Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 5.258

IJCSMC, Vol. 5, Issue. 7, July 2016, pg.535 – 544

SIMULATION BASED INTELLIGENT WATER COOLING SYSTEM FOR IMPROVEMENT THE EFFICIENCY OF PHOTO-VOLTAIC MODULE

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ABSTRACT: Solar cells are sensitive to temperature. Increases in temperature reduce the band gap of a semiconductor, thereby effecting most of the semiconductor material parameters. In a solar cell, the parameter most affected by an increase in temperature is the open-circuit voltage. As the temperature increases, the open-circuit voltage decreases, thereby decreasing the fill factor and finally decreasing the efficiency of a solar cell.

One of the main obstacles that face the operation of photovoltaic panels is overheating due to excessive solar radiation and high ambient temperatures. Overheating reduces the efficiency of the panels dramatically.

"Hence we have to use cooling systems to avoid the overheating of the system"

Active cooling units are examined in two groups;

- ***Air cooled systems***
- ***Water or refrigerant liquid cooled systems***

Air cooled systems cannot be used in every region and on every system, because if the air temperature is above 20 °C, effectiveness for PV cooling would be very low.

Water or refrigerant liquid cooled systems has no such a limitation so, in this study only water or refrigerant liquid cooled systems will take into consideration while comparing.

In this project Water cooling system with artificial intelligence for photovoltaic systems are introduced to maximize the produced energy. The general model is implemented on MATLAB, and accepts irradiance and temperature as variable parameters and outputs the I-V characteristic and P-V characteristic. Nowadays solar energy has great importance. Because it is easily available resource for energy generation. But the only problem is efficiency of solar system and to increase its efficiency many techniques are used. Here we are using the cooling effect on the PV panel improves the efficiency.

Keywords: Solar cell temperature, efficiency of solar cell, cooling mechanism

I. INTRODUCTION

A solar cell is a device that directly converts the energy from sunlight in to electrical energy through the process of photovoltaic. The first solar cell was built around 1883 by Charles Fritts, who used junctions formed by coating selenium (a semiconductor) with an extremely thin layer of gold. In 2009, a thin film cell sandwiched between two layers of glass was made.

A typical PV module has ideal conversion efficiency in the range of 15%. The remaining energy is converted into heat and this heat increases the operating temperature of PV system which affects the electrical power production of PV modules and this can also cause the structural damage of PV modules leads to shorting its life span and lowering conversion efficiency. The output power of PV module drops due to rise in temperature, if heat is not removed. The temperature of the solar cell generally reach to the 80℃ or more when the solar cell is a silicon series solar cell.

The various literatures reveal that cell temperature has a remarkable effect on its efficiency. The temperature increase of 1K corresponds to the reduction of thephotoelectric conversion efficiency by 0.2%-0.5%. Various studies have been conducted in order to improve the PV conversion efficiency; among these cooling provides a good solution for the low efficiency problem. Both water and air are suitable as the cooling fluid to cool the PV module in order to avoid the drop of electrical efficiency.

Performance of a solar-photovoltaic (PV) system not only depends on its basic electricalcharacteristics; maximum power, tolerance rated value %, maximum power voltage,maximum power current, open-circuit voltage, short-circuit current, maximum system voltage, but also is negatively influenced by several obstacles such as ambient temperature, relative humidity, dust storms and suspension in air, shading, global solar radiation intensity, spectrum and angle of irradiance.

There are several reasons which motivate the development of the PV/T system. One of the main reasons is that PV/T system can provide higher efficiency than individual PV and thermal collector system. With increased the efficiency, the payback period of the system can also be shorten. Many efforts have been made to find an efficient cooling technology by analyzing the performance of solar cells using different technologies and various cooling liquids.

The technique used in this study is the cooling of solar panel back side using water as the coolant. The main focus of this work is on comparison of the electrical conversion efficiency of the PV panel with and without cooling at optimum flow rate.

WHY THE PV CELL NEED IMPROVEMENT IN EFFICIENCY:

The photovoltaic (PV) cells are able to produce energy from the abundant resource of sunlight. Since the PV modules are exposed to sunlight they generate heat as well as electricity. Typically a PV module converts only 10-15% of the incident power to electricity, while the remaining power is largely rejected as heat. The warm atmosphere affects the current density/voltage J/V characteristics of the PV modules where their electrical efficiencies are adversely affected by the significant increase of cell operating temperature during absorption of solar radiation. Applying a cooling system to a PV module reduces the cost of solar energy in three ways.

First, cooling improves the electrical production of PV modules.

Second, cooling makes possible the use of concentrating PV systems by keeping the PV cells from reaching temperatures at which irreversible damage occurs, even under the irradiance of multiple suns. This makes it possible to replace PV cells with potentially less expensive concentrators.

Finally, the heat removed by the PV cooling system can be used for building heating or cooling, or in industrial applications. To this end, hybrid photovoltaic/thermal (PV/T) solar systems have been investigated as a means of decreasing the temperature of PV modules and boost their electrical efficiency.

EFFECT OF TEMPERATURE VARIATION

Solar cells are sensitive to temperature. Increases in temperature reduce the band gap of a semiconductor, thereby effecting most of the semiconductor material parameters. In a solar cell, the parameter most affected by an increase in temperature is the open-circuit voltage. As the temperature increases, the open-circuit voltage decreases, thereby decreasing the fill factor and finally decreasing the efficiency of a solar cell. It is recommended to operate at 25°C. The power output for different operating temperatures is shown in FigureFig. 1.

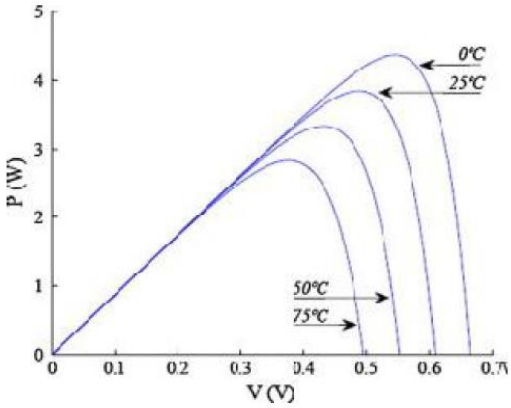


Fig 1: PV cell Power versus Voltage curves for different temperatures[9]

One of the main obstacles that face the operation of photovoltaic panels is overheating due to excessive solar radiation and high ambient temperatures. Overheating reduces the efficiency of the panels dramatically. The P-V characteristics is the relation between the electrical power output P of the solar cell and the output voltage V, while the solar irradiance E, and module temperature T_m, are kept constant. If any of those two factors, namely T_m and *E*, are changed the whole characteristics change. The maximum power output from the solar cells decreases as the cell temperature increases. Thus the heating of the PV panels can affect the output of the panels significantly.

EFFECT OF SOLAR RADIATION VARIATION

The term irradiance is defined as the measure of power density of sunlight received at a location on the earth and is measured in watt per meter square. Irradiation is the measure of energy density of sunlight. As the solar insulation keeps on changing throughout the day similarly I-V and P-V characteristics varies. With the increasing solar irradiance both the open circuit voltage and the short circuit current increases and the maximum power point varies. The light intensity on a solar cell is called the number of suns, where 1 sun corresponds to standard illumination 1 KW/m^2. Solar cells experience daily variations in light intensity, with the incident power from the sun varying between 0 and 1 KW/m^2.

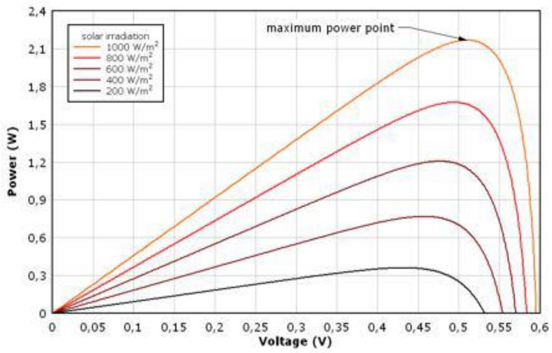


Fig 2: PV cell Power versus Voltage curves for different solar radiations[9]

COOLING SYSTEM

Heat can be extracted from the PV system in broad sense by two modes of cooling namely

- Passive cooling
- Active cooling.

A passive system requires no added power, while some external power source is required for an active cooling system[10].

Passive cooling system: Passive cooling system may be a series of panels that are placed and set on the roof, in which air is allowed to flow naturally above and below the pv panels and some lateral projections which are also called as fins may be provided at the rear surface of the panel to draw some heat from the system, or for the prevention of heating the surface around the panels white-color is provided to the roof.

Active cooling system: when the heat is drawn from the panel forcefully then some fans are provided to blow air above and below the panels and also pumps are provided for circulating the water above and rear side of the panel. Active cooling system may be of great use in certain situations such as where the added efficiency to the panels is greater than the energy needed to run the system, for example a solar power plant in a desert, domestic water heating etc.

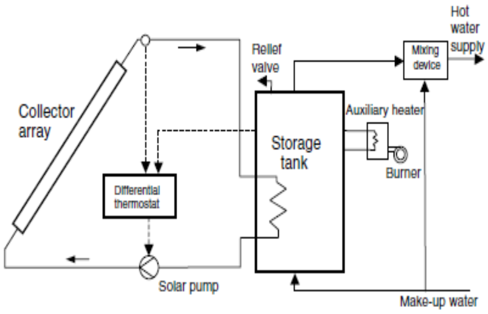


Fig 3: A typical Active cooling system[10]

To increase the efficiency of a photovoltaic system it is necessary to cool the module because each 1°C temperature increases on a photovoltaic module at 25°C causes power decrease up to 0.4-0.5% . Active cooling units are examined in two groups;

- Air cooled systems
- Water or refrigerant liquid cooled systems

Air cooled systems cannot be used in every region and on every system, because if the air temperature is above 20 °C, effectiveness for PV cooling would be very low.

Water or refrigerant liquid cooled systems has no such a limitation so, in this study only water or refrigerant liquid cooled systems will take into consideration while comparing.

Increase in efficiency while using an active cooling unit depends on environmental temperature, design of cooling unit and the material of photovoltaic cell.

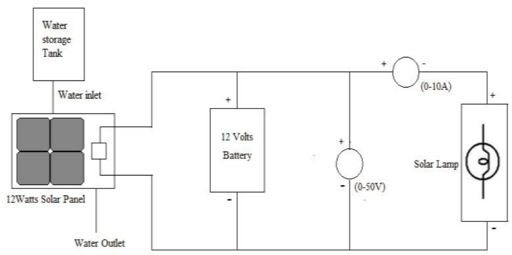


Fig 4: A basic idea of water cooling system of PV panel[1]

Mathematical Model of Cooling System for Photovoltaic Panel:

The temperature which a PV module works is an equilibrium point between the heat generated by the PV module and the heat losses to the surrounding environment. The different mechanisms of heat losses dissipation are conduction, convection and radiation. Conductive heat losses are due to different temperatures between the PV module and other materials with which the PV module is in contact. The ability of the PV module to transfer heat to its surroundings is characterized by the thermal resistance.

Convective heat transfer arises from the transport of heat away from a surface as the result of one material moving across the surface of another. In PV modules, convective heat transfer is due to wind blowing across the surface of the module. The last way in which the PV module may transferheat to the surrounding environment is through radiation.

Cooling system efficiency used to PV panel expresses the conversion efficiency of solar radiation unused in the photovoltaic process into heat. This is the impact on the physical and constructive parameters of subassemblies that make up the cooling system. Obtaining a maximum output requires an optimization process of building solar collectors. To this end it is necessary to know the analytical form of efficiency to identify parameters that it depends. Research is needed on the size of the collector efficiency parameters influence, followed by optimization of collectors building on the influential parameters for obtaining maximum yield.

Processes involved in these conversions are illustrated in Figure 5.

Figure 5 shows a schematic drawing of a solar panel which is considered as a multi-layer wall. A PV panel is composed of three layers, the glass cover, the solar cell and the frame.

Defining the analytical form of efficiency is based on the energy balance equation, considering the processes taking place in a photovoltaic panel.

Efforts have been made to combine a number of the most important factors into a single equation which will describe the thermal distribution.

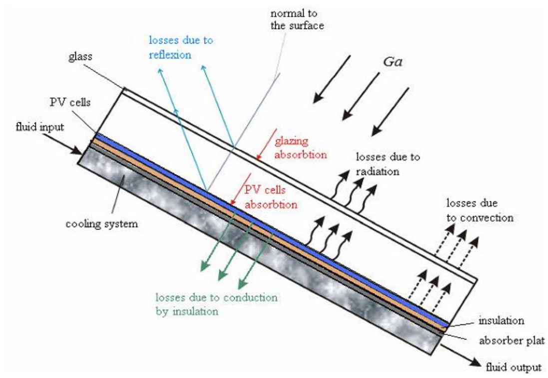


Fig 5: Thermal processes of PV panel

ARTIFICIAL NEURAL NETWORK

A neuron is a cell made up of a cellular body and a core in which the cellular body ramifies to form the dendrites. Dendrites transfer the information between the neuron and the soma, body of the neuron. There is an intercellular space between the axon of the related neuron and dendrites of the efferent neuron. The junction between two neurons works like a valve controlling the rate of flow of information, and is called as synapse. It is necessary to parameterize all these synapses to achieve a goal. The neural network[11] works according to the Eqn.

$$a_i = \sum_{j=1}^{N} W_{ij} X_j \qquad \text{(A)}$$

Where, a_i is output of the neural network at node i;

W_{ij} is the weight between the nodes i and j;

X_j are the states variables evaluated by activation functions.

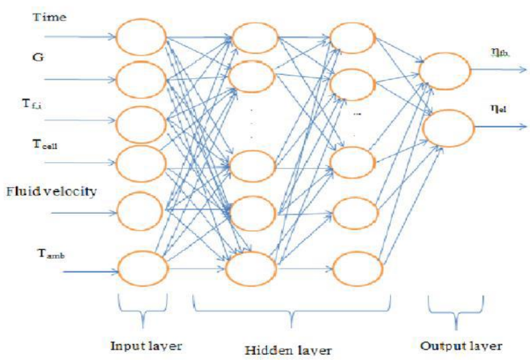


Fig 6: Architecture of the ANN[12]

The network is composed of an input, output, and hidden layer of parallel processing elements called neurons or nodes, with each layer being fully connected to the next layer by interconnection weights. Initially, assigned weight values are progressively changed at the each iteration during a training process that compares predicted with known outputs, and back propagate any errors to determine the appropriate weight adjustments, which are necessary to minimize errors. In this study, we consider the NN with three layers of adjustable weights.

Ambient temperature of collector, cell temperature, fluid temperature at duct inlet, fluid velocity in duct, solar identity and time are used in the input layer and the thermal efficiency and electrical efficiency are outputs. The ANN[12] architecture is depicted in Figure 6.

In the hidden layers of the networks sigimoid transfer functions and in the output layer linear transfer functions can be used. The Levenberg-Marquardback propagation algorithm can be been used for training networks[11].

During the training phase[12] the network weights are adapted to reflect the problem domain. In the testing phase, the weights have been frozen and the network when presented with test data will predict the correct output. In the proposed model, measurement voltage and current of PV panel are being used as the input of ANN, the output is the voltage at MPP and power corresponding. The training data is obtained by simulating the PV array in Mat lab/Simulink using the parameters that are supplied by manufacturer. The current, voltage and power at MPP for a range of irradiance and ambient temperature conditions are recorded which are then used as the training data for ANN. This recorded data can be compared with theStandard test conditions. If the temperature of the PV panel is higher than the rated value then a feedback signal moves towards a DC pump which can control the water flow on the panel. Then, the atmospheric conditions recorded are used as the input data and corresponding MPP values are used as the output data for training the ANN. The Pumping takes water flow on the surface of Panel to decreasing the temperature.

The neural network is obtained by training in Mat lab/Simulink with trainlm function using Levenberg – Marquardt algorithm. Due to some reasons like variation of the parameters of solar panel along with time and consideration of a tolerant error, the reference voltage that is generated is not the exactly optimal voltage but itis near to the MPP. So a reference point which is closer to the MPP is achieved by this.

II. RELATED WORK

"Efficiency Enhancement of P3HT: PCBM Based Organic Photovoltaic Devices via Incorporation of Bio-synthesized Gold Nanoparticles [01]",Bio-synthesized goldnanoparticles (AuNPs) withbacteria have been used to enhance the efficiency of P3HT: PCBM based Organic Photovoltaic (OPV) devices. First, AuNPs were synthesized in Bacillus Subtilis containing medium and characterized by zeta potential analyzer, energy dispersive X-ray spectrometer (EDS), UV-Vis spectrometer and Transmission Electron Microscope (TEM). The shape of AuNPs was found to be mainly spherical with an average diameter of 8.01 nm bearing negative surface charge (pH: 2~11). Next, the AuNPs were added to the PEDOT: PSS solution and spin-coated on the ITO substrate, followed by coating the active layer (P3HT: PCBM) and deposition of the metal electrodes. It has been observed that the power conversion efficiency (PCE) increased from 2.98 to 3.39% (enhancement of 14%) at optimum conditions by incorporation of bio-synthesized AuNPs in the whole transport layer.

"Efficiency Enhancement of Photovoltaic Silicon Cell by Ultrashort Laser Pulses [02]",they present an experimental evidence of the effect of the femtosecond laser pulses on the spectral response of the Silicon photovoltaic cell. The response of this device is covering the visible to near infrared spectral region. The responsivity of the photovoltaic solar cell is enhanced from 0.18A/W to 0.25A/W and/or the conversion efficiency increase from about 9% to about 14% due to irradiation effect. All treatments and measurements are made at room temperature. Results show that the responsivity is enhanced and the nano-structured groves of the 700-900 nm range are observed.

"Enhancing Photoelectric Conversion Efficiency of Solar Panel by Water Cooling [03]",Photovoltaic solar cell generates electricity by receiving solar irradiance. The electrical efficiency of photovoltaic (PV) cell is adversely affected by the significant increase of cell operating temperature during absorption of solar radiation. This undesirable effect can be partially avoided by fixing water absorption sponge on the back side of the photovoltaic panel and maintain wet condition by circulation of drop by drop water through sponge. The objective of the present work is to reduce the temperature of the solar cell in order to increase its electrical conversion efficiency. Experiments were performed with and without water cooling. A linear trend between the efficiency and temperature was found. Without cooling, the temperature of the panel was high and solar cells achieved an efficiency of 8–9%. However, when the panel was operated under water cooling condition, the temperature dropped maximally by 40 C leading to an increase in efficiency of solar cells by 12%.

"Efficiency Improvement of the Hybrid PV/T System Applied on Kuwait [04]", this paper presents a noel model and performance evaluation of a low concentrating photovoltaic (CPV) and photovoltaic/thermal system CPV/T systems to improve the efficiency of the PV systems. Two types of reflective optics are used with V trough and parabolic mirror concentrators of point focus type and the triple-junction cells (InGaP/InGas/Ge) assembled to obtain a low and high concentration system. The proposed model was built in the MATLAB/Simulink environment by considering constant PV cell temperature. The model adopts a mathematical approach in order to simulate and investigate the cell characterization curves including module electric and thermal efficiencies, thermal and electric energies provided by cell and module, and cooling fluid temperatures. Also an active system of the photovoltaic cells is considered. The model analyzes the CPV and CPV/T system working for different time levels in terms of direct normal irradiance. The comparison of these systems operating confirmed the improvement of the electrical performance of the concentrating photovoltaic/thermal system.

"Methods for Increasing Energy efficiency of Photovoltaic Systems [05]", this paper shows aspects regarding to photovoltaic systems efficiency. The main methods to increase the efficiency of photovoltaic systems are detailed. These methods are verified by numerical simulation, using dedicated software and experimentally.

"Experimental Assessment of PV Panels Front Water Cooling Strategy [06]",The electrical performance and reliability of flat-type photovoltaic (PV) modules can be severely affected by elevated cell operating temperature due to elevated ambient temperatures. In this work the free flow front water cooling solutions to enhance flat-type PV module electrical performance is experimentally explored on laboratory scale module operated outdoors under natural lightluminance. Water-cooling is implemented using a perforated tube disposed on the top of the panel and a chilled water source, both attached to the module active surface. The cooling water directly wets the module active surface, thereby decreasing the light reflection loss and cleaning the panel surface in the same time. For given meteorological conditions, the efficiency of free water cooling was measured and the corresponding additionally electrical energy yield was determined. The equivalent electric circuit of the PV panel cooling system is developed and an appropriate algorithm for its parameters experimental determination is proposed.

III. PROPOSED METHODOLOGY

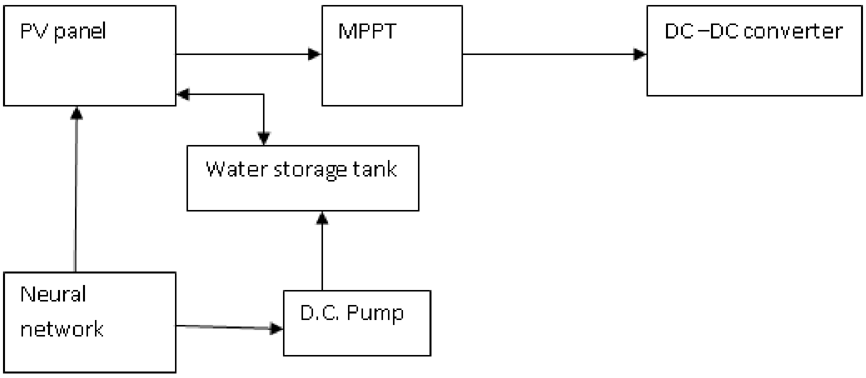


Figure: Proposed Architecture

In the proposal of architecture, the temperature increment is control by the artificial neural network which is associated to employ the water cooling system as shown in basic block diagram.

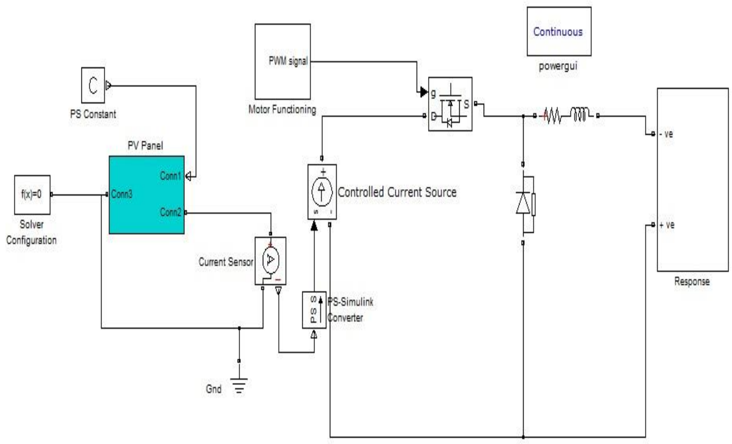
To overcome this reduction in power, module surface cooling using water circulation is employ. The surface cooling system also clean the module surface via water circulation, which resulted in anadditional power up of the PV module in response to removal of theparticles that interfere with solar radiation from the surface of the PV module. Accordingly, the cooling system could reduce maintenance costs and prevent accidents associated with cleaning. In addition, the increase in cooling water temperature can serve as a heat source.

Here, I want to make a system in which solar panel can be get cooling by circulating water on the surface of the panel. When the temperature of the photo voltaic cell gets overheated, the rise in temperature of PV cell occurs. If this rise in temperature count by the intelligent panel(which used neural network technique) then the water can be flow on the surface of PV cell which commanding by the dc pump situated with the water storage tank. This water is not only cools the panel but also clean the surface of panel. After this process, the water is moved to the water tank and panel works to extract the solar irradiance from the sunlight.

With this system, we can easily maintain the temperature of panel and improves the efficiency of photo- voltaic cell. By using intelligent panel with the neural technology, the temperature can be maintained.

IV. RESULT ANALYSIS / IMPLEMENTATION

Working Model of the system



From the working model, it is seen the output of the system can be achieved. As we have a solar panel whose temperature can be control by the intelligent cooling system which is shown in above model and the results could be achieved as shownin below. In this system, the model represents that the rise in temperature can be identify by the intelligent panel and the preset value is set to control the output power as shown in results.

Results:

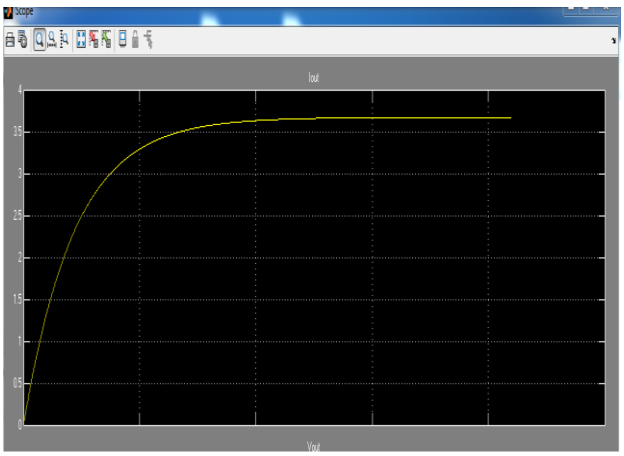


Fig 2 :- the output Current waveform

In the current wave form, we can see that initially waveform starts without any cooling system implementation. Whenever temperature of the panel is increases beyond the set limit which is set by the neural networking, the neural network controls the cooling system section and the output current is constant. This controlling is shown in the graph.

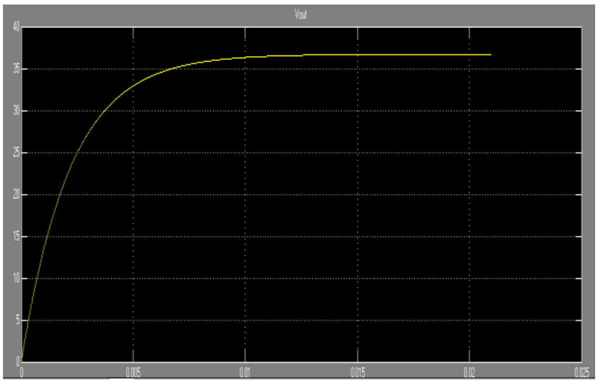


Fig 3 :- the output voltage waveform

In the voltage waveform, it is seen that the action of panel is controlled by the controlling of panel's temperature. In the starting of graph, as the solar irradiance increases the temperature of the panel increases.Because Solar cell is sensitive to temperature. But with the help of the intelligent system the output voltage is constant. When the temperature increases beyond the set value of temperature, then the output is constant which reduces the voltage losses.

V. CONCLUSION

This paper examined the main obstacles that face the operation of photovoltaic panels is overheating due to excessive solar radiation and high ambient temperatures. Overheatingreduces the efficiency of the panels dramatically. "Hence we have to use cooling systems to avoid the overheating of the system". With the method proposed in this paper, the improved efficiency gets which verified with the output waveforms. This method can be utilized where the ambient temperature is high such as dessert.

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