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ANALYSIS ON MAXIMUM POWER POINT TRACKING ALGORITHM FOR PHOTOVOLTAIC SYSTEMS USING GOLDEN SECTION SEARCH METHOD

Mohamed Ibrahim

ABSTRACT
The photovoltaic (PV) module has been the interface of electrical energy generation from the solar irradiation. The solar radiation, ambient temperature and solar cell temperature are not constant throughout the day. So, the maximum power condition varies all the time due to which the efficiency of PV cell decreases. To increase the efficiency of PV cell maximum power point tracking is used. Maximum Power Point Tracking (MPPT) is an algorithm that includes charge controller that is used for extracting maximum power available power from PV module under certain conditions. In addition to the above conditions, the irradiance on PV module is non-uniform due to shading of trees, clouds etc., called partial shading. Using conventional MPPT technique such as Perturb and Observe, Incremental conductance, Hill climbing it is not possible to track maximum power condition in partial shading condition. The main objective of the present work is to consider MPPT even during partial shading conditions such that the overall efficiency of the system is improved.

1. INTRODUCTION

The steadily increasing demand on electric energy and rising prices of the fuel used in conventional power plants together with increasing concerns about their environmental effects, have encouraged intensive research for, friendly environmental, lowcost generation plants, particularly solar energy which has proved its worth for power plants of multiple MW proportions, as well as smaller applications such as rural electrifications [1]. Solar energy is considered as one of the most promising renewable energy of the future in Algeria [2] and has become a necessity for people living in the southern to cope with the long hot season [3]. Besides the availability of the sunlight along the year, PV systems are easy to install, present neither moving parts nor combustion processes hence environmentally friendly and almost maintenance free [2]. However, PV systems, which mainly comprise the PVG and power electronic processor, suffer from very low system efficiency, a problem that arguably needs to be addressed. One should differentiate between conversion efficiency and utilisation efficiency of PV modules. Conversion efficiency, being difficult to estimate as a parameter [1], is very low compared to utilisation efficiency which is the ratio of output power to the maximum power that can be extracted at given atmospheric conditions (irradiance, temperature and air mass). In the present work, the latter efficiency is the only parameter of interest. Therefore, one of the most economical ways to improve the utilisation efficiency of PVGs is to ensure that it is always operating at its maximum power point irrespective of the environment conditions. This can be achieved by associating a maximum power point tracking (MPPT) controller to the power electronic converter (usually a chopper) in order to adjust the duty cycle to match the load.

Much work has been devoted to improve the performance of PV systems through developing new or upgrading already existed MPPT algorithms. To this, several papers have been published to review, discuss and classify these MPPT algorithms. For instance, in [4] two main groups of MPPTs are distinguished: conventional group that includes Perturb and Observe (P&O), Incremental Conductance (IC), and Hill Climbing (HC) techniques and stochastic based methods group, then a

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comparison between those techniques within the same group is done in terms of convergence speed, complexity, ability to truck the true MPP, etc. Different MPPT algorithms which are based on the use of either AI or evolutionary methods have been listed in [5]. A focus has been given to their implementation using FPGA ships and subsequently a comparison between them is made in terms of complexity, efficiency, rapidity and memory space requirement. Classification adopted in [6] is based on the ability of MPPT technique to cope with uniform and non-uniform irradiance. This paper raises the outcome that evolutionary algorithms based MPPT techniques outperform others in terms of seeking GMPP but there are still many concerns when it comes to implementation. A comparison through simulation and implementation using FPGA of four MPPT techniques is presented in [7]. Fuzzy logic, Artificial Neural Network (ANN), Adaptive Neuro-Fuzzy Inference System (ANFIS) and GAoptimized FLC based MPPTs are considered and compared in terms of complexity, rapidity, oscillation around MPP and memory space requirement.

None of the previously mentioned review paper has considered MPPTs which are based on the mathematical model of the PVG. Finding relationship between weather parameters and PVG output voltage and current using either curve fitting or training techniques would make deriving the MPP parameters (duty cycle, current or voltage) an easy forward task. These relationships can be obtained by training an ANFIS to become MPPT controller estimating the input resistance of the PV system (PVG + chopper) which has a direct relationship with MPP or applying nonlinear model identification methods. Model-based MPPT techniques offer the advantage of being very fast but valid only for the PVG under test and cannot cope with partial shading operations. In general, MPPT algorithms are classified according to the type of the algorithm used. This classification makes difference between conventional methods, Artificial Intelligence techniques (AI) and population-based techniques. Conventional MPPT methods include P&O, IC, HC and their modified version techniques [4]. AI-based MPPT methods use one or combine two of the soft computing techniques:

In [11] the authors have designed a fuzzy-logic controller (FLC) for seeking the MPP deliverable by a photovoltaic module using the measured values of the photovoltaic current and voltage. The simulation results show a satisfactory performance with a good agreement between the expected and the obtained values. An adaptive fuzzy logic based MPPT method is proposed. It consists to integrate two different rules; the first one is used to adjust the duty cycle of the DC–DC converter, while the second one is employed for an online adjusting of the controller's gain. Results indicate that the proposed method outperforms the conventional fuzzy-logic controller. A new embedded digital MPPT system based on ANN is recently developed. The advantages of the proposed system include low computation requirement, fast tracking speed and high static/dynamic tracking efficiencies. In addition, using the developed neural network model, the photovoltaic generation systems user can apply the developed MPPT controller to any photovoltaic module without the need to modify the firmware of the photovoltaic generation system.

Major sources for generating electricity are non-renewable energy sources such as coal, gas, nuclear etc. are extracted in large amount so their availability is reducing continuously. It takes more time to replenish these sources. So, it is necessary to choose the alternative sources called Renewable energy sources like sun, wind, biomass, tide, geothermal etc. which are always available in nature. The power generation from these sources is intermittent.

Solar power generation involves clean, noise less operation. The main component which generates electricity from the solar is the PV cell. The PV cell converts visible light into Direct current (DC) based on photovoltaic effect.

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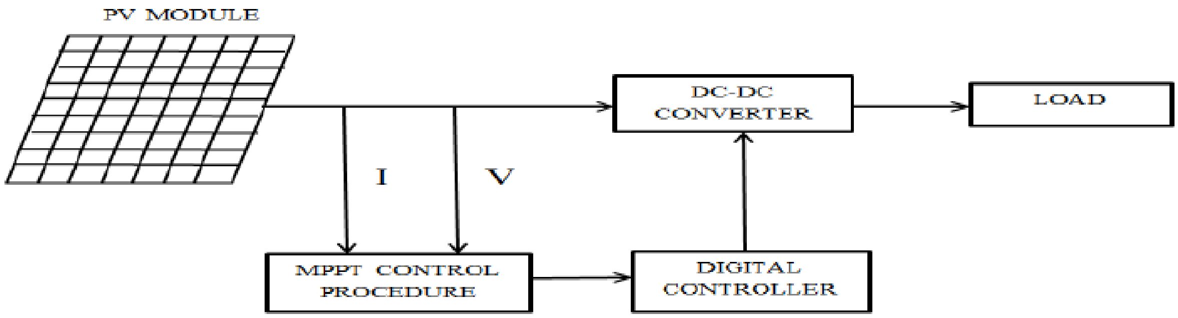

Figure1. Block diagram of PV system.

The main objective in designing the PV panel is to absorb the sunlight and convert it into required form of energy. To convert the obtained voltage from PV panel to the load voltage a DC-DC converter is used. For the system to operate at maximum efficiency, The MPPT charge controller takes the voltage from the PV panel and maximizes the amount of current flowing through the battery.

2. PV SYSTEM MODELLING

Fig. 2 shows a simplified scheme of a standalone PV system with DC–DC buck converter.

This section is devoted to PV module modelling which is a matrix of elementary cells that are the heart of PV systems. The modelling of PV systems starts from the model of the elementary PV cell that is derived from that of the P–N junction.

2.1. Ideal photovoltaic cell

The PV cell combines the behavior of either voltage or current sources according to the operating point. This behavior can be obtained by connecting a sunlight-sensitive current source with a p–n junction of a semiconductor material being sensitive to sunlight and temperature. The dot-line square in Fig. 3 shows the model of the ideal PV cell. The dc current generated by the PV cell is expressed as follows

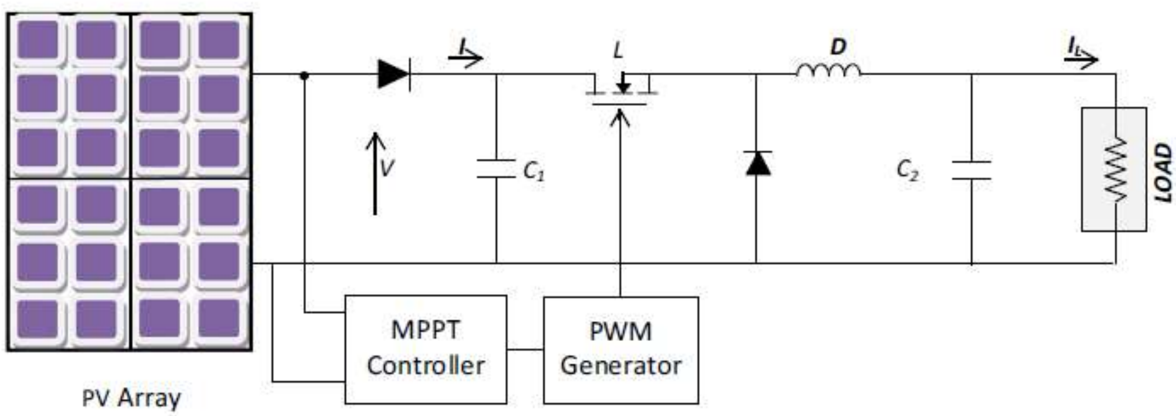

Fig. 2. A PV system with a DC–DC buck converter.

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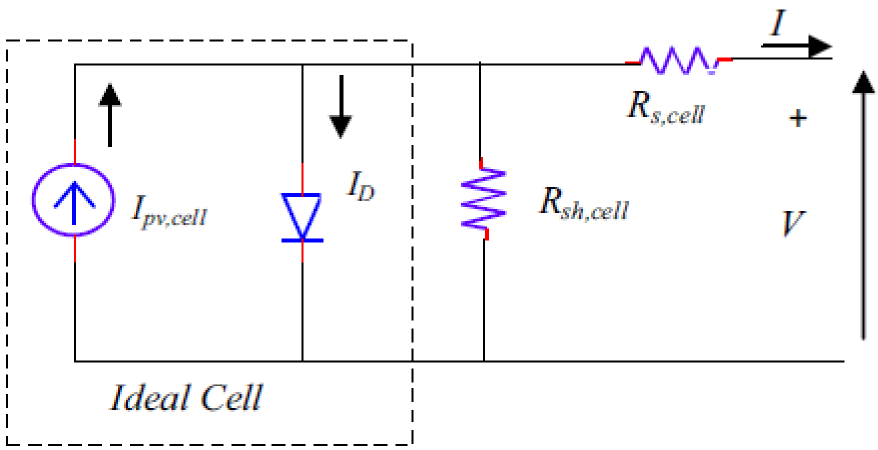

Fig. 3. Equivalent circuit of an ideal and practical PV cell.

2.2. PV module modelling

Commercially photovoltaic devices are available as sets of series and/or parallel-connected PV cells combined into one item, the PV module, to produce higher voltage, current and power, as shown in Fig. 3.

The equation of the I–V characteristic of the PV module is obtained from Eq. (1) by including the equivalent module series resistance, shunt resistance and the number of cells connected in series and in parallel.

$$I = I_{\mathrm{pv,cell}} - I_{s,\mathrm{cell}}\left(e^{\frac{V}{aV_t}} - 1\right)$$

$$I = N_p\left(I_{\mathrm{pv}} - I_s\left(e^{\frac{q(V+I.R_S)}{aN_S KT}} - 1\right)\right) - \frac{(V+I}{R_{sh}}$$

3. GSS METHOD

A. Optimization:

Optimization Techniques:

An optimization technique is used to optimize the given objective function. The procedure consists of finding the design variable values that results in the best objective function value, while satisfying all the equality, inequality and other constrains.

Advantages:

1. It yields the best solution within the domain of study.
2. Requires fewer experiments to achieve an optimum formulation.
3. It predicts the direction of improvement.

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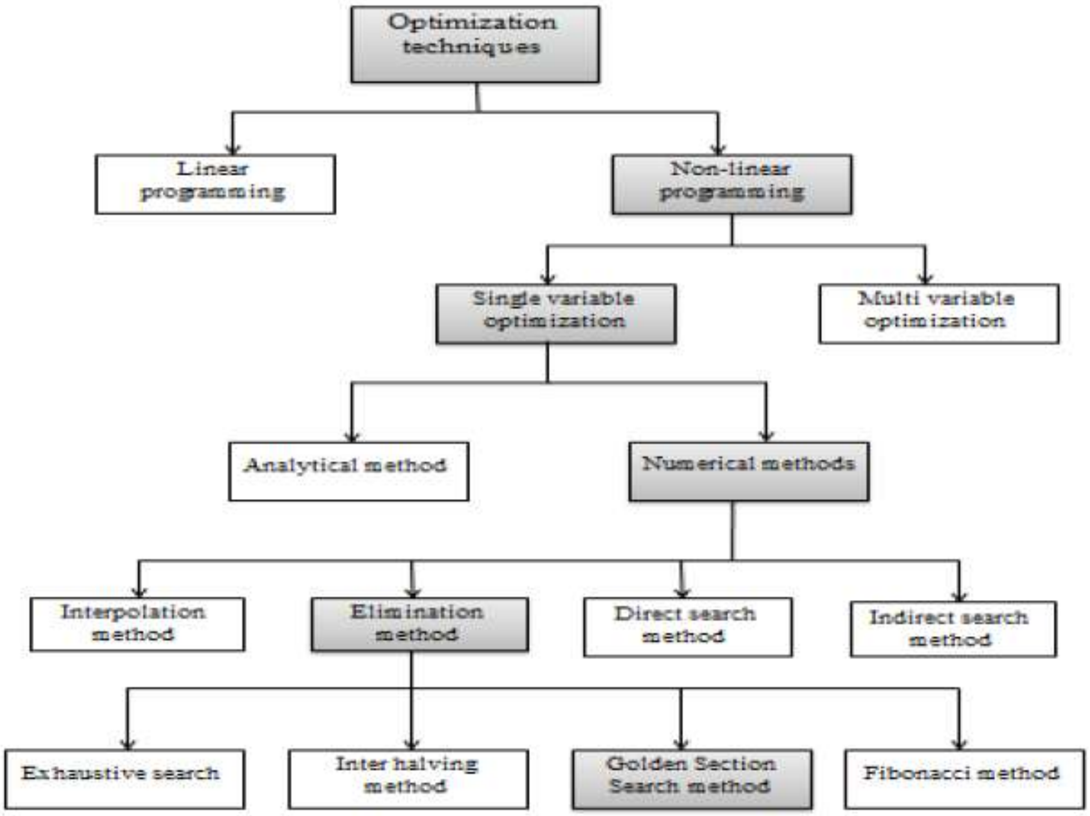

Figure4: Classification of Optimization techniques

Derivation of the Method of Golden Section Search:

Consider a continues and unimodal function 'f' over a given interval [a,b]. A reduction factor is required for the search to get minimum iterations.

CONCLUSION AND FUTURE WORK

In order to improve the efficiency of PV systems, the PV module is associated to a chopper whose voltage or duty cycle is controlled by a MPPT algorithm. In this paper, a new MPPT algorithm which is based on Golden Section Optimization technique is proposed. First, the paper presents the principle of the Golden Section Optimization technique and then derives the flowchart of the MPPT based on this new investigated technique. Several tests have been conducted to verify the performances of the algorithm under STC conditions, fast changing conditions and partial shading operations. The main advantages are:

1. Only addition/subtraction and multiplications are used in the algorithm which employs a few arithmetic operations to compute the reference voltage.
2. The convergence of the algorithm is very fast as the MPP is reached approximately within seven (7) steps.
3. Once the MPP is reached, the PV module operates with constant voltage and current without any steady state oscillations avoiding hence waste of energy due to oscillations.
4. Under fast changing atmospheric conditions, the algorithm exhibits high dynamic efficiency with very low tracking error.
5. Finally under partial shading condition, the proposed MPPT technique behaves like a global search algorithm and efficiently tracks the global MPP.

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