage (Voc) is virtually constant (VMPP/Voc 0.78), regardless of external variables. The measured PV array voltage is compared to a reference voltage to provide an error signal, which regulates the boost converter's duty cycle [18]. The algorithmic stages are as follows

Algorithmic steps:

Step 1. Read the open-circuit voltage Voc.

Step 2. Measure the present voltage of solar PV, VMPP.

Step 3. If the ratio is V_{MPP}/Voc = 0.78, do not adjust the duty cycle.

Step 4. If the ratio is V_{MPP}/Voc= 0.78, adjust the duty cycle.

Step 5. Go to step 2.

1.4.5 Sliding Mode Control

This method is quite similar to the incremental conduction method. Measurement of voltage and current of the solar PV panel is obtained. The following equation 1.1. is expressed [19].

$$h = \frac{I}{V} + \frac{\Delta I}{\Delta V} \quad (1.1)$$

The switching action is done based on the following conditions

$$u = \begin{cases} 1, & h < 0; \\ 0, & h > 0; \end{cases}$$

when u=0, the converter switch is open, and when u=1, the converter switch is closed. This is how the boost converter is operated at the maximum power point. This technique is compatible with most processors like DSP, Microcontroller, FPGA, etc. Continuous measurement of PV voltage and current is to be carried out. The need for a state observer for the current measurement is the disadvantage of this method.

1.5 Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) investigates global optimization solutions by utilizing particle and swarm memory. PSO has become one of the most significant Swam Intelligence techniques and Evolutionary Computation algorithms due to its qualities of minimal constraint on the continuity of goal function and joint of search space, as well as its capacity to adapt to changing environments.

PSO is a stochastic and population-based search method inspired by the behaviours of bird flocks. Optimization is carried out by a swarm of individuals known as particles, each of which represents a possible solution [20]. The particles can move about in the search space as they track the progress of neighbouring particles. PSO was able to successfully place and assess the fitness of different positions thanks to the separated search particles in the search space. The search particles eventually converge towards a place with optimum fitness known as the maximum power operating point with the help of successive iteration. PSO employs an efficient searching method for MPP in a variety of maximum conditions in partially darkened conditions [21].

A PV system can establish a PSO with a direct duty cycle for MPP tracking. The MPPT controller used an adaptive formulation of the Hill Climbing technique. The particles in the search were, then reassembled to produce a new MPP by employing a generic and well-organized technique, to increase tracking speed with better dynamic responsiveness. MPP was positioned for environmental changes and optimal tracking speed was achieved with zero oscillations. Furthermore, microcontrollers with excellent cost efficiency were used to implement PSO where MPPT failed in such cases when the ambient conditions changed.

Chapter 2

Literature Survey

The primary sources of renewable energy resources are solar and wind power. To obtain the most energy, researchers are focusing on these two areas. In these two, solar energy has attained a great attraction. Many algorithms are being developed to operate the solar energy conversion system at its Maximum Power Point (MPP) by using different techniques.

Steven L Brunton et al. (2010) described the MPPT algorithm for improving the performance of solar arrays. The robust unreliable irradiance conditions were modified, and an Extremum Seeking (ES) controller used the natural inverter ripple seen on a replicated solar array with a grid-connected inverter. With transient rise-time to the MPP, the ES controller boosted efficiency. The voltage control was more consistent, and the precise detection of strong irradiance transients was accomplished. Furthermore, the effects of capacitor size on ES control based on ripple were investigated. Boost converters did not recognize the tracking strategy [22].

Sebastijan Seme et al. (2011) discussed the two-axis sun tracking system for a PV system. The sun tracking system pathways were created in an optimization approach to advance the generation of electric energy in a PV system by taking tracking system use into account. Tilt angle and azimuth angle pathways were then represented as nonlinear and optimization problems. Following that, a stochastic search method known as Differential Evolution was used. The goal function was calculated using solar radiation models, a tracking system, and the efficiency of solar cells with appropriate DC/DC converters. Suitable pathways for tilt and azimuth angle were also suggested based on solar radiation, solar cell efficiency, tracking system usage, and optimization boundaries [23].

Mohammed et al. (2012) presented the Perturb and Observe approach for extracting the most electricity from a solar PV system. This is a simple method that requires no prior knowledge of the PV system. It is simple to construct in conjunction with analog circuitry. The operational point of the PV system is perturbed by this technique by raising or reducing the control parameters in modest steps. If the power rises, the perturbation continues in the same direction; otherwise, in the other direction. The benefits of the P&O technique are fewer control parameters, ease of implementation, and a straightforward algorithm. This method's drawbacks include oscillations in achieving MPP and poor tracking when external circumstances change [24].

Mohammed et al. (2013) used the Incremental Conductance (IC) approach to track the maximum power point in a solar PV system. The solar power and voltage curve at constant temperature and irradiance are the foundation of this method. The incremental conductance dP/dV is 0 at MPP. This indicates that incremental conductance is the inverse of instantaneous conductance. The incremental and instantaneous conductance are negative on the right side of the MPP and positive on the left side of the MPP. The downside is that tracking is poor when weather conditions vary, such as temperature or irradiance [25].

Fuzzy Logic Control (FLC) was developed by **Bader et al. (2013)** for MPP in a solar PV system. Changes in power and current were regarded as an input variable in this method, whereas changes in duty cycle were considered as output variables. Positive Big, Positive Small, Negative Small, and Negative Big are the four fuzzy levels assigned to the input variables. Positive Big, Positive Medium, Positive Small, Negative Small, Negative Medium, and Negative Big were the six fuzzy levels assigned to the output variable. The rule basis is created by connecting the input and output variables. As the fuzzy level grows, so does the accuracy, and the MPP is rapidly attained [26].

Sathish Kumar Kollimalla and Mahesh Kumar Mishra (2014) established an adaptive perturb based on short-circuit current and used an MPPT technique to extract the most power from a PV panel. A current perturbation and adaptive control strategy were proposed. These methodologies were used to construct PV panels that functioned at maximum power, and the operating limit difficulties were identified to assign an operating point closer to MPP. The limits were then created as a result of changes in irradiance and current. Following that, an operating point was designated based on the approximation of short-circuit current. To continually alter irradiance, a variable current perturbation was used. Later, the boost converter was used to identify the tracking strategy. The problems caused by changes in irradiance and temperature remain unsolved in the existing perturbation and adaptive control approaches [27].

Ali Chikh and Ambrish Chandra (2015) developed an MPPT approach for photovoltaic (PV) systems. The MPPT approach was created by measuring instantaneous and junction conductance. Using an Adaptive Neuro-Fuzzy (ANFIS) solar cell model, an array voltage and current were used as a function of array junction current. Following that, an analytical model was presented to simulate hardware circuitry and measurement noise using a wavelet technique that was dependent on denoising. The MPPT technology reduced the hardware setup with the use of a single voltage sensor, resulting in improved array power efficiency and faster reaction time. The MPPT technique's efficiency was not increased to the anticipated degree [28].

A novel method for partially shaded environmental conditions was suggested by **Mohammad mehdi Seyed mahmoudian** et al. (2015) for the maximum power point technique in a solar PV energy conversion system. This algorithm is a mix of Differential Evolution and Particle Swarm Optimization (DEPSO). In most cases, partially shaded conditions reduce the overall efficiency. This MPPT method has been validated using simulation and an experimental setting [29]. The benefits of these strategies are as follows:

- DEPSO makes for a complete system independent MPPT Technique.
- The presence of random numbers aids the algorithm in maintaining its metaheuristic approach and determining the global MPP under any partial shading scenario.
- The algorithm's computing load is lowered, and the approach can be simply implemented on a low-cost microcontroller.

Yuxiang Shi et al. (2016) suggested a low frequency ripple less MPPT method for grid-connected photovoltaic systems. A current fed dual active bridge converter with a multilayer inverter connects the solar PV system to the load. The little film capacitor substitutes the high capacitor that is generally included in the system in this form. This configuration provides great efficiency even under quickly changing environmental conditions. To evaluate the performance of this method, a 5kW PV converter was created. The drawbacks of this technology are the control of the dual active bridge and multilayer inverter [30].

Vivek Nandan Lal and Sri Niwas Singh (2016) addressed MPPT using modified Particle Swarm Optimization (PSO) to improve performance. To include reactive power into the grid, a single-stage utility-scale PV system with grid and current control was used. The single-stage approach was then used to improve efficiency and power converter topology. Following that, a modified PSO methodology was combined with additional control mechanisms. The MPP is also affected by changes in sun irradiance and temperature. Various peaks showed the PV power characteristic of a large installation. MPPT was suitable for all situations with little steady-state fluctuations. Energy usage was inefficient to achieve higher MPPT outcomes [31].

Mohamed A Enany (2017) described a tracking controller for PV Water Pumping Systems that improves MPP functioning (PVWPS). PVWPS was built with a PV array and a regulated DC converter to power an external magnet DC motor connected to a centrifugal pump. The tracking controller was an adaptive-logic system that employed the Cuckoo Search (CS) technique for searching, prediction, and identification. Then, for MPPT, control techniques were presented. For identifying maximum point voltage and power, the two CS control systems were dependent on chopping ratio, insolation, and temperature. The outputs of the first two CS control techniques, as well as motor–pump performance characteristics for detecting the DC-DC converter duty ratio, prevented the third CS control strategy [32].

PV array architecture and Maximum Power Point Estimation were explored by **Mahdi Jedari and Hamid Fathi (2017).** PV array polynomial model was developed using a single diode equivalent circuit, and polynomial model parameters were derived by evaluating voltage and current around MPP. The Maximum Power Point Voltage (MPPV) was then calculated, and the PV array voltage was set to MPPV permanently. Furthermore, computing complexity and estimate power losses were reduced [33].

T. Babu et al. (2018) offered an alternative to physical relocation linked module using particle swarm optimization (PSO). While the electrical connections were changed in this technique, the physical direction of the model remained unchanged. Based on the performance study, the proposed PSO method's capability was developed through energy savings and money generation. As a result, the panels were adjusted for row current difference reduction to eliminate power extraction as a PV array [34].

Bhim Singh and Sachin Devassy (2018) described a three-phase single-stage solar PV-UPQC. PV-UPQC was a voltage compensator that combined shunt and series links with a generic DC-link. The shunt compensator was used to execute the dual mining operation of electricity from the PV array. Then, to acquire the load active current component, a moving average filter based on an improved synchronous reference frame control was used. Furthermore, grid-side power quality issues were handled by employing a series compensator. During sag and swell conditions, the compensator combined an in-phase/out-of-phase voltage with a Point of

Common Coupling (PCC) voltage. With the creation of clean energy, the power quality has improved. In PV-UPQC, the irradiation variance remains unsolved [35].

Bhim Singh et al. (2018) introduced a solar PV system to improve performance. To finish the MPPT procedure, a boost converter was used. The 3-leg Voltage Source converter was then used to obtain PV power using an allocation method to improve energy quality. To estimate genuine power based on load current division, an improved adjustable step adaptive neuron control mechanism was used. Through the use of feed forward, an efficient dynamic response was produced. The minimizing of distribution losses in PV systems was insufficient [36].

M. Kermadi et al. (2019) described an improved MPPT for a photovoltaic (PV) system. The primary goal of the research was to create a hybrid of adaptive perturbation and observe (P&O) and PSO. This algorithm discusses the search-skip-judge (SSJ) approach for narrowing the region in which the PSO will search inside the P-V curve. Furthermore, PSO performance was enhanced by specifying that locations that have already been scanned (by another particle) will not be searched again. As a result of the quicker convergence, undesired particle movement was decreased. The current approach was developed by combining four well-known MPPT methods: hybrid PSO, SSJ original version, customized cuckoo search, and modified incremental conductance [37].

CHAPTER 3

Modeling of Solar PV SYSTEM

This chapter explains how to use SIMULINK model to design photovoltaic system. In this thesis, the PV system's configuration is explained in details. In order to model this module, weather data (temperature and irradiance) is used as input variables. The output of the PV system is in the form of voltage, power and current. Any variations in temperature and irradiance change to the outputs of PV system immediately.

3.1 Photovoltaic system:

A photovoltaic system converts solar energy into direct current electricity. Open circuit voltage (Voc),Short circuit current(Isc),maximum voltage (Vmax) and MPP current are all characteristics of PV. Current-voltage and Power-Voltage curves will be created using these parameters. PV output voltage is controlled by load[38-42]. PV may be modelled with one or two diodes in most cases. The two-diode model is more accurate, but it also requires more variables, making it more complicated [42].

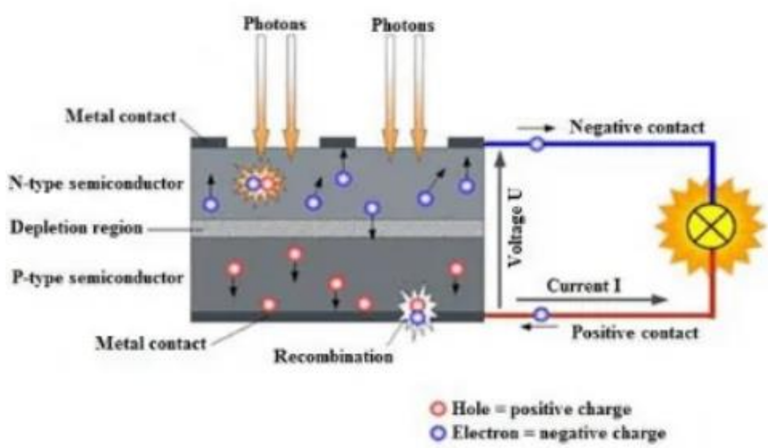

Figure 3.1 Photovoltaic cell [42].

3.1.1 Photovoltaic Cell:

Individual solar cells provide a relatively small amount of power, but electrical output can be significant when connected together. The cells, modules, and arrays can be connected in series or parallel, or typically a combination, to create a desired peak voltage output.Fig. 3.1 depicts the equivalent model of Photovoltaic cells.

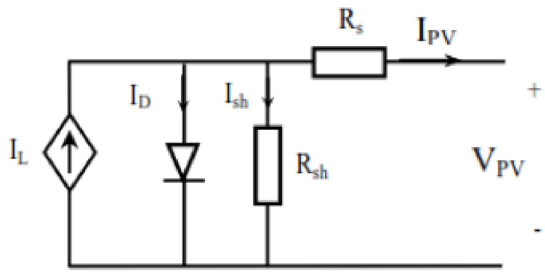

Figure 3.2. Photovoltaic cell equivalent circuit [43].

The current-voltage characteristic of the ideal photovoltaic cell is mathematically described by the following basic equation from semiconductor theory:

$$I_1 = I_2 - I_o\left[exp\left(\frac{qV}{aKT}\right) - 1\right] \qquad (3.1)$$

The PV curves keep changing with solar irradiance and temperature. The features of a PV array are described using equations (3.2) and (3.3) [43-44].

$$I_1 = I_2 - I_o\left[exp\left(\frac{V+R_S I}{V_T a}\right) - 1\right] - \frac{V+R_S I}{R_p} \qquad (3.2)$$

$$P_{PV} = \text{V I} \qquad (3.3)$$

Where A is the diode factor, PV module current is I (A), I_2 is the produced light current (A), Io is the reverse saturation current, R_S is the module resistance (ohm), R_P is the parallel resistance module (ohm), V is the output voltage module(V), and PPV is the PV extracted power (W). PV modules must function at the optimum power point to obtain the maximum amount of power from a PV system. The thermal voltage of the array with Ns cells connected in series is V_T = NskT/q, where q represents the electron charge (coulomb), K represents the Boltzmann constant (j/K), and T represents the module temperature (k). Cells joined in parallel generate more current, while cells joined in series provide higher output voltages. The photovoltaic and saturation currents can be represented as I_2=I_2Np, I_0= I_0Np if the array is made up of Np parallel connections of cells. In (2), Rs is the array's equivalent series resistance, and Rp is its analogous parallel resistance.

$$I_2 = \left(I_{2,x} + K_I \Delta_T\right)\frac{R}{R_n} \qquad (3.4)$$

where $I_{2,x}$ [A] is the light-generated current at the nominal condition (25 ˚C and 1000W/m^2), Δ_T = $T_1 - T_x$ (being T_1 and Tx the actual and nominal temperatures),R[W/m^2] is the device surface irradiation, and R_x is the nominal irradiation. The diode minority current I_0 and its depend on the temperature may be expressed by equation(3.4):

$$I_O = I_{3,x}\left(\frac{T_x}{T_1}\right)^3 exp\left[\frac{E_g q}{ak}\left(\frac{1}{T_x} - \frac{1}{T_1}\right)\right] \qquad (3.5)$$

where Eg is the band gap energy of the semiconductor (Eg ≈1.12 eV for the polycrystalline Si at 25 ˚C) and $I_{0,x}$ is the nominal saturation current:

$$I_{3,x} = \frac{I_{sc,x}}{exp\left(\frac{V_{OC,x}}{aV_{t,x}}\right) - 1} \qquad (3.5)$$

3.1.2 Photovoltaic Module: PV modules are sometimes called solar panels. Photovoltaic modules is a collection of PV cell. The application and study of photovoltaic devices is known as photovoltaics. PV cells operate via the photovoltaic effect which describes how certain materials can convert sunlight into electricity; they absorb some of the energy of the Sun and cause current to flow between two oppositely charged layers.

3.1.3 Photovoltaic Array: A photovoltaic array is a linked collection of photovoltaic modules. Each photovoltaic (PV) module is made of multiple interconnected PV cells. The cells convert solar energy into direct-current electricity. The array voltage is obtained by multiplying the output voltage of the cell by the number of cells in series n_{ose}. The number of series connected cells in the array is given by $n_{ose} = n_{ms} \times n_{an}$ Where n_{ms} stands for number of series connected modules in the array and n_{an} is the number of cells in each module. As shown in Figure 3.3, the array current "I_{array}" is calculated by multiplying the cell current by the number of modules linked in parallel (n_{ap}). Using the dot product block, multiply the array voltage and current to get the array power.

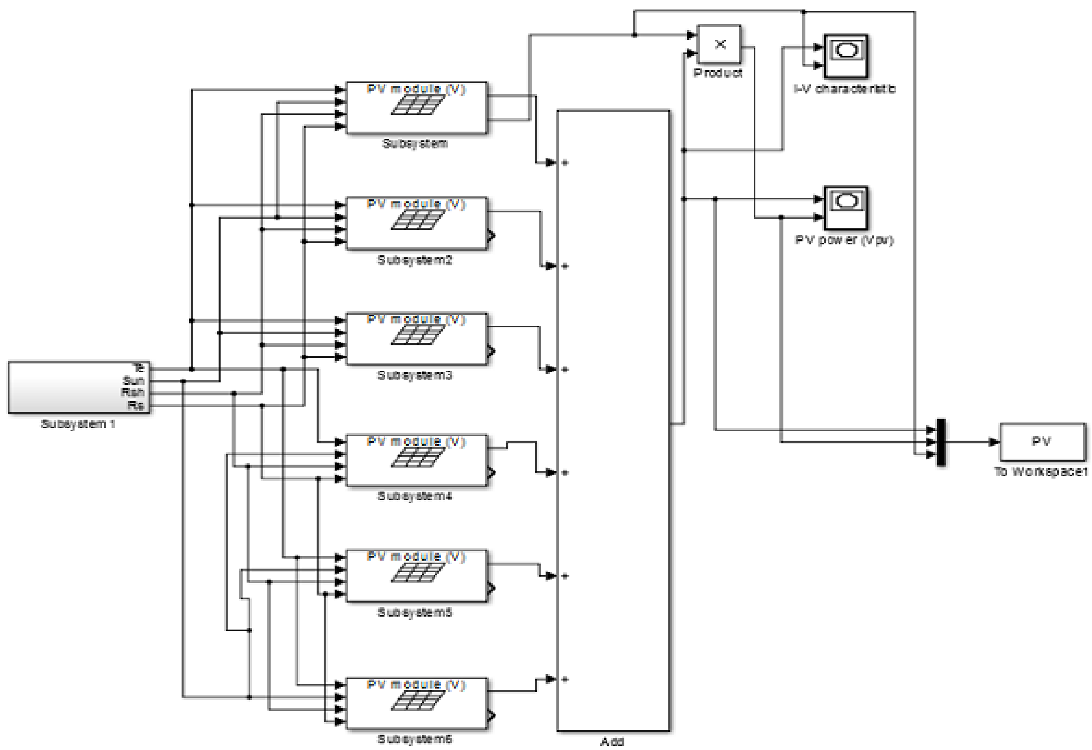

Figure 3.3: SPV Array

3.2 Simulation Model of Photovoltaic System:

Simulation model of PV system from the PV module and PV module come from PV cell model is presented in figure 3.4. Module is first modelled by connecting 72 cells in series. First connected 6 cell in series make three subsystem module of 18 cell . Then connected 18 cell in series make two subsystem module of 36 cell. Then connected 36 cell in series make two subsystem module of 72 cell. Figure 3.4 consists of 72 cell module and variable resistance and two scope for I-V and P-V characteristics.

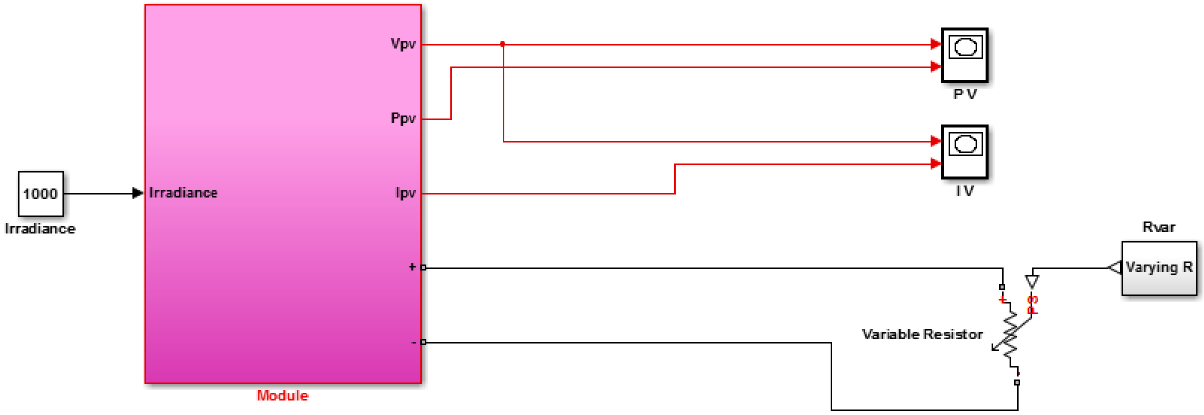

Figure 3.4: SPV system

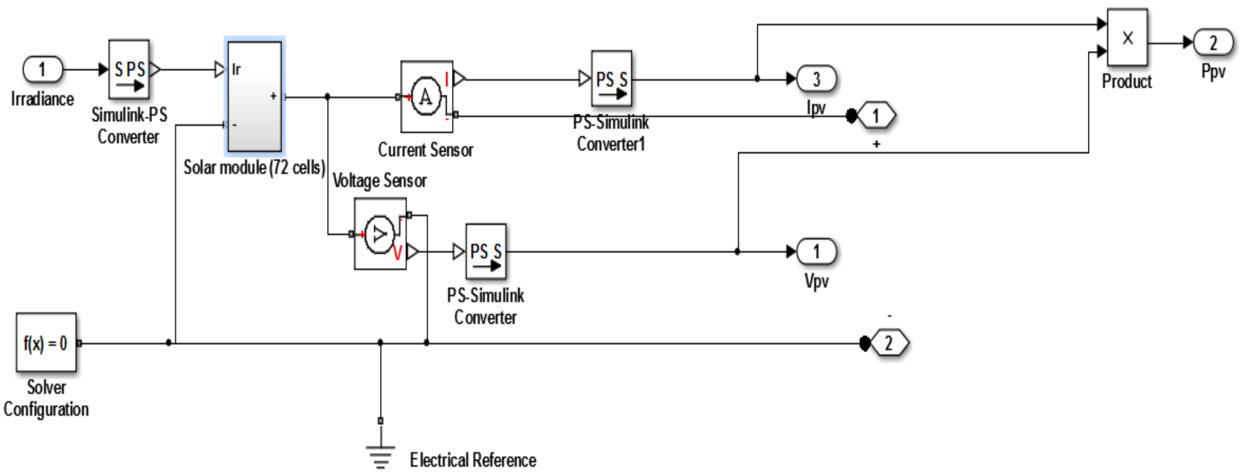

Figure 3.5: Subsystem of SPV module

Figure 3.5 show the subsystem of SPV module consists of SIMULINK-PS converter converts the unitless SIMULINK input signal to a Physical Signal. The unit expression in 'Input signal unit' parameter is associated with the unitless SIMULINK input signal and determines the unit assigned to the Physical Signal. 'Apply affine conversion' check box is only relevant for units with offset (such as temperature units).There are three options to handle the input: you can use it as is, filter input, or provide the input derivatives through additional signal ports. Input filtering also provides time derivatives. The first-order filter provides one derivative, while the second-order filter provides the first and second derivatives and solver configuration block specifies the solver parameters that your model needs before you can begin simulation, the solver attempts to find the steady state that would result if the inputs to the system were held constant for a sufficiently large time, starting from the initial state obtained from the initial conditions computation and PS-SIMULINK converter converts the input Physical Signal to a unitless SIMULINK output signal. The unit expression in 'Output signal unit' parameter must match or be commensurate with the unit of the Physical Signal and determines the conversion from the Physical Signal to the unitless SIMULINK output signal and two sensor is connected one is voltage sensor which calculate the voltage and current sensor which calculate the current.

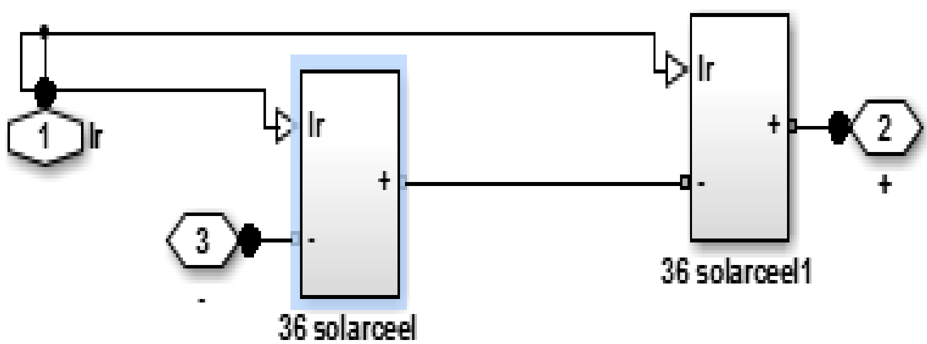

Figure 3.6: Subsystem of Solar module (72 cell)

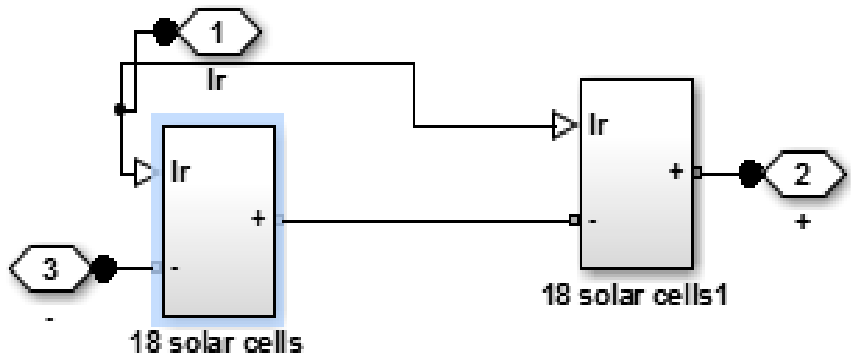

Figure 3.7: Subsystem of 36 solar cells

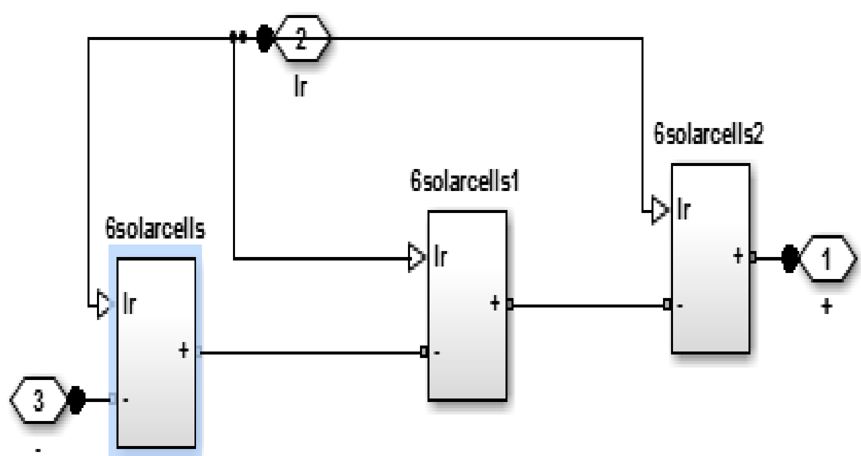

Figure 3.8: Subsystem of 18 solar cells

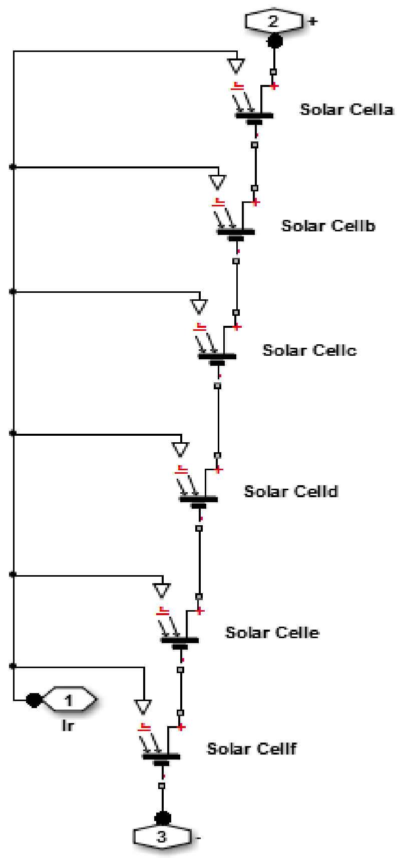

Figure 3.9: Subsystem of 6 solar cells

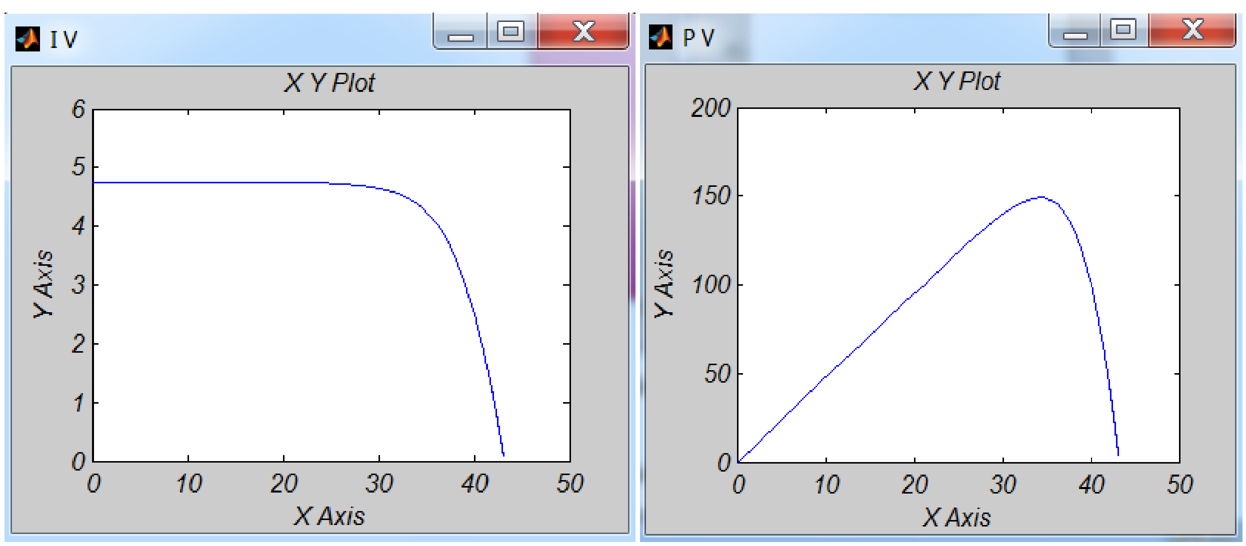

Figure 3.10: (a) *I-V* Characteristics of PV system (b) *P-V* Characteristics of PV system

The PV system is depicted in figure 3.4, and the I-V and P-V characteristics of the PV system are depicted in figure 3.10. The current is shown on the Y axis and the voltage is shown on the X axis in figure 3.10a, while the power is shown on the Y axis and the voltage is shown on the X axis in figure 3.10b.

CHAPTER 4

Modeling of MPPT using PSO

4.1 Introduction:

This chapter describes a SIMULINK model that uses the Particle Swarm Optimization technique to track the maximum power point of solar panels. Particle swarm optimization has parallel processing, good robustness characteristics, and high probability of finding the global optimal solution and higher computational efficiency than the traditional random method. Its greatest advantage lies in its simple realization, easy and fast convergence. Due to its good performance in the multi-peak function optimization, particle swarm optimization is applied to the PV system. The simulated system's configuration is completely described.

4.2 MPPT based on PSO :

R.Eberhard and J.Kennedy introduced the PSO algorithm in 1995. PSO is an artificial intelligence optimization method that represents the social behaviour of flocks of birds or fish. The PSO algorithm is designed based on the social behaviour of the organism as an individual and as a herd (swarm). This population-based optimization method is frequently utilized by academic and industrial researchers due to its simple algorithm structures and fast convergence rates, which are simply regulated by a few parameters. The equations utilized in the PSO optimization algorithm [46] are as follows:

$$v_i^{k+1} = \omega v_i^k + c_1\, rand_1 x\left(\text{pbest} - s_i^k\right) + c_2\, rand_2 x(\text{gbest} - s_i^k) \quad (4.1)$$

Equation is updated for each iteration of the inertia weight value(4.2).

$$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{\text{iter}_{max}}\ x\ iter \quad (4.2)$$

Equation is used to update the particle position after each iteration. (4.3):

$$S_i^{k+1} = S_i^k + v_i^{k+1} \quad (4.3)$$

Where: v_i^{k+1} is the particle velocity at iteration k, ω is the inertia weight factor, c_1 and c_2 are called acceleration constants, $rand_1$ and $rand_2$ are random numbers and S_i^k is the particle position in the search space at iteration k, $pbest$ is called local best and $gbest$ is called global best.

The particle position is determined as the duty cycle that will be given to the DC-DC converter boost, and particle speed is set as a change in duty cycle, while the evaluation function of the fitness value or objective function is chosen as the maximum power generated in PV for the MPPT system based on the PSO algorithm designed. The technique for designing the PSO algorithm is show in the flowchart.

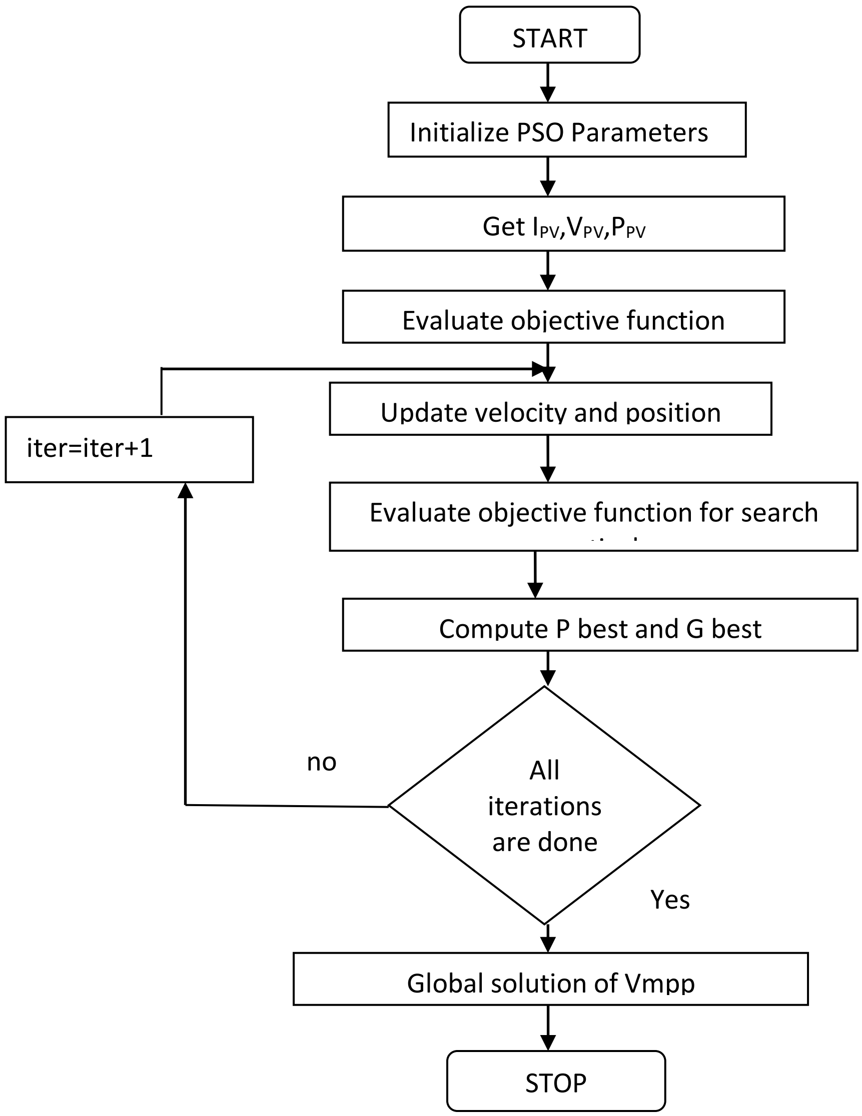

Figure 4.1: PSO Flowchart

First, the swarm is initialized; that is, the position and velocity of particles within the search space are randomly initialized. The particle's objective values are then calculated. Personal best values and personal best positions are naturally the first objective values and positions. The objective value and location of the particle with the best objective value in the entire swarm are assigned as the global best value and position. Equation (4.1) is used to transfer all particles to their new places after the initial step. All objective values are reassessed. If any particle has an objective value that is better than the old global best value, the global best position is modified. Again using equation(4.1), all particles are transferred to their new positions . The programme then evaluates the objective values and updates the positions, as well as the personal best positions and global best position. When a termination criterion, such as a restriction on the number of iterations, is met, the algorithm comes to a halt.

4.3 Simulation Model of PV system with PSO based MPPT :

This block uses the Particle Swarm Optimization technique to track the maximum power point of solar panels. This MPPT PSO technique is implemented using MATLAB code written in a MATLAB function block. This MPPT PSO block receives voltage and current from a solar panel and generates a PWM switching signal that drives a DC converter.

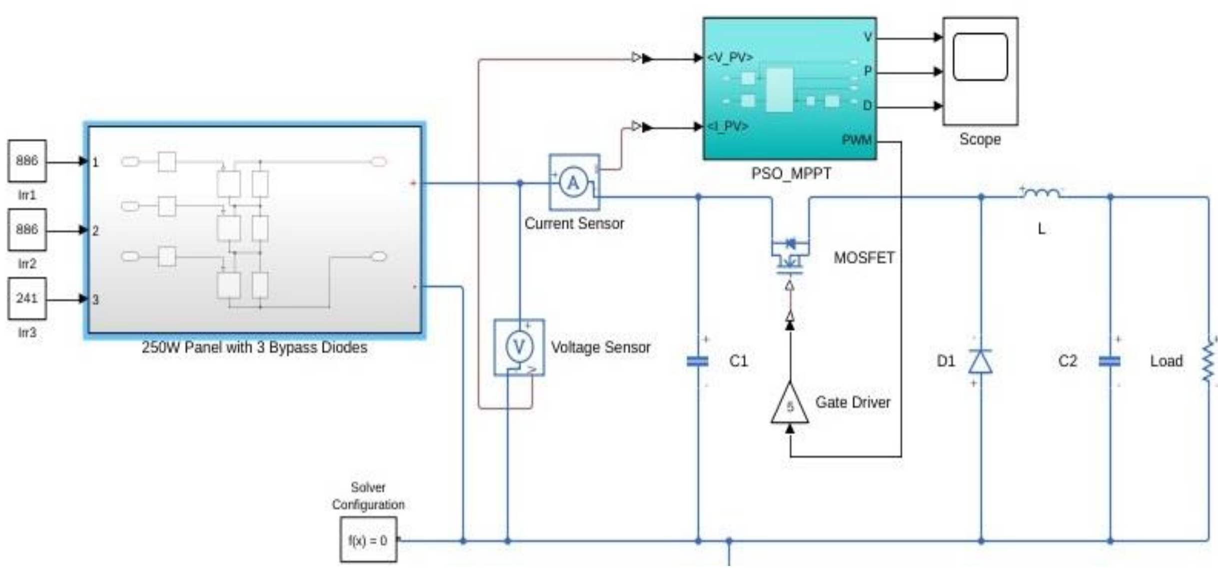

Figure 4.2. PV system with PSO based MPPT control unit

4.3.1 250W Photovoltaic Panel with 3 Bypass diode :

A photovoltaic system converts solar energy into direct current electricity. Short circuit (Isc), open connection voltage (Voc),maximum voltage (Vmax), and MPP current are all characteristics of PV. I-V and P-V curves will be drawn based on these values. The load has depend on PV output voltage [38-41]. PV may be modelled with one or two diodes in most cases. The two-diode model is more accurate, but it also requires more variables, making it a more complicated model[42]. PV curves vary depending on solar temperature and irradiation. PV modules must perform at the optimum power point to obtain the maximum amount of power from a PV system. Thus, a power electronics converter powered by the suitable MPPT algorithm is used to track the PV module's brief maximum power point[39,43-44].The 250W solar panel is shown in figure 4.2

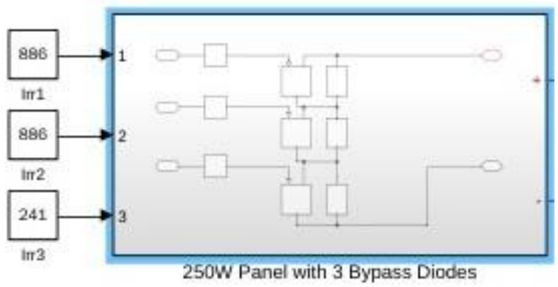

Figure 4.3. 250W solar panel

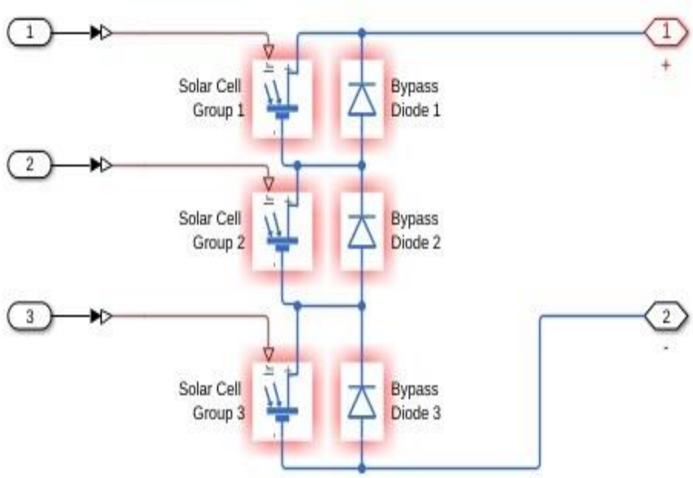

Figure 4.4. Internal block of PV Panel

4.3.2 Boost converter:

The DC-DC Boost Converter's design acts to stable the voltage by boosting it when the output voltage is higher than the input voltage without having to remove a considerable amount of power to overcome the voltage shortage. During the process of converting electrical energy, the DC-DC converter simply changes the voltage and current levels of the DC output, not the power. The principle of altering voltage using a DC-DC converter is shown schematically in Figure 4.4. [45].

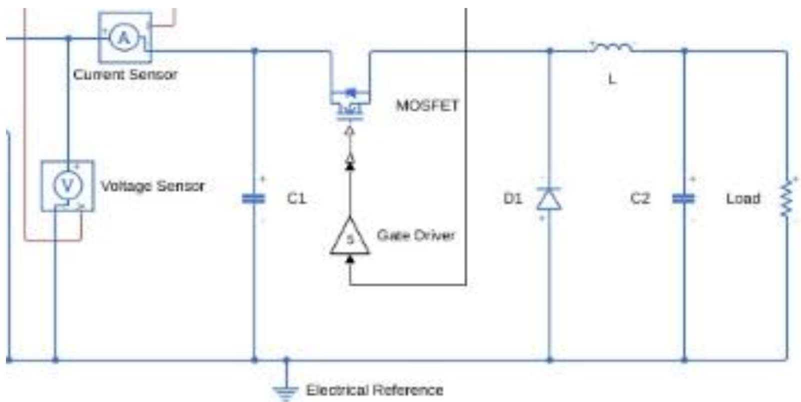

Figure 4.5. Boost converter

The average output voltage is defined using the formula below(4.4).

$$\frac{V_O}{V_d} = \frac{1}{1-D} \qquad (4.4)$$

Where V_O is output voltage of boost converter across the load and V_d is the input of boost converter or output voltage of solar panel and D is the duty cycle.

The Voltage Sensor block is an ideal voltage sensor, which is a device that converts voltage measured between two positions in an electrical circuit into a physical signal proportionate to the voltage. The Current Sensor block is an ideal current sensor, or a device that converts current sensed in any electrical branch into a physical signal proportionate to the current. The gate signal (g>0) controls a semiconductor device called a metal-oxide semiconductor field-effect transistor (MOSFET). When the MOSFET device is reverse biased (Vds< 0) and no gate signal is supplied (g=0), it is coupled in parallel with an internal diode that turns on. An ideal switch operated by a logical signal (g > 0 or g = 0) with a diode connected in parallel simulates the model. Whether the drain-source voltage is positive or negative, the MOSFET device switches on when a positive signal is applied to the gate input (g > 0). Only the internal diode conducts when the voltage exceeds its threshold voltage V_{th} when no signal is applied to the gate input (g=0). The MOSFET goes off when the gate input becomes 0 with a positive or negative current flowing through it. If the current I is negative and flowing through the internal diode (no gate signal or g = 0), the switch goes off.

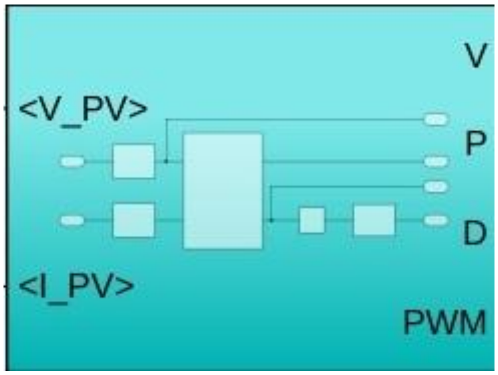

Figure 4.6. SIMULINK block PSO MPPT

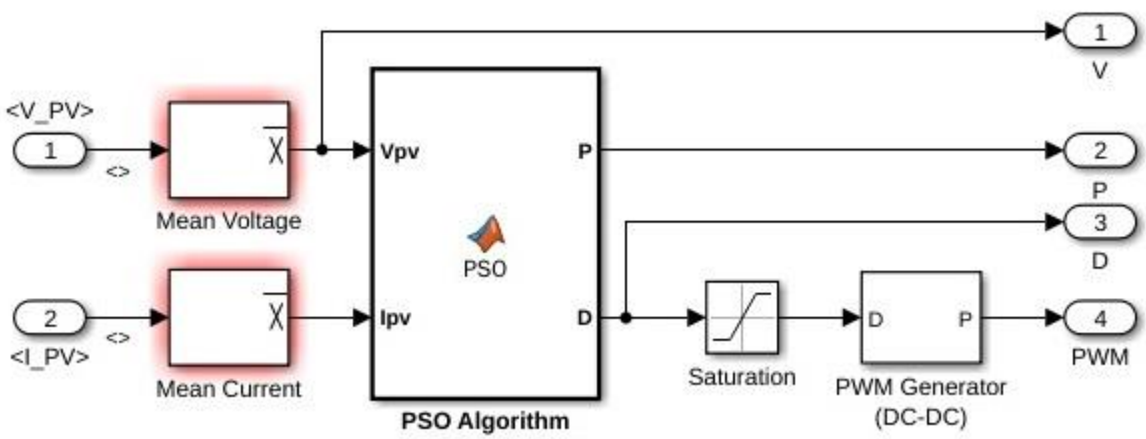

Figure 4.7.Internal SIMULINK block PSO MPPT

4.3.2.1 PWM Generator:

The PWM Generator (DC-DC) block generates a pulse that is used to turn on a one-quadrant converter's MOSFET, GTO or IGBT switch (buck or boost). The generator's duty cycle is determined by the input D. The proportion of the pulse period that the output is on is determined by a value between 0 and 1.

4.3.2.1.1 Switching frequency (Hz):

Set the generator switching frequency (Fsw) in hertz. The frequency of the internal sawtooth signal used to generate the pulse is known as the switching frequency.

4.3.2.1.2 Sample time:

Specify the sample time of the block, in seconds. Set to 0 to implement a continuous block.

CHAPTER-5

RESULT AND DISCUSSION

MATLAB SIMULINK was used to design and simulate the MPPT using PSO algorithm. The duty cycle value was changed based on the results of the MPPT algorithm computation. The MOSFET used has a switching frequency of 20 KHz. The duty cycle value, which can be stated in equation (4.4),determines the boost converter's output voltage. The PV model with MPPT utilising the PSO method is shown in Figure 4.2. At a constant temperature of 25° C, the simulation was run by changing the irradiation. The initial simulated irradiation was 500 W/m^2, eventually increasing to 1,200 W/m^2. The presented work is a detailed modelling and simulation of the PV system. It is implemented under MATLAB/ SIMULINK environment; the most used software by researchers and engineers. The PV system parameters have been selected according to their variation with irradiance 1000W/m^2. In this thesis, the characteristics of PV system (I-V and PV) were obtained both at constant 1000 W/m^2 irradiation. When there is change in the solar irradiation, the MPP changes therefore there is a need to track this maximum power point according to varying irradiations. Therefore, the MPPT control algorithm i.e. Particle Swarm Optimization (PSO) algorithm was implemented to control the duty cycle of the converter so as to track the maximum available power. The operation of boost converter was to boost the solar panel voltage up to the required level. The loss of power from solar panel side to boost converter side is mainly due to switching losses of power electronic devices and losses in inductor, capacitor at boost converter side.

When given an irradiation value of 500 W/m2, simulation results of PV systems with MPPT based PSO algorithm show that the output system power utilising MPPT with PSO algorithm is 110.21 W. When given a 700 W/m2 irradiation value, the MPPT with PSO algorithm outputs 150.10 W. When given a 900 W/m2 irradiation value, the MPPT with PSO algorithm outputs 205.12 W. When given a 1200 W/m2 irradiation value, the MPPT with PSO algorithm outputs 300.2 W. Figures 5.1, 5.2, and 5.3 demonstrate the output voltage, power, and tracking duty cycle of the PV system model with MPPT using the PSO algorithm:

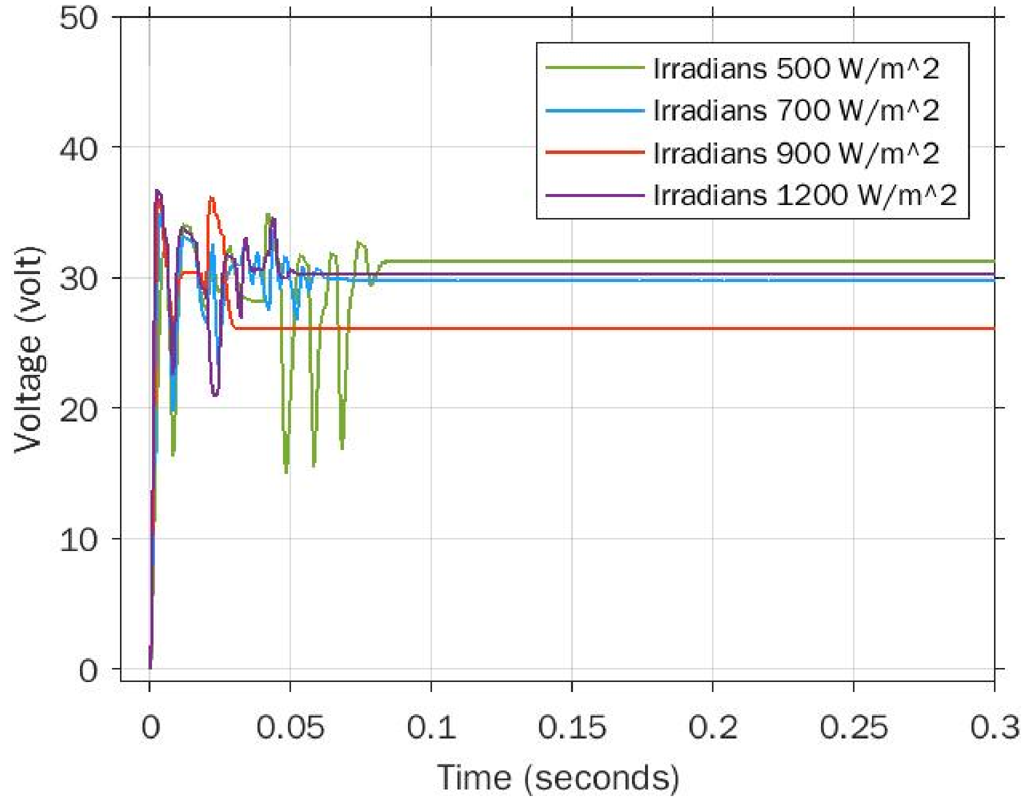

Figure 5.1. Voltage output of MPPT

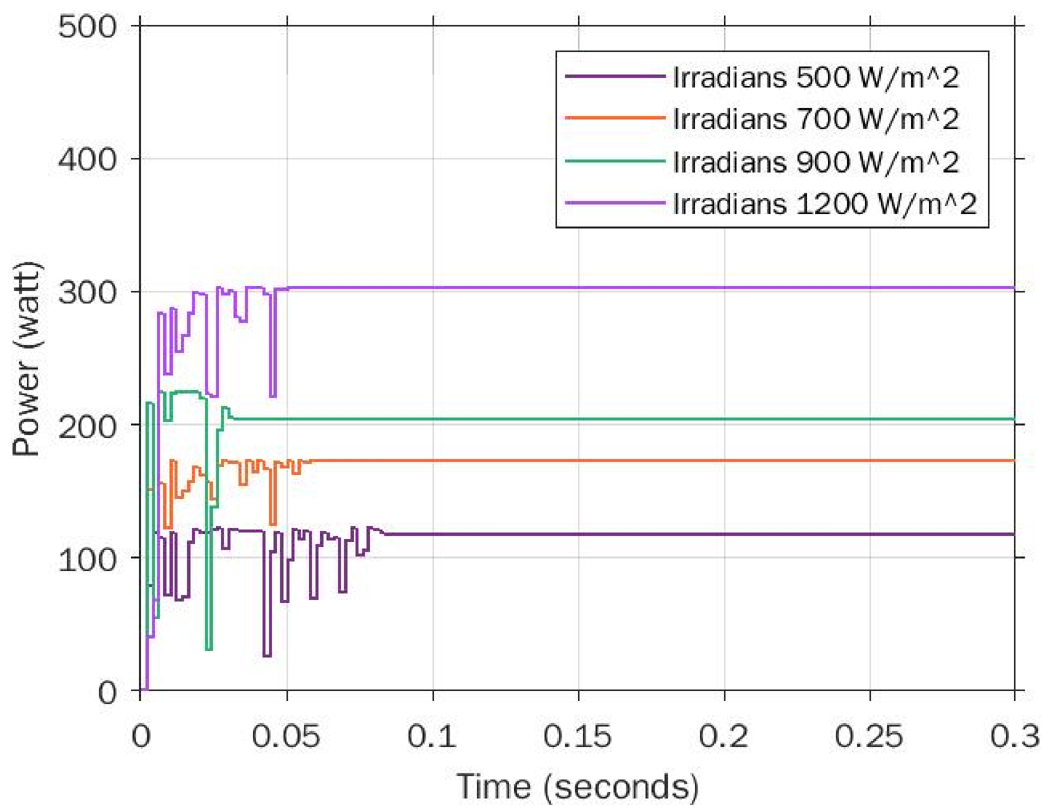

Figure 5.2. Power output of MPPT

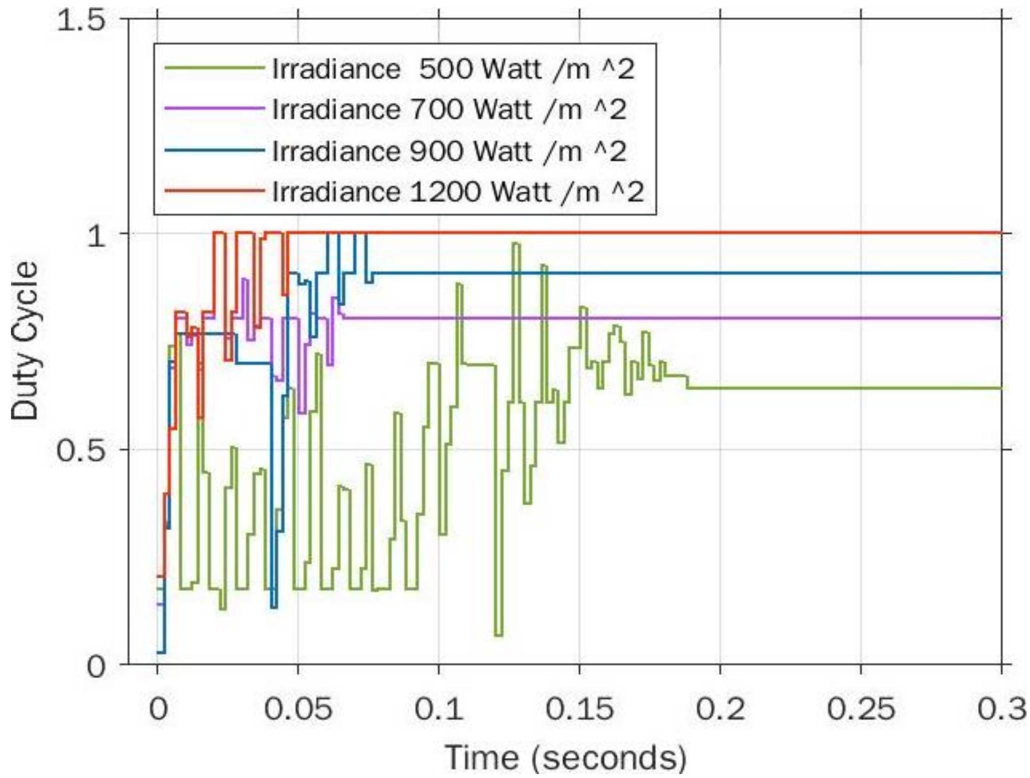

Figure 5.3. Duty cycle of MPPT

The MPPT approach using the PSO algorithm was found to be capable of detecting irradiance changes and maintaining PV performance at the MPP point by modifying the Duty Cycle, based on simulation results. The PSO algorithm's task is to calculate the Duty Cycle value in response to changes in solar irradiation so that the output voltage in the Boost Converter remains at MPP.

CONCLUSION

Simulation results of PV systems with MPPT based PSO algorithm when given an irradiation value of 500 W/m^2, output system power without MPPT is 56.21 W, while using MPPT with PSO algorithm increased to 110.21 W. This MPPT system managed to increase the average output power of 47.98 W. Similar types of pattern are obtained at 700 W/m^2 , 900 W/m^2 and 1200 W/m^2 . This demonstrates that PV systems with MPPT outperform the PV system without MPPT.

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Annexure

Statistical Evaluation of Renewable Energy Technologies in Lucknow: Prevailing Schemes, Barriers and Future Scope

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***Abstract*—Present manuscript deals with the progression of Renewable Energy Technologies in the Indian city of Lucknow which is the capital of India's most populous state, Uttar Pradesh. India has adopted many Renewable Energy Technologies, but major portion of those technologies is composed of large renewable energy-based power plants and usage of renewable energy technologies is very less by the common citizens of India. This paper provides an analytical approach towards factors which present themselves as roadblocks in the way of adoption of renewable energy technologies by the common citizens of Lucknow. Schemes and subsidies provided by the Government of India, intended for the common citizens of Lucknow have been mentioned and the reason for sub-par adoption of these schemes has been statistically explained. Origin, awareness and educational background of 200 citizens of Lucknow have been used as parameters for this study. The authors of this paper have provided several corrective measures for full utilization of Schemes and Subsidies provided by the Government of India to the common citizens of Lucknow in order to increase the usage of Renewable Energy Technologies and make India a less pollutive nation.**

Keywords—Lucknow, Awareness, Renewable Energy Technology

I. INTRODUCTION

The renewable energy resources are considered as inexhaustible sources of energy. The word "renewable" itself indicates that these sources of energy can be renewed and regenerated without being exhausted. The renewable energy resources are also termed as non-conventional sources of energy. These energy resources occur naturally, are restorable and infinite so they are referred to as "renewable energy" resources. The renewable energy resources such solar energy, hydroelectric, biomass fuels, wind and geothermal energy are naturally replenished on a human timescale[1].

This paper deals with the current scenario, obstacles and the future issues related to the renewable energy resources faced in the capital city of Uttar Pradesh, Lucknow. Uttar Pradesh was earlier known as United Provinces under the British rule and today it is the most populated state of India . According to the census in 2011, the population of Lucknow was 28,17,105. The administration of Uttar Pradesh is divided into 18 administrative divisions which are subsequently divided into 75 districts. The administrative division of Lucknow consists of Hardoi, LakhimpurKheri, Raebareli, Sitapur ,Unnao and Lucknow itself [2]. The decisions and policies implemented in Lucknow resonate through the entire stretch of Uttar Pradesh. According to the World Health Organization (W.H.O.),Lucknow stands 7th in the list of world's most polluted cities. As India is a signatory to the Kyoto Protocol and Paris Climate Change agreement ,it is the responsibility of the capital of the most populated state of Uttar Pradesh to set an example in the fight against pollution, but this is not the case[3]. Poor literacy rate, lack of awareness and negligence among the people are some of the major causes due to which the renewable energy resources have been neglected by the people. Various government schemes on renewable energy resources have been launched which lay emphasis on the advantages in the usage of renewable energy while the energy resources like coal, fuel, petroleum also have adverse effects on the environment. They cause pollution on a large scale and degrade the quality of air further causing various air borne diseases among the people. On the other hand, the renewable energy resources are environment friendly. The electricity generated from renewable energy resources produces between 90-99% less greenhouse gases when compared with the electricity produced by the power plants. Not only this, the renewable energy resources cause 70-90% less pollution when compared with the traditional resources.

This survey comprises of 200 respondents from the capital city of Uttar Pradesh, Lucknow. Lack of awareness and negligence regarding renewable energy resources can be seen among the people in this survey. Althoughvarious schemes are launched by the Government of India regarding renewable energy resources, but people seems to be unaware regarding the government schemes. A majority of people have no idea about the recent schemes which were launched by the government of India ,as monitored in the survey.

The various schemes related to the renewable source of energy which the government of India has proposed are:-

1) The Ministry of New and Renewable Energy has proposedSRISTI-SUSTAINABLE ROOFTOP IMPLEMENTATION FOR SOLAR TRANSFUGATION OF INDIA. The scheme proposed to incentivise the installation of the rooftop solar power plant project all over the states of India. The scheme aims to achieve a national solar rooftop target of 40 GW till the year 2022. This rooftop solar power plant is schemed to be installed only in the

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residential areas of the country. The total outlay of the scheme is 23,450 crore rupees for 40,000 MW of roof top solar installation[4].

2) The Jawaharlal Nehru National Solar Mission has been implemented by the government of India to establish India as a global leader in the solar sector by creating the policy norms. An ambitious target of deploying 20,000 MW of grid connected solar power plant by the year 2022 has been set[5].

The government of India has even provided subsidy on the installation of solar power plants both off grid and on grid. About 50% of subsidy is provided to the people of general category, 75% of subsidy is provided to the people of scheduled caste and 90% to the people belonging to the category of scheduled tribe.

II. DISCUSSION

A. *Areas from which the respondents belong*

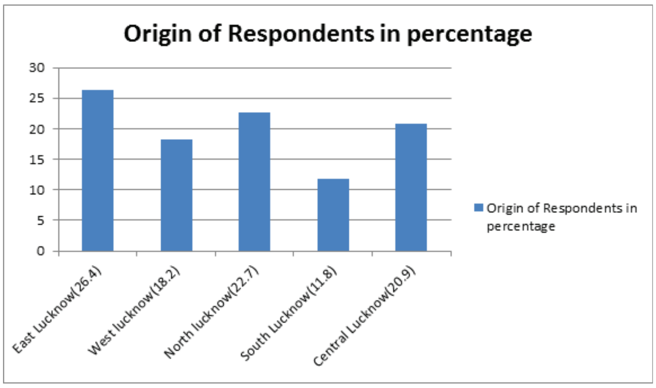

Fig. 1. Origin of Respondents

The survey in Fig 1, consists of 200 respondents from all the regions of Lucknow. Among these 200 respondents, about 26.4% belong to Lucknow East which includes parts of Gomtinagar, Indra Nagar, Mahanagar, Nishatganj, Khurram Nagar, 18.2%of the respondents belong to West Lucknow which includes areas of Rajajipuram, the old city areas, Chowk etc, about 22.7% of respondents belonging to North of Lucknow which includes the areas of Jankipuram, Aliganj, Faizabad Road, Sitapur Road , Husinabad and other areas, 11.8% of the respondents belong to South Lucknow which includes the areas of Alambagh, VidhanSabha, RDSO colony, Kanpur Road and other areas and 20.9% of the respondents belong to Central Lucknow which includes the areas of old city, sectors of Hazratganj, Gomti Nagar and other attached areas.

B. *Size of the house*

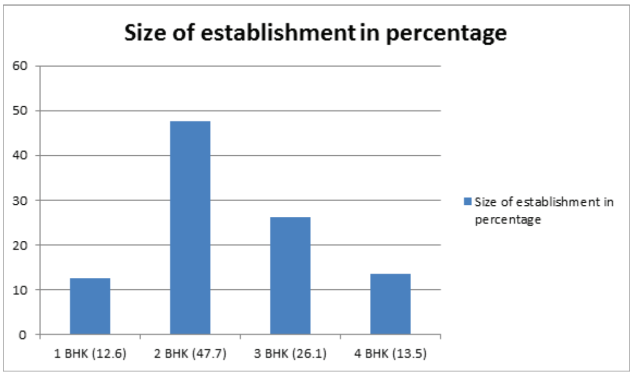

Fig. 2. Size of Respondent’s establishment

In Fig 2, about 12.6% of the respondents reside in a 1 BHK house, 47.7% of the respondents stay in a 2 BHK house. About 26.1% of the respondents reside in a 3 BHK house. Whereas 13.5 % of the respondents are lodged in a 4 BHK house. The Pradhan MantriAwasYojna was launched by the Prime Minister of India, Mr Narendra Modi, in the year 2015, behind which the objective was to provide affordable houses to the people, under the government scheme[6]. These houses will be affordable to the people under the Middle-Income Group, Low Income Group and Economically Weaker Section. Since the middle-class population is on an increase in comparison to the other classes, we can see the maximum percentage of the respondents reside in a 2 BHK house.

C. *Educational background*

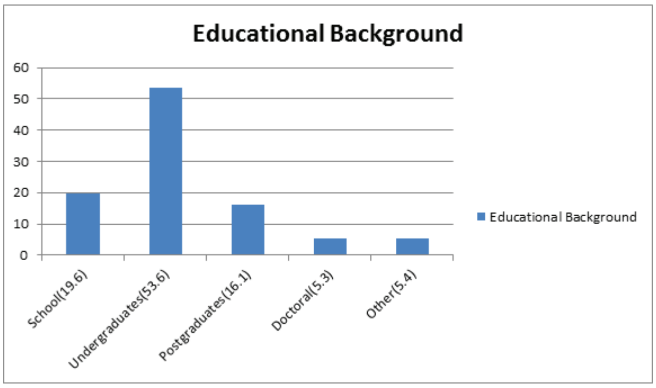

Fig. 3. Educational background of Respondents

In Fig 3, about 19.6% of the respondents are school going pupil, the maximum number of the respondents that is 53.6%, are undergraduates. About 16.1% of the respondents are post graduates,5.3% of the respondents are doctoral students and 5.4% of the respondents belong to the other categories.

D. *Awareness regarding renewable energy resources*

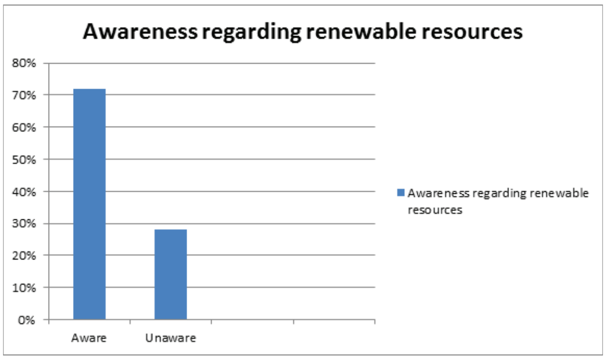

Fig. 4. Respondent’s awareness regarding renewable energy

In Fig 4, as we can see the bar graph, about 72% of the respondents are aware regarding renewable energy resources whereas 28% of the respondents do not have even a basic idea regarding the renewable energy resources.

Since the non-renewable energy resources are easily available and thus are being depleted on a large scale, the only other alternative left is renewable energy resources. The non-renewable energy resources take millions of years to get replenished whereas the renewable energy resources replenish naturally and over relatively short time periods, so people must have general awareness regarding these energy resources and their beneficial outcomes[7].

E. Effects on environment

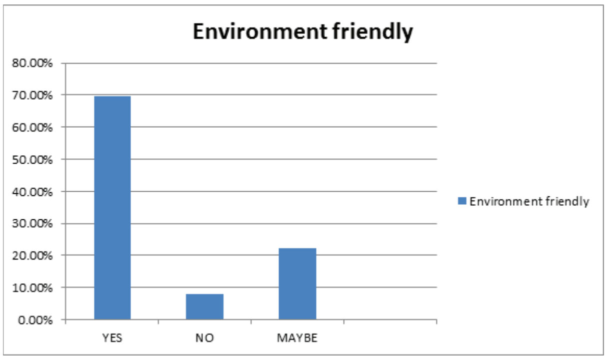

Fig. 5. Respondent's awareness regarding Renewable Energy

In Fig 5, about 69.6% of the respondents are aware of the fact that renewable energy resources are environment friendly. Pollution levels can be decreased if the non-renewable resources can be replaced by renewable ones. 8% of the respondents disagree on the fact that renewable energy resources safeguard the environment and about 22.3% respondents are unsure whether the renewable energy resources are environment friendly or not.

On the contrary, the traditional resources of energy like fossil fuels, coal, petroleum etc have been the major cause of air pollution since ages, therefore switching to the non-conventional energy resources would definitely ensure lesser air pollution and safeguard the environment.

F. Replace non-renewable resources with renewable ones

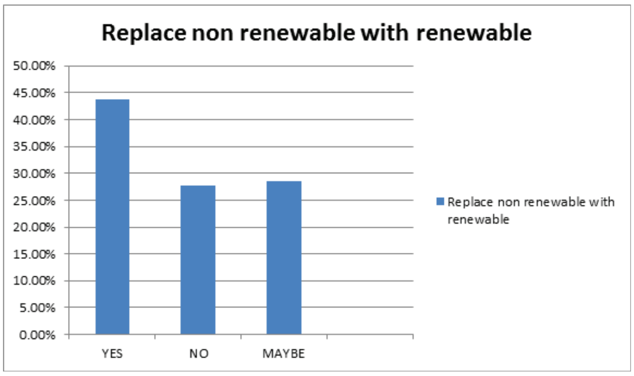

Fig. 6. Future plans regarding renewable energy

In Fig 6, about 43.8% of respondents plan to replace the non-renewable energy resources which they use in their day to day lives with renewable ones, 28.6% of respondents wish to stick to the traditional sources of energy rather than switching to renewable energy resources and 27.7% are unsure whether to switch to renewable energy resources or not.

We can observe that a number of people lack awareness regarding the beneficial outcomes of switching the non-renewable energy resources with renewable ones.

G. Awareness regarding environmental hazards

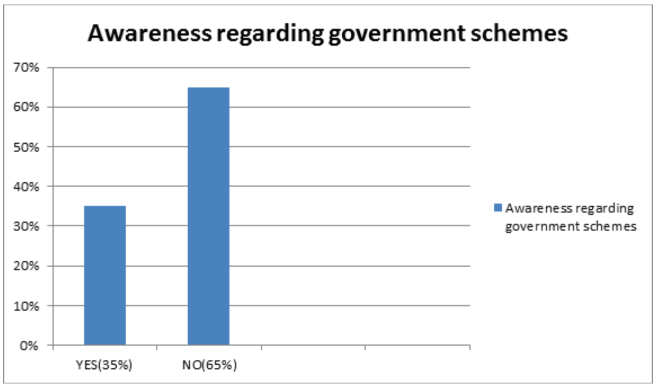

Fig. 7. Respondents awareness regarding Renewable Energy

In Fig 7, about 81% of the respondents are aware regarding the environmental hazards and still due to their negligence, less than half the majority of the respondents are planning to switch to the renewable energy resources as we can see in our survey whereas only a handful respondents that is 19%, are unaware of the environmental hazards and their adverse effects on the environment.

We can see a high ratio of awareness regarding pollution and environmental degradation at school and undergraduate level is due to the introduction of Environmental Science course, a subject which basically emphasizes upon human interaction with their environment and deals in solving complex environmental problems; in their respective syllabus.

H. Awareness regarding government schemes

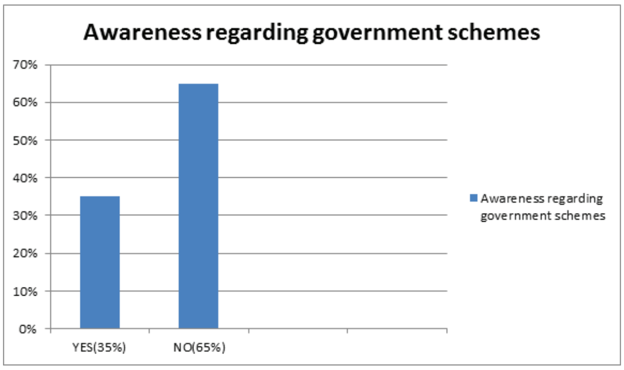

Fig. 8. Respondent's awareness regarding Government Renewable Energy Schemes

The Government of India has launched many schemes regarding renewable energy resources, few of which are mentioned earlier in the paper, but we can observe in Fig. 8, that the majority of respondents that is 65%, are unaware regarding the various government schemes on renewable energy resources and due to this negligence among the people, the renewable energy resources are not fully utilized. Only 35% of the respondents are aware regarding the schemes launched on renewable energy resources and thus a huge capital amount is being wasted as the people lack awareness. Not only this, the young generation too, lacks awareness regarding the government schemes and thus have no contribution towards the development and betterment of the Renewable Energy Technology.

I. Solar panels installation in residential areas

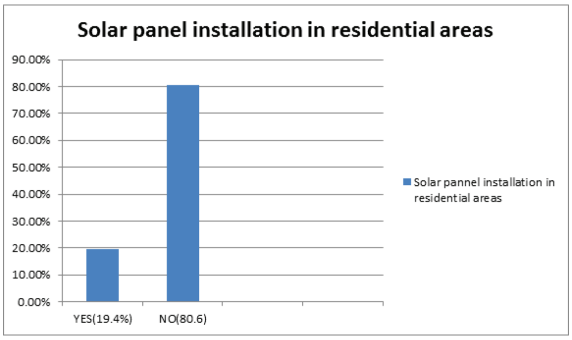

Fig. 9. Installation of Solar Panels in residential areas

As it can be seen in the survey in Fig 9, about 80.6% of the respondents do not have any installation of the solar panels by the government scheme, these respondents are from all over the area of Lucknow as mentioned earlier but still a majority of them do not have the solar panels installed in their residential areas, only a handful of respondents that is 19.4% , have the facility of solar panels in their respective residential area.

This survey also points towards the mismanagement regarding spreading of awareness and its practical implementation by the government of India.

J. Reduction of electricity bills with the usage of renewable energy resources

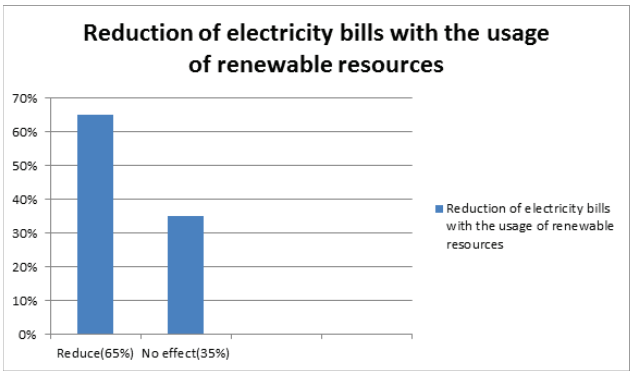

Fig. 10. Respondents' views on reduction of electricity bill with usage of renewable energy

As observed in the survey in Fig 10, about 65% of the respondents are aware of the fact that the usage of non-conventional sources of energy will decrease their electricity bills when compared to the conventional or traditional sources of energy whereas 35% respondents are still unaware that their electricity bills could actually be reduced if they switch to the renewable energy resources.

We all must be aware of the fact that the geographical area of Lucknow receives sunlight for 300 days on an approximation and by investing in the renewable energy resources like in the installation of solar panels, energy can be generated on a large scale and thus the usage of non-renewable energy resources can be reduced, and electricity bills can be decreased.

III. RESULT AND CONCLUSION

The Central and the State Government must ensure that renewable energy resources and the related technology must be implemented in the syllabus at basic schooling levels. IIT's and NIT's must introduce Renewable Energy Technology at undergraduate level. Advertising campaigns must be initiated with separate focus on the rural population as majority of the people in India reside in the rural areas.

There are major drawbacks of non-renewable energy resources, they cause adverse effects on the environment, pollute the air and takes years to replenish. On the contrary the renewable energy resources are infinitely available and are environment friendly. Every second, the sun produces enough energy to sustain the earth's need for 500,000 years and this energy can be harnessed only if people are aware regarding renewable energy resources and its beneficial outcomes[8]. In rural areas where electric power is not easily available, installation of solar panel is a boon. Electricity can be easily accessed in an eco-friendly manner and not only this, installation of solar panels by the government subsidy schemes in the rural areas, especially for the farmers who require electricity for large scale irrigations have become much easier, but the only thing required is awareness. Many are still unaware regarding the subsidies provided by the government of India and still rely on the non-renewable energy sources which are actually not under their approach.

The help of Non-Governmental Organizations should be taken to spread awareness regarding the renewable energy resources especially among the rural areas and in accelerating the renewable energy technology programs so that the resources can be more beneficially utilized.

"Let's go green to get our globe clean."[9]

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