Hybrid Method for Maximum Power Point Tracking in Photovoltaic Cell using Perturb Observe and Least Mean Square

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ABSTRACT
At a geographical location of Indian sub-continent, solar energy has been recommended and implemented as an alternative to traditional methods of electricity generation. It allows direct conversion of sun photonic radiations to electrical energy. This is conceivable due to Photo-Voltaic (PV) systems. Boost converters and maximum power tracking control system. An effective photovoltaic system should operate at its best i.e. should extract maximum power from the system with least fluctuations in voltages/currents. The tracking becomes complicated due to solar irradiance level & temperature, varieties in the maximum power point and the non-linear conduct of PV systems. Maximum Power Point Tracking (MPPT) can be accomplished in the PV cells at particular operating point but it needs good control at the output boost converter side by using an effective control technique. There are many techniques available i.e. Perturb-Observe (PO) etc. but they do not consider the predictive or future power in making decisions for IGBT on/off operation; hence have slow initial start points and fluctuations as well. Here, a hybrid technique is proposed that make use of perturb-observe at output and Least Mean Square (LMS) for filtering to get the predictive power values which results in maximum point tracking and has lesser oscillations.

Keywords
Least Mean Square Filter, Maximum Power Point Tracking, Photo-Voltaic, Perturb-Observe;

1. INTRODUCTION
In recent years, utility of solar and wind energy sources is vastly advocated. These modern energy sources are sustainable, limitless, naturally, friendly, and cheap over duration of years. Out of these sustainable energy sources, solar energy is an appropriate member because it permits direct transformation of this type of energy to the electrical energy with the help of Photo-Voltaic (PV) systems. Solar energy can be straightforwardly changed over into the electrical energy with the use of a photo-voltaic cell, with two drawbacks: a) has lower conversion rate in converting photonic energy to electrical energy, especially when photonic irradiation is less b) dependability of generated power on the existing climate Conditions, (such as thermal reading and solar radiation) fermenting and load conditions [1]. It is therefore, recommended to keep up the photo-voltaic operation at its highest ability of operation for extracting power. The tracking of it becomes complicate because of solar irradiance level & temperature, varieties in the Maximum Power Point Tracking MPPT) systems and the non-linear conduct of PV systems. In simple words, MPPT control block is the dominant block which effects efficiency of the whole system. It has been figured out that the maximum power point is obtained just at a particular operating point which involves the values of both current and voltage at that point.

1.1 Photovoltaic Solar Energy (Solar Electricity)
The energy from solar radiations is straightway used in primarily by two means. First, direct transformation into electricity by semiconductor devices and second, extracting the heat by means of solar collecting materials. Direct transformation of sun photonic radiation into electricity can be achieved by means of PV cell arrays in which output power is based on photovoltaic effect. Small PV cells are combined in parallel or series to get a photovoltaic array. In general, the photovoltaic effect is the potential difference at the intersection of distinct materials in respond to viewable or variant photonic radiations [2]. The entire field of this transformation from radiations to electricity is termed as “photovoltaic”. Photovoltaic truly signifies “light-electricity”, since “photo” has originations in Greek language named as “phos” which is light and “Volt” is derived from Alessandro Volta’s (1745-1827) name who was a famous physicist, chemists as well as a pioneer in electricity. As a common person does not know about the photovoltaic term hence PV term is generally used for such systems.

1.2 Materials Utilized in Photovoltaic Cell
The materials utilized in photovoltaic cells are per the following:

1.2.1 Single-crystal Silicon
The widely use of these cells are in the photovoltaic manufacturing unit. The Czochralski (CZ) is the fundamental procedure for creating single-crystal silicon cells. At first, high purity polycrystalline has been melted in a quartz crucible and then a single-crystal silicon seed is
placed in the molten mass of polycrystalline. A single-crystal ingot is created when this seed is extracted from the melt. The material is then cut in form of the wafers around 200 to 400 micrometer thickness. Then cleaning process is applied to the wafers after which doping, covering processes has been applied. Further the outcomes are attached to form array-patches& modules.

1.2.2 Polycrystalline Silicon
Single-crystal silicon is the dominant constituent of such type of cells. These cells consume more energy than the single-crystal silicon photovoltaic cells. The flow of electrons is retarded by the complex structure of polycrystalline silicon cell that results into decreased output power of the cell. Slicing of the PV cells into the wafers from pieces of polycrystalline silicon is the most conventional method to produce the cells. “Ribbon growth” technique is another cutting-edge technique for producing these cells. In this, silicon is developed straightaway in the form of thin ribbons or sheets.

1.2.3 Gallium Arsenide
Gallium Arsenide is a compound semiconductor formed of Gallium (Ga) and Arsenic (As). The crystal structure of this Gallium Arsenide (GaAs) is similar to silicon. It consumes more photonic energy, which causes its high acceptability in the market than other materials. For absorbing the same quantity of sunlight GaAs needs just a few micrometer thick set layers whereas crystalline silicon needs around 200 to 300micrometers thick layer. Moreover the energy conversion efficiency of GaAs is greater that is 25 to 30%. The primary disadvantage of GaAs is that the crystal substrate, on which it is grown, is highly expensive.

1.2.4 Cadmium Telluride
Another product used is Cadmium Telluride. It is a polycrystalline compound which consists of cadmium and telluride. It has excessive light absorb ability; even a very thin layer of it has the ability to group 90% of solar irradiation. The instability of PV cell or module performance is the only drawback of the compound. Due to its highly toxic nature, extra care needs to be taken during its manufacturing.

1.2.5 Copper Indium Dieseline
It is a polycrystalline compound which consists of copper, selenium and indium. This compound conveys maximum energy conversion efficiency as it is not effected by outside degradation issue. Being a complex material and owing to its toxic nature assembling process suffers some difficulties.

The organization of the remaining paper is as follows: In section 2, a literature review showing the performance of different MPPTs is presented. In section 3, design of proposed MPPT block with PO and improved LMS algorithm is presented. The simulation, results and discussions are given in section 4. Finally, we conclude the paper in section 5.

2. LITERATURE REVIEW
In [3] author studied about various methods of maximum power point tracking of photovoltaic array. There are minimum nineteen different methods that have been inducted in the literature with various changes in implementation. This work will prove beneficial in reference for futuristic work in field of photovoltaic array. In [4], author studied and investigated the most appropriate operating conditions for find out the cutting edge performance of MPPT method for photovoltaic appliance. It is observed that if proper predictive and adaptive scenarios are adopted then Perturb and Observe (PO) ensure top-level efficiency. The motive of this presented approach was realizing, furthermore complete desirable presentation of tracking, maximum strength and expeditiousness in summer as well as darkened weather. The power gain subject to standard PO method is obtained with the use of exploratory calculations accomplish over a lower power system. The presented approach also permits conceivable minimization of equipment expenses of analog to digital converter that is utilized in the MPPT control circuit. In [5] author studied the impact of partial shading on the various MPPs with the use of MATLAB simulink simulation model of photovoltaic generator consisting of 18 series interconnected photovoltaic modules. In large number of cases, the partial shading conditions leads to the existence of various MPPs, additionally just a single maximum power point is available regardless of the partial shading. Various conditions that prompt to single or more MPPs in electrical attributes of photovoltaic generators have been studied. It was discovered that purpose behind having at least a single MPPs commenced specifically from physical characteristics of photovoltaic modules: the ratio of MPP current to short circuit current, power losses in bypass diodes, and the value of the parasitic shunt resistance of photovoltaic cell.

In [6] author described microcontroller based incorporated system for checking of PV system. This has metrological unit for measuring the metrological parameter such as pressure, temperature, wind strength, humidity, etc and has a main unit for measuring the electrical parameter such as current and voltage of photovoltaic system. Data-logging software is used for convey the data to computer. By utilizing RS-485 bus, the measured parameters are transmitted to main unit by metrological unit. IEC 61724 techniques are utilized for measuring the system parameter. To check 1kW standalone system, the monitoring setup has been established and to monitor the standalone photovoltaic system a low cost instrument is provided. In [7] a shadow model for depicting the shadow and its progression is suggested. A technique for assessing the estate of the shadow is also presented. This technique is then concentrated through a theoretical proposal, followed by simulations, and all outcomes are approved through measurements.

3. PROPOSED WORK & ITS IMPLEMENTATIONS
Since the conventional source of energy has been depleted throughout the years, the PV energy conversion has assumed immense significance amid the previous years. Now a day, the main concentrates of research is on diminishment in size and simplifying the PV energy conversion system. Photovoltaic systems incorporates PV array that provides storage of energy in the system with the help of a Maximum Power Point Tracker (MPPT). Solar cell is not highly efficient. For increasing its efficiency various techniques are to be adopted so as to properly coordinate the load and source. Maximum Power Point Tracking is one of the compatible techniques to be employed. In PV system, it is very difficult to power the assertive load since the I-V curve is non-linear [8]. For
achieving this, boost converter is used whose duty cycle is altered with the help of a MPPT technique. Some of the algorithms are stated beneath. The boost converter is powered by solar panel and is employed on the load side. In this work, we bid for FIR filter based MPP tracker that utilize recursive least square in order to avoid errors and then we compare its results with existing PO technique usually employed for the purpose of MPP tracking. The figure 1 consists of the photovoltaic array model in which the combination of a MPPT with boost dc converter, single phase series load is associated to ac grid, dc to ac inverter.

This system use an FIR based adaptive prediction model in which the optimization criteria rely upon forecast error which require minimum mean square error value, for which least mean square algorithm is used [9]. The equation is

\[ e^2(n) = (y(n) - \hat{y}(n))^2 \]  

(1)

e^2(n) is a mean square error; \( y(n) \) is desired output; \( \hat{y}(n) \) is predicted output.

Even for solving the equation and co-efficient of the above equation the gradient-descent method is used which is

\[ H_N(n + 1) = H_N(n) + 2\mu[p_N - R_{NN}H_N(n)] \]  

(2)

\( \mu \) is step size; \( p_N \) and \( R_{NN} \) values are complex to calculate so the equation is deduced to an approximate format which is

\[ H_N(n + 1) = H_N(n) + 2\mu e(n)X_N(n) \]  

(3)

In the figure 2, \( p(n) \) and \( p(n-1) \) is the output power of same and previous time, \( d(n) \) is duty cycle. The input voltage predicts the output power of next moment by prediction machinery. And then the system enters a judgment based on control rules. Hence the duty cycle can be determined and PWM pulse signal which can drive switching devices after comparison between duty cycle and triangular wave is generated.

In the control mechanism, \( P1 \& P2 \) are the output power of same and next moment. \( P3 \) is the power of last moment. When \( P1 > P3 \), assign it with positive. When \( P2 \geq P1 \), assign positive. Otherwise negative. The voltage rule is then applied on the basis of power perturbation. If two power is positive then voltage will be in disturbance mode. If two power is negative then voltage will be in opposite disturbance mode and if one is positive and other negative then unchanged voltage will be that show the presence of MPP. Figure 3 show the flowchart for PO-MPP tracker with LMS algorithm used to decrease the harmonics in the system.
4. SIMULATION RESULTS AND DISCUSSION

The simulink model actualized in case of single phase power grid photovoltaic system in connection with MPPT at various thermal reading conditions is shown in figure 4. When RLS algorithm and PO is combined, MPPT block is modeled by hybrid method.

![Simulink model of solar energy PV system](image1)

**Fig 4: Simulink model of solar energy PV system**

The term MPPT which is called single unit represents the MPPT and gating signal generator. The ‘I’ represents the current generated by light which uses some mathematical equations of current and voltage conversions based on a single diode model of photovoltaic cells. Along with this, other systems are included i.e. boost converter, the boost converter has the inductance of 2e-3H and it has the capacitance of 2000e-6F. This is utilized to step up the voltage up to the desired value. By contrasting the duty cycle output of MPPT block in terms of 0 to 1 to a continuously saw-tooth produced signal working at a duty-cycle depending frequency values, the gating signal to the boost converter is produced. Universal bridge with PWM is viewed as the dc–ac power conversion circuit to cope up with the necessity of grid connection. Pulse PWM control based carrier are generated with the help of discrete PWM generator.

The technique of PWM (Pulse Width Modulation) can be understood from the concept that it generates amplitude pulses by modulating the pulse according to the duty cycle. In this a base signal is set at some base value and continuous analog signals are compared such that they should be less than in value than the base signal voltage level. Then comparator is used to compare the values of two signals and results in a logical output. The reference signal is the signal one needs as output and generally square waves or sinusoidal waves are used for this purposes. On the other hand, the carrier signal can be one from saw tooth-triangular type having the frequency larger than the base signal. Since there is numerous types of PWM methods and one can acquire various outputs. For choosing the type of inverter one can have to rely upon the cost, efficiency and the noise factor. The various blocks utilized in simulation have been provided as

4.1 Photovoltaic Cell

![Solar cell modeled in single diode](image2)

**Fig 5: Solar cell modeled in single diode**

A regulated source of current is used to run the solar cell. The “1 generator” unit provides the control signal. It takes in to the consideration the number of solar cell connected and the thermal reading to decide the input signal received from the solar cell as shown in figure 5.

4.2 Current Generator Unit

![Current generator subsystem](image3)

**Fig 6: Current generator subsystem**

Figure 6 provides the input to the solar cell. The Simulink block accessible in the MATLAB is used for simulating this block. This unit provides the current utilizing the equations provided in the form of function blocks.

MPPT method depends upon the PV power calculation and the power changed by sampling PV current as well as the voltage. The tracker works when the increment and decrement of solar array voltage occurs regularly. This technique employs when there is a usage of immediate Photovoltaic array voltage and currents such that sampling happens just a single time in every cycle of switching. The procedure is done again and again as far as we reached the MPP. One can decrease the oscillation by decreasing the perturbation step size. Despite, a lower perturbation size decreasing down the MPPT. So to defeat the issue of this slow respond in getting to MPP, a new technique has been invented so as MPP can be achieved faster contrasted with that of conventional PO. The power predicted by least mean square filtration is shown in figure 7.

![Power predicted by LMS filtration](image4)

**Fig 7: Power predicted by LMS filtration**

Figure 8 and 9 shows the current, power and voltage waveforms obtained at the output using PO-MPP tracker and using PO-MPP with LMS algorithm.
This method shows better results as compared to Perturb and observe method by using the same parameters such as irradiance value, temperature etc. In the starting, previous method gets poor tracking and become stable after long period of time at MPP than the hybrid method. Secondly we achieved an improvement of less range of power produced fluctuates as compared to PO method.

5. CONCLUSION

In this work, an improved MPPT method has been proposed for photovoltaic energy systems. Existed methods generally considers current and previous power comparisons to evaluate the coming duty cycle for IGBT pulses but in this method predictive power has been introduced which derives from the outputs of the perturb observe methods. As least mean square filtering is used to reduce the error or smaller variations in the one-dimensional time varying signals, this property of LMS has been used by us by considering output of perturb observe as input to LMS which reduce the fluctuations in the input signal. This is then fed as a predictive signal to increase or decrease duty cycle based on previous and current power reading. It has been found that, the proposed system not only reduces the fluctuations in the system but also achieve initial power point tracing earlier than the traditional perturb observe method. In future, the proposed system can be amended in order to use it along with other renewable sources i.e. hydro power, wind energy and diesel based generation systems. So a system can be built in which multiple sources of generation can be attached to a single distribution unit. In this work, AC to DC and DC to AC converters will be needed that can be explored in future work.

6. REFERENCES


