INC-MPPT based Optimization of Solar Energy Harvesting System for WSN Nodes: A Review

Rajat Goel, M.Tech Scholar, Department of Computer Science & Engineering, KanpurInstitute of Technology Kanpur, India

Pronab Kumar Adhikari, Assistant Professor, Department of Computer Science & Engineering, Kanpur Institute of Technology Kanpur, India

Abstract—**Solar energy is the energy source which is clean and sustainable. The implementation of WSN with Solar energy harvesting technique has been in research in IoT in recent times. The WSN node battery energy is minimal and can last for just a few days depending on the operating duty cycle. In this paper we are proposing a new SEH technique for energy constrained WSN nodes. Solar Energy Harvesting Wireless Sensor Network (SEH-WSN) nodes will usually run for years to come. In the past, the harvesting of solar energy was developed using the technique of P&O Maximum Power Point Tracking (MPPT). This paper review on Solar Energy Harvesting System for WSN Nodes With MPPT.**

Index Terms—Solar energy harvesting, INC, MPPT

I. INTRODUCTION

A Wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless Ethernet. WSN is a wireless network that consists of base stations and numbers of nodes (wireless sensors).These networks are used to monitor physical or environmental conditions like sound, pressure, temperature and co-operatively pass data through the network to a main location.

Modern innovative enhancements have made the deployment of small, in-expansive and low-power wireless communication devices with computation capability, a reality. Such devices are distributed in a sensor field and are often referred to as sensor nodes [6]. A Wireless Sensor Network (WSN) is an accumulation of sensor nodes, which coordinate to perform a specific task. The sensor nodes are usually randomly deployed in an unattended environment. They perform sensing and work together to monitor the environment and provide high-quality information. Each sensor node takes the decision based on sensed information, its expertise in processing, ability to communicate and energy resources. Sensor nodes sense the environment and then send that information to the sink as shown in Figure 1.

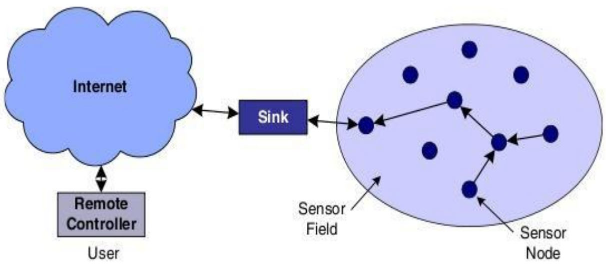


Figure 1: WSN architecture [6]

A wireless sensor node is equipped with one or more sensing units, a microcontroller, a radio transceiver for receiving and transmitting information and a source of energy such as battery. The sensing unit or units of a sensor node measures ambient conditions of the surrounding and transform those into an electrical signal. Such ambient conditions may be temperature, humidity, acoustic, seismographic data of the environment or may be motion, direction of living beings. Based on application and capability, those electrical signals are processed to reveal some vicinity properties or compressed to reduce the communication overhead. The communication unit then, wirelessly directs the attained data towards a central control either directly or via other sensors. This central control is often regarded as a sink or a Base station. In this way, these sensor nodes form an ad-hoc network which is referred as Wireless Sensor Network (WSN).

Wireless sensor networks, just like wireless ad-hoc networks are dynamic in nature due to the frequently changing wireless links and thus network connectivity. In addition, the topology of WSNs changes when the nodes die out or join the network. Further, WSNs and wireless ad-hoc networks show similarity in communication as well as WSNs communication conventionally happens in an ad-hoc manner.

Since sensor nodes [6] are remotely deployed and need to communicate through a wireless channel, it is very difficult for sensor nodes to survive on small and finite sources of energy. In WSNs, maximum energy is consumed during communication as compared to processing and sensing of information. In centralized system, some of the sensors nodes need to communicate over long distances that lead to even more energy depletion. As the sensor nodes in a WSN are densely deployed and may suffer from redundant information, therefore, it would be a good idea to process locally as much information as possible in order to minimize the total number of bits transmitted. Hence, distributed processing is another requisite for sensor networks.

A heterogeneous wireless sensor network consists of different types of sensor nodes, which might measure different data and perform different tasks. To operate such a (sub) network the following devices are required.
Heterogeneous model is shown in figure 2. The nodes always have data to transmit to a base station, which is often far from the sensing area. This kind of sensor network can be used to track the military object or monitor remote environment. Without loss of generality, assume that the base station is located at the center of the square region. The network is organized into a clustering hierarchy, and the cluster-heads execute fusion function to reduce correlated data produced by the sensor nodes within the clusters. The cluster-heads transmit the aggregated data to the base station directly.

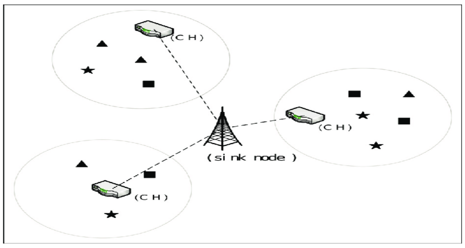


Figure 2: Heterogeneous Models for WSN

For many of the WSN applications like deep forest monitoring, disaster management etc. in which the sensor nodes are inaccessible by humans and cannot be intervened, battery replacement is a very difficult task. In such circumstance, the WSN lifetime entirely depends upon the limited battery capacity, making energy a valuable resource. Thus, the energy which is harvested from the environment is currently one of the most promising areas of research and an extensive research work is required to be accomplished from every possible aspect to make the networks energy efficient. Depending upon application, sensor nodes may be mobile through air or underwater after deployment. In such cases, network topology gets affected and so does the network performance and lifetime. Very small and inexpensive nodes are also aimed to be developed for military purposes, which can be heavily stationed in a larger area. Moreover, whether mobile or stationary, WSN communication can be disrupted by other moving objects such as animals, vehicles or by a natural disaster.
The WSN hubs experience the ill effects of a significant plan imperative that their battery energy is restricted and can work just for a couple of days relying on the obligation pattern of activity (Sharma H, Haque A, 2018). The sunlight based energy generally put away in sun powered cells so the energy putting away proficiency must be expanded. Sunlight based energy framework can be changed over quickly into power utilizing PV boards through the photovoltaic impact (Mohamed, S. A., &Abd El Sattar, M., 2019). Be that as it may, the transformation productivity is low and the expense of intensity created is similarly high. PV age has numerous favorable circumstances, for example, it has low fuel costs, doesn't create contamination, requires little upkeep, and PV framework has more different highlights (Ahmad, T., Sobhan, S., &Nayan, M. F., 2016).
Sunlight based photovoltaic (PV) energy collecting alludes to changing over sun based light energy into electrical energy to work an electrical or electronic gadget. As applied to WSNs, sun based light energy is changed over into electrical energy and is used to revive the battery of a WSN hub at the activity site itself (Sharma, H., Haque, A. and Jaffery, Z.A., 2018). In this manner, battery substitution is required over and over once the battery energy has been released. The electrical energy gathered from sun based energy can likewise be utilized legitimately to control a WSN hub. Then again, the gathered energy might be warehoused in a battery-powered battery for future purposes. The SEH-WSNs comprise of little self-sufficient WSN hubs connected to little measure sunlight based boards for their energy collecting needs. It is seen that the greatest conceivable gathered force from sun powered energy at outside is 15 mW/cm2 with a productivity up to 30% (Rasheduzzaman, M., Pillai,2016). Accordingly, we have picked sun based energy gathering for providing substitute capacity to the WSNs as it has the most powerful thickness and great productivity.
Various techniques to follow the most extreme force purpose of a PV module have been proposed (Choudhary, D., &Saxena, A. R., 2014) to beat the restriction of effectiveness. MPPT is utilized for removing the most extreme force from the sun oriented PV module and moving that capacity to the heap. DC-DC converter goes about as an interface between the heap and the PV module as it effectively transfer greatest force from the sun powered PV module to the heap. By changing the obligation cycle the heap impedance is coordinated with the source impedance to accomplish the most extreme force from the PV board (Veerachary, M., &Saxena, A. R., 2011).

II. LITERATURE REVIEW

Power system networks take the PV-created energy by methods for matrix associated inverters. There is some of the time, no coordinating of the working particular highlights of the heap and PV clusters, which is an eminent trouble in PV power frameworks. In particular, with various ecological states, PV Module exhibit shows non-direct style for V-I bend and greatest force point on V-P bend. PV module productivity is in the scope of 10-25%.
This means greatest force point following (MPPT) calculations are gotten together with the whole framework to augment their capacity and lessen modules cost. Different key research findings available in the literature are summarized in Table 1.

Table 1: Summarization of different key approaches proposed in literature

Paper Ref	Objective	Strategy
(Baci, A. B., Salmi, M.,2020)	Here the creator has depicted the length of daylight outperforms 2000 hours every year	The model of new counterfeit sun based tree is proposed tentatively by utilizing material

	and can arrive at 3900 hours on the good countries and the Sahara. The significance of this work depends on misusing sun oriented energy to create power..	accessible in the nearby market: 25 sun based panels,metal uphold, electrical lines, controller, and battery.
(Sharma, H., Haque, A.,2018)	The WSN hubs experience the ill effects of a significant plan limitation that their battery energy is restricted and can turn out just for a couple of days relying on the obligation pattern of activity.	we propose another answer for this plan issue by utilizing surrounding sun based photovoltaic energy. Here, we propose a profoundly productive and special sunlight based energy reaping framework for battery-powered battery based WSN hubs.
Akinaga, H., KapoorS, 2020)	The principle commitment of thisexploration article is to propose an effective sun based energy gathering answer for the restricted battery energy issue of WSN hubsby using surrounding sun basedphotovoltaic energy. Preferably, theOptimized Solar Energy HarvestingWireless Sensor Network (SEH-WSN) hubs ought to work for an endless organization lifetime.	It propose a novel and effective sun based energy collecting framework with heartbeat width adjustment (PWM) and greatest force point following (MPPT) for WSN hubs. The exploration center is to expand the general collecting framework proficiency, which further relies on sun powered board effectiveness, PWM productivity, and MPPT effectiveness.
(Eseosa, O., & Kingsley, I., 2020).	The paper is on reenactment of MPPT utilizing P&O also, INC techniques. Numerical model of 100KW PV framework was created utilizing Matlab M-document. The two models were planned and reenacted utilizing MATLAB/SIMULINK. t is shown that PV framework yield power increments with ascend in sun powered illumination and in lower cell temperature. Accordingly, sun based cell performs preferred in warm climate over virus climate.	It is suggested that the MPPT The framework should comprise of partial, three-point, temperature-based MPPT for more successful and improved examination. Moresothe annoy and noticed technique ought to be enhanced by fluctuating of the irradiance to keep an increment consistent voltage.
(Kumar, R., Choudhary, A., 2017)	This paper manages reproduction/demonstrating, controlling of greatest force point following (MPPT) utilized in PV frameworks to augment the yield force of photovoltaic framework, light conditions independent of the temperature of VI attributes of burden.	In this exploration a significant greatest force point following method has been created, comprising a lift converter, which is controlling heartbeat given by a microcontroller-based unit.
(Kinjal, P., Shah, K. B.,2015)	Of late, sustainable power innovation has had critical impact in energy application. One commendable sort of sustainable energy will be energy from the sun that creates electrical power straightforwardly by utilizing PV modules helped by MPPT calculations to make as extensive as conceivable the sunlight based yield power.	More or less, by changing the yield force of the inverter, the objective of accomplishing MPPT in PV frameworks is to change the conceivable working voltage of PV boards to the voltage at MPPT.

The table 1 has three columnsfirst one shows reference numbers, second one shows objective of the related work and third column shows strategy of the work that how the perform.

III. Need of Solar Power Generation

In the field of power sector in these days one of the major concerns is day by day increasing more power demand but the quantity and availability of conventional energy sources are not enough resources to meet up the current day's power demand. While thinking about future availability of conventional sources of power generation, it is become very important that the renewable energy sources must be utilized along with source of conventional energy generation systems to full fill the requirement of the energy demand.

In order to rigging the current day's energy crisis one renewable method is the method in which power extracts from the incoming son radiation calling Solar Energy, which is globally free for everyone. Solar energy is lavishly available on the earth surface as well as on space so that we can harvest its energy and convert that energy into our suitability form of energy and properly utilize it with efficiently. Power generation from solar energy can be grid connected or it can be an isolated or standalone power generating system that depends on the utility, location of load area, availability of power grid nearby it. Thus where the availability of grids connection is very difficult or costly the solar can be used to supply the power to those areas. The most important two advantages of solar power are that its fuel cost is absolutely zero and solar power generations during its

operation do not emanate any greenhouse gases. Another advantage of using solar power for small power generation is its portability; we can carry that whenever wherever small power generation is required.
In the last few years the power conversion mechanisms for solar energy has been significantly comes in compact size. The advance research in the field of power electronics and material science have greatly helpful for engineers to develop such a system that very small but effective and powerful systems that have capability to withstand for supplying the high electric power demand. For every country day by day power density demand is increasing. Solar power generation have also the capability to handle the voltage fluctuation very effectively by setting the system for the use of multiple input converter units. But in solar power generation system due to its high installation cost and the low efficiency of the solar cells, this power generating systems can hardly participate in the competitive power markets as a main renewable source of power generation. Scientists are constantly trying to improve in the field of development of the solar cells manufacturing technology for increasing efficiency. That will definitely help to make the solar generation as in habit for use in daily life as prime renewable source of electrical power on a wider range basis than present day conditions. In solar power generation system the latest power control mechanisms is using now these days calling the Maximum Power Point Tracking frequently referred as MPPT, it has guide to the increase in the efficiency of operation of power generation from the solar cells. Thus MPPT is most important in the field of consumption of renewable sources of energy.

IV. PV Model with Parameters

A single PV cell is a thin semiconductor wafer made of two layers generally made of highly purified silicon (PV cells can be made of many different semiconductors but crystalline silicon is the most widely used). The layers have been doped with boron on one side and phosphorous on the other side, producing surplus of electrons on one side and a deficit of electrons on the other side.
When the wafer is bombarded by sunlight, photons in the sunlight knock off some of excess electrons; this makes a voltage difference between the two sides as the excess electrons try to move to the deficit side. In silicon this voltage is 0.5 volt Metallic contacts are made to both sides of the semiconductor. With an external circuit attached to the contacts, the electrons can get back to where they came from and current flows through the circuit. This PV cell has no storage capacity; it simply acts as an electron pump. The amount of current is determined by the number of electrons that the solar photons knock off. Bigger cells, more efficient cells, or cells exposed to more intense sunlight will deliver more electrons.
Transformation of light energy in electrical energy depends on a marvel called photovoltaic impact (Mathew, A., &Selvakumar, A. I., 2006). At the point when semiconductor materials are presented to light, theportion of the photons of light beam is consumed by the semiconductor gem which causes a critical number of free electrons in the gem. This is the essential purpose behind delivering power because of photovoltaic impact. Photovoltaic cell is the fundamental unit of the framework where the photovoltaic impact is used to create power from light energy.
Silicon is the most generally utilized semiconductor material for developing the photovoltaic cell. The silicon molecule has four valence electrons. In a strong precious stone, every silicon iota shares every one of its four valence electrons with another closest silicon particle thus making covalent connections between them. Along these lines, silicon precious stone gets a tetrahedral cross section structure. While light beam strikes on any materials some part of the light is mirrored, some bit is sent through the materials and rest is consumed by the materials. Something very similar happens when light falls on a silicon precious stone. On the off chance that the power of episode light is sufficiently high, adequate quantities of photons are consumed by the gem and these photons, thus, energize a portion of the electrons of covalent bonds. These energized electrons at that point get adequate energy to move from valence band to conduction band. As the energy level of these electrons is in the conduction band, they leave from the covalent bond leaving a gap in the bond behind each eliminated electron. These are called free electrons move arbitrarily inside the precious stone structure of the silicon. These free electrons and openings have a fundamental part in making power in photovoltaic cell. These electrons and openings are henceforth called light-created electrons and gaps separately. These light created electrons and openings can't deliver power in the silicon gem alone. There ought to be some extra system to do that.

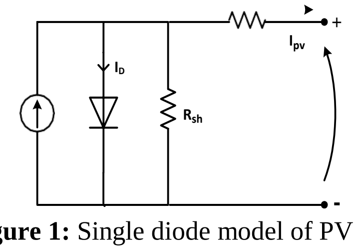


Figure 1: Single diode model of PV cell

Figure 1 is a PV cell in which one current source, one forward bias diode, 2 resistances are connected.
The electron-hole pair (EHP) is produced Incident of a photon of light energy (hv>Eg) over a solar cell. The newly created EHP relates to electric current denoted by (IL) termed light induced current. The ideal equation of a solar cell with current-voltage (I – V) is given as

$$Solar\ Cell\ Current\ (I) = I_{ph} - I_0 \left[\exp\left(\frac{qV}{kT}\right) - i1\right] \qquad (1)$$

Where, I = solar cell output current, I_{ph} = light produced by solar cell, Io = Reverse current of saturation because of reconjunction, q = electron charge ($1.6 * 10^{-19}$ C), V = Open-circuit voltage of solar cell, k= Boltzmann constant ($1.38 * 10^{-23}$J/ K), T = solar cell temperature (300 K).

The circuit model in figure 1 represents equivalent of solar cell. It comprises light-produced source current (Iph), a Shockley equation-modeled diode (D), and two series and parallel resistances. Figure 3.11 shows the VI and PV characteristic in which on voltage shows and on y axis current lsft side and power right side shows.

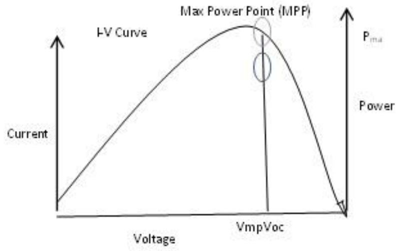


Figure 2: V-I and P-V Characteristic

The maximum power point (MPP) is a point on the Power voltage (P-V) characteristic of the solar cell, where the maximum power can be extracted from the solar cell as shown in Figure 2. Ideally, the solar cell efficiency should be high. But practically, it is limited to 5%–15%only (Green, M. A., Hishikawa, 2018).

In Figure 2, the current law of Kirchhoff (KCL) can provide characteristic equation of current for that corresponding circuit:

$$\text{Equivalent Cell Output Current } (I) = I_{ph} - I_D - I_P \qquad (2)$$

Where,I_P= parallel resistance current, I_{ph} = Light produced current, and I_D = diode current.

$$Diode\ Current\ (I_D) = I_o\left[\exp\left(\frac{V+IR_s}{nV_T}\right) - 1\right] \qquad (3)$$

Where, I_o = Reverse Saturation current because of reconjunction, V = solar cell open circuit voltage, R_s = series resistance, Ipv = solar cell output current, n = diode norm factor, (1 termed as ideal, 2 termed as practical diode), k = Boltzmann constant (1.38×10^{-23} J/K), V_T = Thermal voltage (kT/q), T = Solar cell Temperature (300 K). Q = electron charge (1.6×10^{-19} C). The parallel-resistance current is determined as:

$$Current\ in\ parallel\ resistance\left(I_p\right) = \frac{V+IpvR_s}{R_p} \qquad (4)$$

Now, by placing the I_D and Ip value in the equation (4), we obtain complete equivalent circuit fourth equation of solar cell, under that all values are defined as connected with output current and voltage [9]:

$$Solar\ Cell\ Current\ (I) = I_L - I_0\left[\exp\left(\frac{q(V+IpvR_s)}{nkT}\right)\right] - \left(\frac{V+IR_s}{R_p}\right) \qquad (5)$$

Where, Rp = Parallel Resistance and in Equation (5), the other parameters Io, I_L, V, I, q, Rs, n, k, T were already declared. The solar cell efficiency (η) is termed as:

$$Solar\ Cell\ Efficiency\ (\eta) = \frac{V_{OC}I_{SC}FF}{P_{in}} \qquad (6)$$

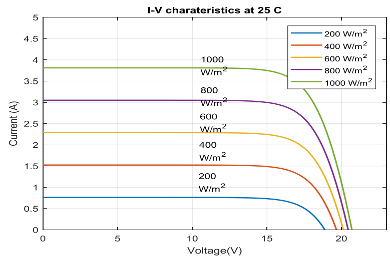
Where Isc is Current Short Circuit, Voc is called Open Circuit Voltage, FF = Fill Factor and Pin = optical incident power. A Solar Cell's Fill Factor (FF) is given as

$$Fill\ Factor\ (FF) = \frac{P_{max}}{P_{dc}} = \frac{I_mV_m}{I_{SC}V_{OC}} \qquad (7)$$

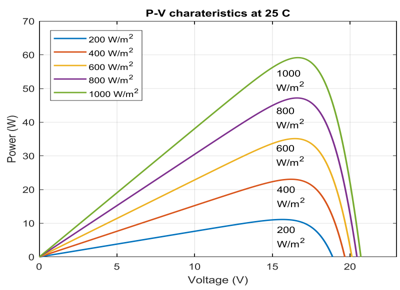
Where V_m is the solar cell's maximum voltage and I_m is called maximum current. There are practically many kinds of solar cells, like amorphous silicon solar cells (a-Si), mono-crystalline silicon solar cells (C-Si), thin film solar cells (TFSC), polycrystalline solar cells (multi-Si) etc. But the productivity of a-Si solar cells is greater than any other efficiency till 18 per cent.

- **Solar Radiation Effect (G)**

The efficiency of solar cell (η) is proportional to solar radiations variations. The efficiency of solar cell (η) increases, on increasing the solar radiation and vice versa. Figure 3 (a) displays the current-voltage (I–iV) properties of a commercial solar panel of 10 watts with varying values of irradiance.



(a)



(b)

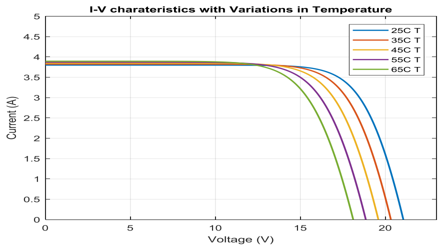
Figure 3: Solar Panel characterization with Irradiance level variations (Watts/m^2). (a) Characteristics of (I–V) (b) Characteristics of (P–V)

The solar panel of 10 watts 10 watts (Dow Chemical DPS 10–1000) is 232 mm * 546 mm in size and has 0.13 m^2 module area. By Figure 3 (a), it is identified that the solar panel current is increasing with increase in degree of irradiance. Here the solar cell current for solar irradiance of 1000 W/m^2 is optimum (6.2 A). Figure 3 (b) shows the Power-Voltage properties of Solar Panel in various radiation levels. For highest solar irradiance like 1000, the extracted power is the optimum (9.8 W).

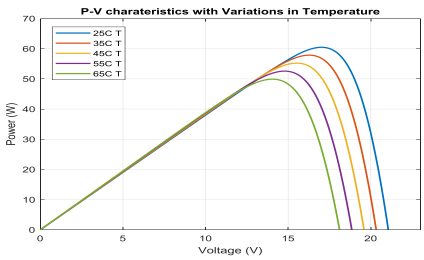
Figure 3 (a) shows solar panel irradiance variation IV characteristic in which x axis shows voltage and y axis shows current. In figure 3 (b) x axis is voltage and y axis is power.

- **The Temperature Effect (T)**

Such as the one in Figure 4 (a), if the temperature of the solar panel increases then the production value decreases and vice versa. And the increase in output is in direct accordance with the fluctuations in temperature. Similarly as the temperature in Figure 4 (b) increases, output capacity decreases, and vice-versa. Hence the output power is inversely proportional to the variations of temperature.



(a)



(b)

Figure 4:.Characteristics of solar panels with Temperature (^oC) variations. (a) Characteristics of (I–V); (b) Characteristics of (P-V)

Figure 4 (a) and (b) shows characteristic of solar panel with temperature variation in figure (a) x axis is voltage and y axis is current, in figure (b) x axis is voltage and y axis is power.

- **Systems for Harvesting Solar Energy**

A simple solar energy harvesting system is a combination of rechargeable battery, solar panel, DC-DC converter, Battery Management System (BMS) safety charging circuit and DC-DC converter control unit. For DC-DC converters, control methods are generally maximal power point tracking control (MPPT). The SEH unit in Figure 3.14 contains rechargeable battery, DC-DC buck converter, maximum power point (MPPT) solar panel and transmitter, and a WSN sensor node attached to the DC.

Solar energy from the natural sun is collected in solar panels and transformed into electricity. The DC-DC Buck converter is shut off and this caused voltage magnitude is controlled and transferred to the same rechargeable unit. An MPPT sensor controls the Solar Panel's current and voltage, changing the duty period as a Buck MOSFET DC-DC converter (Mathews, I., King, 2015).

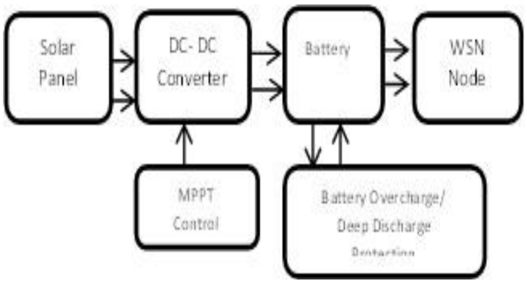


Figure 5: Solar energy recovery (harvesting) system block diagram, using input from MPPT capacity

Figure 5 shows block diagram of solar energy harvest and it has DC-DC converter, battery, WSN node, solar panel etc.Finally, the wireless sensor node is regulated by the voltage of the batteries. The WSN performs the role of detecting, analyzing and interacting the same characteristics with other nodes. Thus, as with vibration, temperature, acceleration and humidity, the SEH-WSN nodes can be used to track and control any physical phenomenon autonomously. In this scenario, solar harvester circuit's efficiency exhibits a very significant function. If solar power harvester's performance is low, battery will not be recharged sufficiently, thereby reducing the lifespan of the wireless sensor network.

V. Maximum Power Point Tracking (MPPT) Modeling Technique

The efficiency of a solar cell is very low and also when solar cells are connected together to form a panel then its efficiency is still not increased [8]. In order to increase the efficiency (η) of solar cell or solar panel we have to use maximum power transfer theorem.

The maximum power transfer theorem says that the maximum power is transfer when the output resistance of source matches with the load resistance [18] i.e. solar cell or solar panel impedance. So all MPPT technique's principles are based on maximum power transfer theorem that always trying to matching the impedance of load to source.

The effectiveness of MPPT is given by following equation. [15]

$$\eta_{MPPT} = \frac{\int_0^t P_{measured}(t)dt}{\int_0^t P_{actual}(t)dt} \quad (8)$$

The maximum power point tracking (MPPT) is now habitual in grid connected PV power generation system and it is becoming more popular in isolated or stand-alone power generation systems as well because of the V-I characteristics in PV power generation systems is nonlinear, So it is difficult to supply a constant power to a certain load.

There is confusion with MPPT that many people think that it is a mechanical device that tracking the sun, it rotates the solar panel or solar cells as well as tilts it in the direction of sun where the solar irradiance is more. But the MPPT is an electronic device that extracts maximum possible power from solar panel. It varies the electrical operating point of the panel by changing the DC/DC converter duty cycle to matching the load impedance with PV cells impedance. Mechanical tracking system can be used with MPPT, but these two systems are completely different from each other.

To understand how the MPPT works, let's first consider a solar panel. A solar panel generates power by using the photovoltaic effect then obvious a solar panel has a P-V characteristic that means for a different operating point of the solar panel, a different power output can be achieved. Therefore the maximum possible power is obtain from the solar panel when it operates at only for one specific operating point of the P-V characteristic of solar panel. This point in the P-V characteristic is called the Maximum Power Point (MPP). This MPP changes when the solar irradiation changes or temperature changes or when the solar panel is partially shaded [13]. So when these three factor changes, the solar panel operating point is also changes. To track that constantly changing MPP a device is needed called Maximum Power Point Tracker (MPPT).

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter whose duty cycle is varied by using an MPPT algorithm. MPPT is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' or peak power voltage. MPPT is most effective under, cold weather, cloudy or hazy days. There are large numbers of algorithms that are able to track MPPs. Some of them are simple, such as those based on voltage and current feedback, like (P&O) method.

The P&O algorithms operate by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage or current and comparing the PV output power with that of the previous perturbation cycle. If the PV array operating voltage changes and power increases (dP/dV PV>0), the control system moves the PV array operating point in that direction; otherwise the operating point is moved in the opposite direction. In the next perturbation cycle the algorithm continues in the same way.

A common problem in P&O algorithms is that the array terminal voltage is perturbed every MPPT cycle; therefore when the MPP is reached, the output power oscillates around the maximum, resulting in power loss in the PV system. This is especially true in constant or slowly-varying atmospheric conditions. Furthermore, P&O methods can fail under rapidly changing atmospheric conditions (Figure 6). Starting from an operating point A, if atmospheric conditions stay approximately constant, a perturbation ΔV the voltage V will bring the operating point to B and the perturbation will be reversed due to a decrease in power. However, if the irradiance increases and shifts the power curve from P1 to P2 within one sampling period, the operating point will move from A to C. This represents an increase in power and the perturbation is kept the same. Consequently, the operating point diverges from the MPP and will keep diverging if the irradiance steadily increases.

There are many different P&O methods available in the literature. In this work we consider the classic, the optimized and the three-points weight comparison algorithms. In the classic P&O technique (P&Oa), the perturbations of the PV operating point have a fixed magnitude. In our analysis, the magnitude of perturbation is 0.37% of the PV array VOV (around 2V) In the optimized P&O technique (P&Ob), an average of several samples of the array power is used to dynamically adjust the perturbation magnitude of the PV operating point.

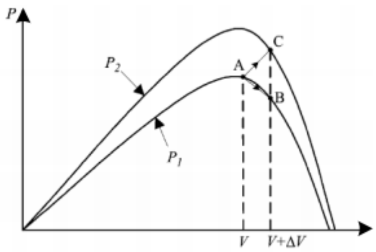


Figure 6: Divergence of P&O from MPPT

In the three-point weight comparison method (P&Oc), the perturbation direction is decided by comparing the PV output power on three points of the P-V curve. These three points are the current operation point (A), a point B perturbed from point A, and a point C doubly perturbed in the opposite direction from point B. All three algorithms require two measurements: a measurement of the voltage VPV and a measurement of the current IPV (Figure 7)

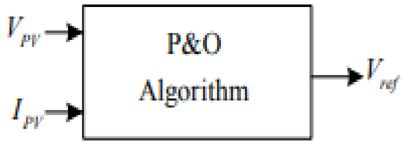


Figure 7: P&O block diagram

VI. Incremental Conductance (INC) Algorithm

The process of incremental-conductance (INC) is also used for PV systems. It monitors MPP by comparing PV array's instant and incremental conductance. The INC system problem is close to P&O's. Usually the fixed step size is used which computes MPPT's speed and accuracy of response. Therefore the tradeoff between tracking speed and steady state efficiency has to be made. Such architecture problem can be stable with MPPT strategies of variable step duration.

The Power respect to Voltage derivative (dP/dV) is utilized to change MPPT phase scale. Incremental Conductance (IC) technique surmounts the perturbation disadvantage and observes method in monitoring peak power in rapidly changing atmospheric situation. This method will decide if MPPT has passed the MPP and also stops perturbing point of service. If the condition is not true, it is possible to determine the direction in that MPPT operating point is to be disturbed using relation between dl/dViand -I/V. This relation is found from fact that when MPPT is to right side of MPP, dP/dViis negative and is positive when to left side of MPP. The phase size increases when operating point is far from the MPP, and progressively decreases when the operating point comes close to the MPP.

The quick tracking velocity and steady performance can be achieved simultaneously by changing the phase size. However, the MPPT algorithm convergence involves a scaling factor, and the factor significantly decreases response speed under abruptly change of atmospheric situations. A MPPT algorithm with incremental-resistance (INR) is to be tested with adjusted step variable size (Ibrahim, R., Chung, 2017). For moving between the fixed step and variable step mode, a threshold function is applied, and variable step phase is felt by scaling factor variation.

This method obtains quick response and precisely steady state output but its implementation is limited by the high computing load and best non-linearity of scaling factor. There really are two phase size alteration coefficients in (Li, Y., & Shi, R. , 2015) to minimize the perturbation effects (duty ratio) underneath the drastic shift in irradiation with less computing, while the influence of the basic step size upon on method efficiency is not considered.

This algorithm decides when MPPT hits MPP, while P&O toggles around MPP itself. This obviously reflects a benefit over P&O. The Incremental conductance could also monitor rapidly increasing and decreasing conditions of irradiance with greater accuracy than disturbance, and observe method (Praveen, K., Pudipeddi, M., 2016). The downside of the algorithm, compared to P&O, is that it is more complicated.

VII. Conclusion

MPPT is algorithm that included in charge controllers used for extracting maximum available power from PV module. The voltage at which PV module can produce maximum power is called ‘maximum power point’ or peak power voltage. This review paper discussed the INC-MPPT concepts with PV module and Solar Energy Harvesting System for WSN Nodes.

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