Performance and Degradation Analysis of Adaptive Reference MPPT Algorithm for Solar Power System

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Abstract- To maximize solar Photovoltaic (PV) output under dynamic weather conditions, Maximum Power Point Tracking (MPPT) controllers are incorporated in solar PV systems. Implementing the MPPT algorithm through digital controllers is easier if it is possible to minimize error functions. The differences between the various MPPT techniques are very slight and they can be evaluated according to the situation. In this work a modified version of adapative reference voltage algorithm has been designed. The model has been simulated in MATLAB/ SIMULINK environment. The modeling of adaptive reference PSO based MPPT algorithm has resulted in considerable improvement in the power output from the PV module. The power output with adaptive reference PSO MPPT algorithm at the load terminal has improved from 3959 Watts to 4969 watts approximately.

Keywords- MPPT technique, PSO algorithm, photovoltaic, PWM technique.

I. INTRODUCTION

It is the world energy demand is increasing due to the increase in technology development, standard of living and world population. In addition, the energy generation from clean, efficient and environmentally friendly sources has become one of the major challenges for engineers and scientists, due to the limited reservoirs of fossil fuels and emission of greenhouse gases.

Renewable energy is expected to have large potential as an alternative energy source without constraint on energy supply or greenhouse gas emissions [1–2].

Consequently, the method initially achieves an incorrect MPP instead of the current one [4]. The new MPP is achieved only after the next sampling of the array voltage. This problem is more pronounced when the irradiation changes quickly. Additionally, when sample and hold amplifier is used, as in this paper, and the sampling period is too long, the hold capacitor will drop.

This causes Vref to change during the sampling period and, as a result, the PV operating point deviates from the MPP. To overcome this problem, extended hold time S&H is used [5, 6].

In this arrangement extended hold time is achieved by stacking two S&H circuits in chain. By adopting this method, the problem of deviation of the PV operating point from the MPP is mitigated, but this arrangement increases the number of components and the system cost. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. [7]
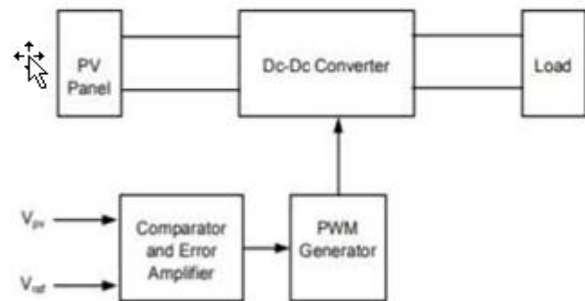

Fig 1. Block diagram of the voltage based MPPT.

It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions.[8] MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

Solar inverters convert the DC power to AC power and may incorporate MPPT: such inverters sample the output power (I-V curve) from the solar modules and apply the proper resistance (load) so as to obtain maximum power.

The power at the MPP (Pmpp) is the product of the MPP voltage (Vmpp) and MPP current (Impp).

Therefore maximum power point tracker methods are required to maintain the PV array's working at its MPP.

Many MPPT methods have been suggested in the literature; example is the Perturb and Observe (P&O) methods, Incremental Conductance (IC) methods and constant voltage methods etc. In this paper the most popular of MPPT technique (Perturb and Observe (P&O) method, Buck and Buck- Boost DC-DC converters will involve in Implementation study. [13]

Some results such as current, voltage and output power for each various combination have been discussed. The MPPT technique will be implemented, by using Matlab tool Simulink, considering the variant of circuit combination
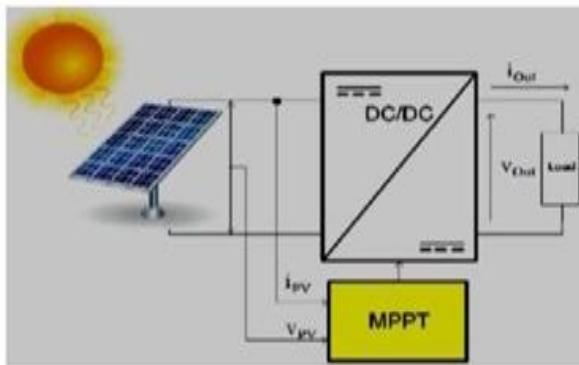

Fig 2. PV module and dc/ dc converter with MPPT.

II. LITERATURE REVIEW

Pooja Singh et. al [1] This study presents an adaptive perturb and observe (P&O)-fuzzy control maximum power point tracking (MPPT) algorithm for photovoltaic (PV) boost dc-dc converter. P&O is known as a very simple MPPT algorithm and used widely. Fuzzy logic is also simple to be developed and provides fast response. The proposed techniques combine both of their advantages. For evaluation and comparison analysis, conventional P&O control algorithm have been developed too.

The entire algorithm were simulated in Matlab/Simulink, together with PV modules of 330 Sun Power Modules (SPR-305) WHT- U connected to PV boost dc-dc converter. This system is followed by dc-ac inverter and the output is connected to the grid. Performance assessment covers overshoot, time response, oscillation and stability as described in this study. From the results and analysis, the adaptive P&Ofuzzy control MPPT shows the best performance with fast time response, less overshoot and more stable operation.

Wernher Swiegers at el [2] This paper proposes a maximum power point tracker (MPPT) for a photovoltaic panel, that is to be integrated with the panel during manufacturing. The MPPT is inexpensive, efficient and has few components that serve to increase the MPPT's mean time between failures (MTBF). The MPPT uses an inexpensive micro-controller to perform all of its

functions. This includes maximum power point tracking, series battery voltage regulation, sensorless short circuit protection of the MPPT's converter and intelligent shutdown and wakeup at dusk and dawn. The MPPT can source 10 A to a 6 V - 36 V lead-acid storage battery and can be connected in parallel or series with other MPPTs.

The MPPT may be easily configured to perform output voltage regulation on passive and water pumping loads. It could also control the actuation of a diesel generator in a hybrid remote area power supply (RAPS).

Energy transfer enhancements of up to 26%, compared to solar panels without MPPTs, have been measured. The complete component and materials cost of the MPPT is approximately 2'8% of the cost of photovoltaic panels with a peak power rating of 154 W. The integrated MPPT also consumes no stored energy at night.

Roberto faranda et al [3] This paper presents a comparative study of ten widely-adopted MPPT algorithms; their performance is evaluated on the energy point of view, by using the simulation tool Simulink®, considering different solar irradiance variations. Many maximum power point tracking techniques for photo voltaic systems have been developed to maximize the produced energy and a lot of these are well established in the literature. These techniques vary in many aspects as: simplicity, convergence speed, digital or analogical implementation, sensors required, cost, range of effectiveness, and in other aspects.

Jawad Ahmad at el [4] This paper describes the design of a voltage based maximum power point tracker (MPPT) for photovoltaic (PV) applications. Of the various MPPT methods, the voltage based method is considered to be the simplest and cost effective.

The major disadvantage of this method is that the PV array is disconnected from the load for the sampling of its open circuit voltage, which inevitably results in power loss. Another disadvantage, in case of rapid irradiance variation, is that if the duration between two successive samplings, called the sampling period, is too long there is a considerable loss. This is because the output voltage of the PV array follows the unchanged reference during one sampling period.

Once a maximum power point (MPP) is tracked and a change in irradiation occurs between two successive samplings, then the new MPP is not tracked until the next sampling of the PV array voltage. This paper proposes an MPPT circuit in which the sampling interval of the PV array voltage, and the sampling period have been shortened. The sample and hold circuit has also been simplified. The proposed circuit does not utilize a microcontroller or a digital signal processor and is thus suitable for low cost and low power applications.

Sahu et al. [5] elaborated a comprehensive overview of a photovoltaic (PV) system model, and maximum power point tracking (MPPT) algorithms in normal and partial shading conditions. Performance evaluation techniques are discussed on the basis of the dynamic parameters of the PV system. The voltage of the photovoltaic generator is nonlinear and exhibits multiple peaks, including many local peaks and a global peak in non-uniform irradiance.

III. METHODOLOGY

1. PV Module Modeling:
PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig.4.2.The MPPT algorithm has been employed in order to obtain the operation of solar module at maximum power continuously.

A cell series resistance (Rs) is connected in series with parallel combination of cellphotocurrent (Iph), exponential diode (D), and shunt resistance (Rsh), I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_S(e^{q(Vpv+Ipv*Rs)/nKT} - 1) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph} - Solar-induced current

I_S - Diode saturation current

q - Electron charge ($1.6e^{-19}$C)

K - Boltzmann constant ($1.38e^{-23}$J/K)

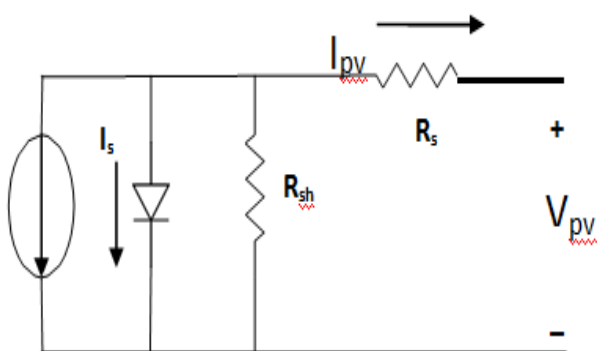n - Ideality factor (l~2)

T - Temperature ^{0}K

Fig 3. Equivalent circuit of solar pv cell.

2. Adaptive Reference Voltage Algorithm:
The PV module has been modeled for varying irradiance. Then the adaptive algorithm has been adopted in order to enhance the output power and mean power. The voltage has been set according to the following table:

Table 1.Varitaion in irradiance and voltage Vm.

Varitaion in irradiance and voltage Vm for $T = 25^0$	
Irradiance (W/m^2)	Voltage output (Vm)
400	32.2803
450	32.4999
500	32.689
550	32.8545
600	32.9987
650	33.1249
700	33.2386
750	33.3393
800	33.4272
850	33.507
900	33.5785
950	33.6424
1000	1000 33.7

3. Adaptive Reference PSO MPPT Algorithm:
Particle swarm optimization PSO is a novel swarm optimization algorithm that is firstly proposed by Kennedy as an evolutionary algorithm based on behavior of birds. PSO uses a set of particles that each one suggests a solution to the optimization problem [13]. It is based on the success of all particles that emulates a population where the position of each particle depends to the agent position to detect the best solution Pbest by using current particles in the population G. The position of any particle xi isadjusted by

$$x_i^{k=1} = x_i^k + v_i \qquad (3.1)$$

Where the velocity component v_i represents the step size and is calculated by:

$$v_i^k = w\,v_i^k + c_1 r_1(Pbest_i - x_i^k) + c_2 r_2(G - x_i^k) \quad (3.2)$$
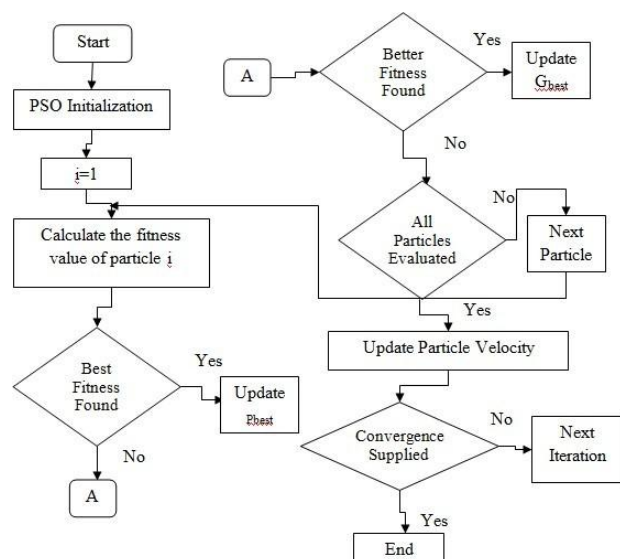

Fig 4. PSO-MPPT Technique.

IV. RESULTS

1. Case 1: Adaptive Reference Mppt Technique:
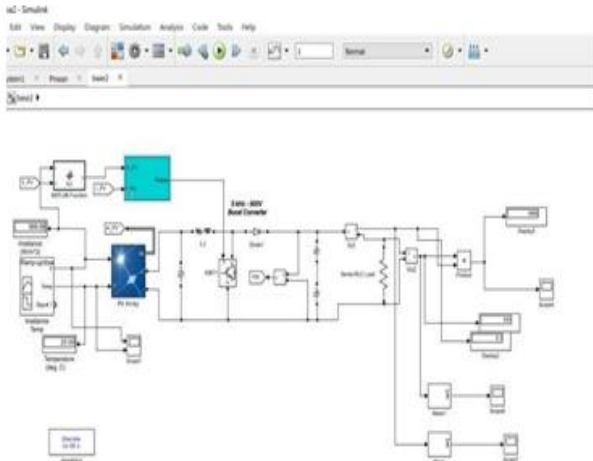
This is shown in figure 4.2 below:

Fig 5. PV SIMULINK model based on adaptive reference algorithm (ARV).
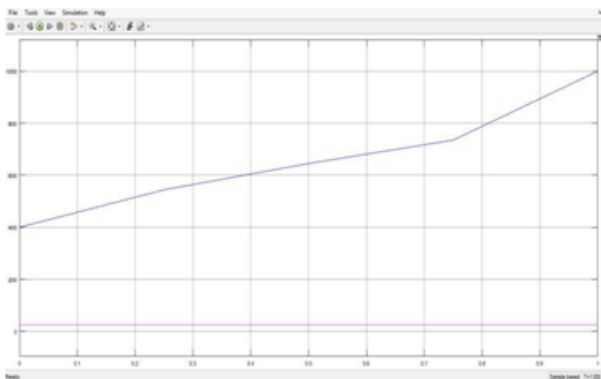

Fig 6. Varying irradiance and constant temperature.
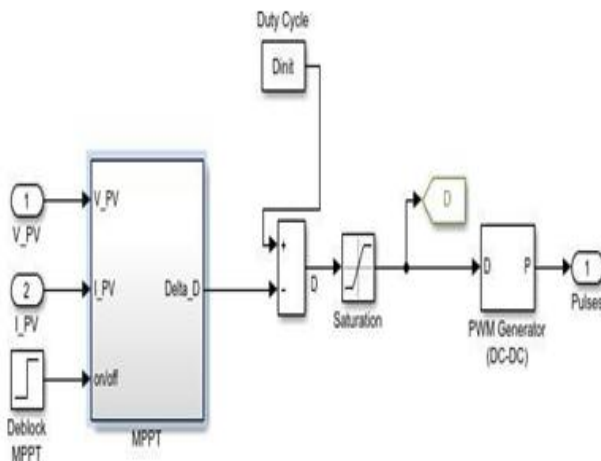

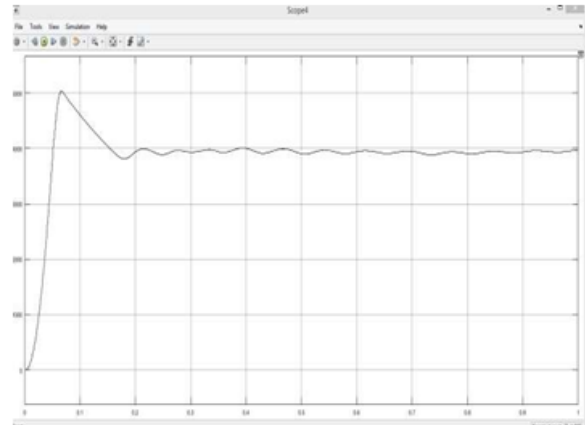Fig 7. MPPT technique based on adaptive reference algorithm.

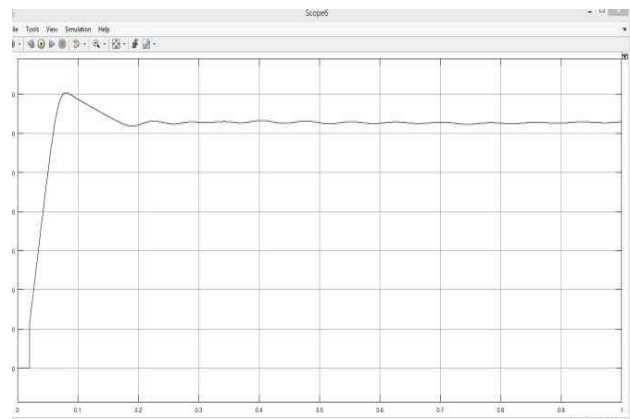Fig 8. Power output at load terminal with adaptive reference MPPT technique.

Fig 9. Voltage output at load terminal with adaptive reference MPPT technique.

2. Case 2: Adaptive Reference Particle Swarm Optimization:

The particle positions are used to define the duty cycle of dc converter, and the fitness value evaluation function stands for the output power of PV array.
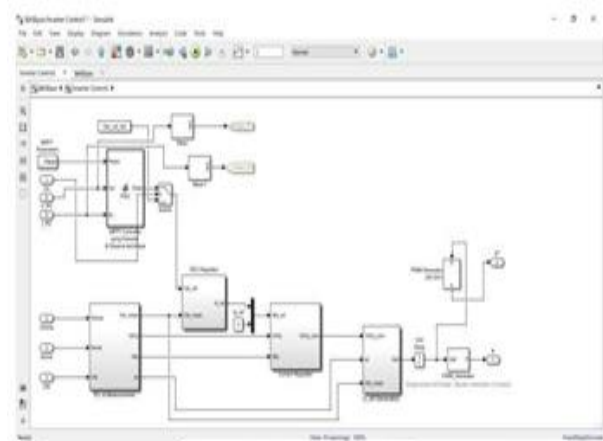

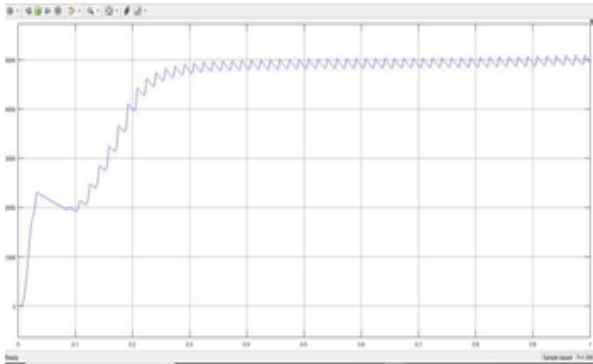Fig 10. Inverter Control based on adaptive reference PSO technique.

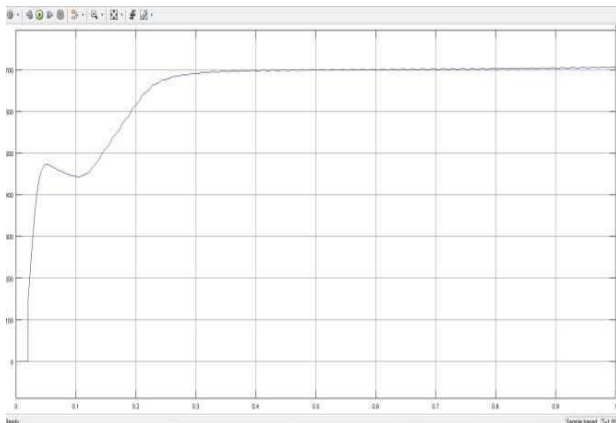Fig 11. Power output at load terminal with adaptive reference PSO algorithm.

Fig 12. Voltage at load terminal Power output at load terminal with adaptive reference PSO algorithm.

3. Validation:

The when comparing the power, voltage, current outputs of the adaptive reference MPPT technique with the modified adaptive reference PSO based MPPT algorithm, we infer that there is considerable improvement in the outputs from both the systems.
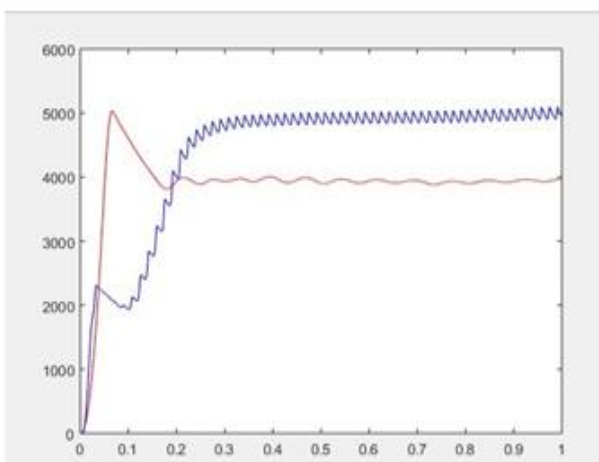

Fig 13. Power outputs from system using Adaptive reference voltage algorithm and adaptive reference PSO based algorithm.
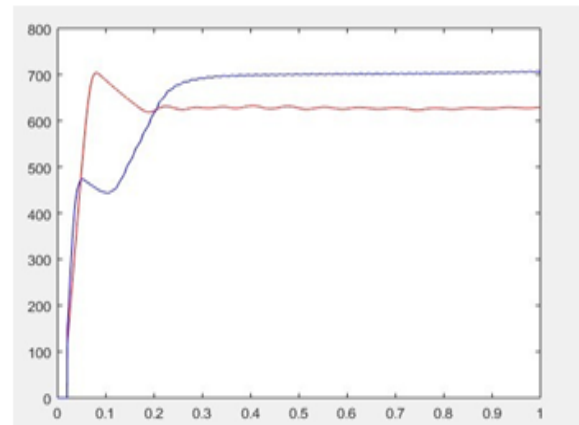

Fig 14. Voltage Outputs from system using Adaptive reference voltage algorithm and adaptive reference PSO based algorithm.

CONCLUSION

It also improves the PV array power efficiency. The power output with adaptive reference algorithm at the load terminal is coming to be 3959 Watts approximately whereas with adaptive reference PSO MPPT algorithm it is calculated to be 4969 watts approximately.

The voltage output with adaptive reference algorithm at the load terminal is coming to be 630 Volts approximately whereas with adaptive reference PSO MPPT algorithm it is calculated to be 710 volts. Thus the system has better efficiency and reliability with adaptive reference PSO MPPT algorithm as compared to simple algorithm.

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