Modelling Analysis of Maximum Power Point Tracking using Extremum Seeking Technique with Application of PV System

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Abstract— Immaculate, bountiful and pollution free source of electricity which turned attention of many researchers has been offered by pv cells. A stability analysis for a maximum power point tracking (MPPT) scheme based on extremum-seeking control has been studied for a photovoltaic (PV) array supplying a dc-to-dc switching converter. The PV output needs to be consistent in terms of voltage, so its output can't be directly fed to electricity bank or to the main grid. Therefore need exists for design of controller. This can extract and calculate the maximum power point from PV array at any moment. PV array usually drives under indistinct/ unclear environmental disturbance and parameters. Here in this paper enhanced extremum seeking MPPT controller is proposed, which has an excellent tolerance of stochastic fluctuations in nature. In the suggested MPPT algorithm, the convergence rate is not pludged by unknown power map as one in conventional ES algorithm. Further the effectiveness of proposed MPPT scheme has been demonstrated using matlab simulations under effect of different irradiations.

Key words: Extremum seeking control (ESC); Maximum power point tracking (MPPT), stochastic fluctuation, P&O (Perturb and observe), IC/Inc Cond (Incremental conductance), MPP (Maximum power point)

I. Introduction

Amid the variety of renewable energy source, solar energy has attracted the rapt attention of various researchers due to its merits like less pollution, safety and its frequent market potential. The photovoltaic (PV) array proved to be widely useful in spacecraft, satellites and solar vehicles as well as for domestic purposes as in houses to deal with peak loads or in rural villages which are not connected to main grid (eg: sagar island, Andaman islands etc).

Maximum power point tracking (MPPT) is a technical device usually used with wind and PV solar techniques to enhance maximum power point extraction under all the conditions (i.e. environmental factors weather input is low irradiance / high).

The hiking growth of embedded technology renders microcontroller based MPPT system a predominating approach in PV systems. Various MPPT algorithm were proposed, in which perturb and observe (PO) and incremental conductance (IC) algorithms were mostly in fashion [6,7] . In perturb and observe algorithm, to monitor the power direction a step perturbation is used in control signal. This PO algorithm can easily be implemented, but having some demerits of oscillating at maximum power point and backs to track in a condition where irradiance switches ON quickly [8]. In IncCond algorithm, rapidly changing irradiance can be tracked, since the maximum power point is tracked comparing the instant and incremental conductance. But because of the usage of low precision sensor error crops up at the maximum power point [9]. To overcome these issues Extremum seeking based MPPT algorithm were used.

The foundations of extremum-seeking control have been found in the early 1920s in the work of Leblanc on the search of the resonance peak of an electromechanical system [16]. In the 1960s, there have been important contributions, among which the works of Korovin and Morosanov constitute the most significant advances [16]. The nonlinear and adaptive nature of such control is clearly shown in [17]. Although there are different extremum-seeking algorithms an important investigative effort should be made in order to establish the stability regions of a great number of reported applications [18].

This technique is well suited for unknown or partially known dynamics in photovoltaic systems. Perturbation signals were useful as a searching signal in ES algorithm, to access the power map gradient, and according to the assessment, control signals were updated.

Simple hardware implementation and variable convergence are the chief merits of ES algorithm [13,18]. In existing ES based MPPT controller, the perturbation signals are presumed as periodic, presumptions may be bit superlative because external disturbances are typically stochastic and unknown. But the orthogonality requirement makes periodic extremum seeking technique much complicated.

II. Modeling of Photovoltaic MPPT System

The PV array ordinarily consists of numerous photovoltaic modules linked to attain the desired output power. The intensity of light variates all the day, which moves the maximum power point to varied current and voltages so an MPPT control system is normally adopted betwixt the load and PV module to adjust the current and voltage, and to maintain the maximum output power. The suggested MPPT based PV control system schematic diagram is demonstrated in Fig 1. In PV panels the solar energy is changed into electrical energy through the photovoltaic effect. The conversion efficiency can be exaggerated by designing the MPPT control system betwixt the load and PV panel. The MPPT control system comprises of DC-DC converter, DC-DC to driver and a MPPT controller.

The suggested Maximum Power Point Tracking system can be either current control or voltage control. In this paper, the MPPT control system is designed with voltage control, which also ensemble the current control. As the converter and DC -DC driver are comparatively grown up in electrical industry, the architecture of control algorithm in MPPT system is a chief function. Several researches were conducted in this field to procure the improvement. Exaggerating the output power with unknown power map against the external disturbance and allocating the convergence speed are the major snags even after the considerable progress in this field.

The boost may be a referred to as improve DC-DC convertor since its output voltage is stepped to a better price. to realize MPPT of the PV panel, the dc-dc boost convertor topology is employed. the pulse generated from the MPPT algorithmic rule is fed to the switch of the convertor.

Boost circuit accommodates a electrical device, high frequency switch MOSFET, diode and a filter across load.

The relation between the load and provide voltage are shown below:

$$V_o = V_s / (1-D)$$

$$D = T_{on}/T$$

Where Vo—Load voltage, Vs Supply voltage

The output voltage of the boost converter depends on the supply voltage and duty cycle.

Where Vo—Load voltage, Vs Supply voltage, D= Duty cycle, Ton = Total time interval.

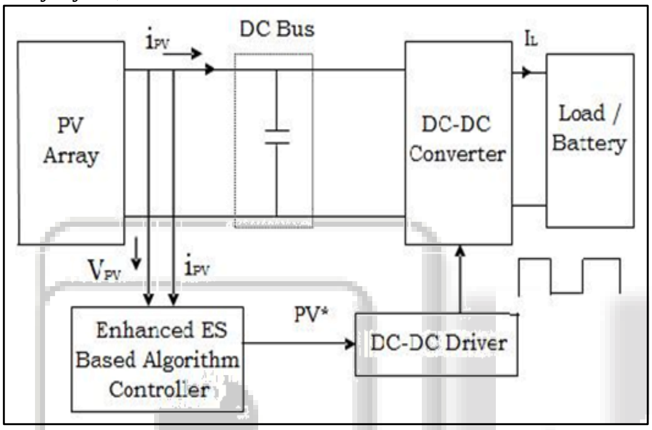

Fig. 1: System Configuration of PV System [19]

III. PROPOSED MPPT CONTROLLER DESIGN

In this paper, we suggest an enhanced extremum seeking MPPT controller to overcome the demerits of the existing ES algorithm. This controller not only possesses the advantages over the conventional extremum seeking method, but also deals with assigning rate of convergence.

An MPPT system repeatedly requires convergence of the controller to be assigned by designer. This can be achieved by the use of the suggested extremum seeking algorithm. After knowing the power map , to find the maximum MPP, the following suggested algorithm can be used

$$dP_{pv}/dt=\{-(d^2f(V_{pv})/dV^2_{pv})^{-1}*(dfV_{pv}/dv_{pv})\} \ ....(1)$$

If the power is not known, at that time estimator is required to roughly access the $df(x)/dx$ and $df^2(x)/dx^2$. The purpose of the suggested design controller is to access the first and second order power map derivatives to achieve the MPPT. We estimate the first order and the second derivative and is denoted as Γ. The first and second order derivative of f is estimated by G =PpvMή and H=PpvNή respectively. When is close to 0,deriving Γ = 1/H is normally difficult. In which the signal generator output are Mή and Nή . In this method, output power is computed after measuring the output voltage and output current. Contingent on the product of stochastic signals and output power, the power map first order derivative and second order derivatives are accessed. It will switch over to the next level, if the criteria is satisfied. Else update the output power by reconciling the output voltage and duty cycle, and go to the next iteration as shown in Fig 2. Tracking efficacy, effect of PV module ageing and effects of partial shading are the major issues to be considered in MPPT controller.

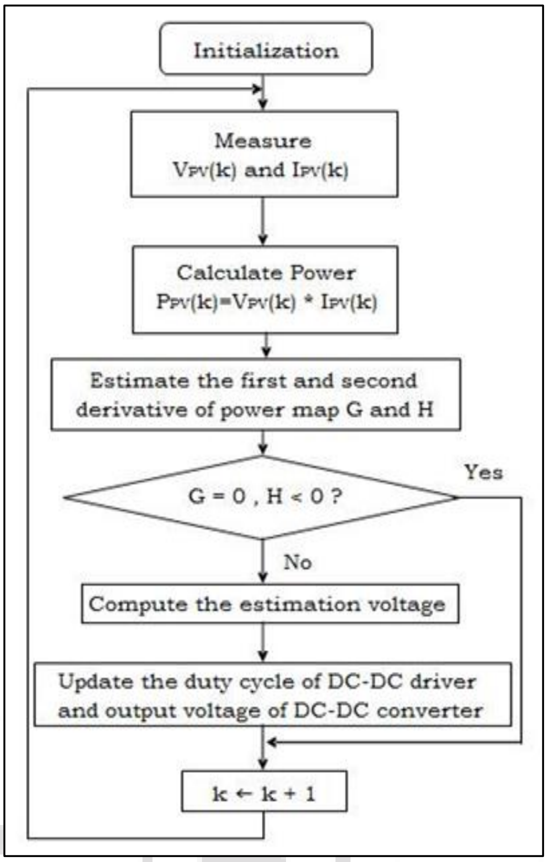

Fig. 2: Flow chart of enhanced extremum seeking MPPT method [19]

Fig 2 shows the flow chart of ESC MPPT technique

With the aid of the following equation (2), the tracking efficiency of MPPT controller can be calculated.

$$ή_T = (\int_0^t P_{pv}(t)dt) / (\int_0^t P_m(t)dt \ .... (2)$$

Where Ppv(t) is calculated power that PV array produces under MPPT algorithm & Pm(t)is the maximum power that PV array can produce.

The tracking efficiency discrete n definition can be as denoted as in equation (3), in which represent the number of channels.

$$ή_Γ = 1/n \sum_{k=0}^{Γ} (P_{pv}(k)/P_m(k)) \ .... (3)$$

The MPPT overall performance is evaluated by the tracking efficiency as well as efficiency of boost converter. Further we have to consider the following factors before evaluating and designing of PV array

IV. EFFECT OF PARTIAL SHADING

The fast development of photovoltaic integration in buildings, the partial shading effect has turned much engrossment in the MPPT controller. As the photovoltaic array is installed on rooftop, due to clouds and space circumspections and also shadings due to local instruments(ie shading of adjacent panels and soon.) it suffers from partial shading. When subjected to partial shading, the photovoltaic system often illustrates severe local and global extremums. So despite tracking power map global MPP, the MPPT algorithm is suggested to have a global convergence in the controller ie. is locally stable at MPP implies that it will get ambushed in local extremums and for photovoltaic systems under partial shading thus might not be a good option.

A. Effect of PV Module Ageing

Lifetime and reliabilities of photovoltaic modules are the chief factors in PV systems performance and are predominated mainly by the effect of PV module ageing. To isolate the effect of ageing from the temperature and irradiance, it is must to evaluate the performance at the very start .The deviation between these elaborates the PV system ageing. Here we have designed the PV module in such a way so that for different values of irradiations (ie for a particular value of irradiation the given module even under the effect of shading also will give its maximum output from the value of irradiation which is instant on a particular module.) in such a way. The proposed MPPT algorithm won't call for model information and with real time measurements it optimizes the power map. Thus the proposed PV module can cope the effect of ageing well.

Thus we see that to most of the extent the proffered model can cope the effect of ageing as well as partial shading.

V. RESULT AND PERFORMANCE EVALUATION

The cogency of the proffered algorithm is proved by the results obtained from simulation. The light source obsessed photovoltaic maximum power point tracking system has been adopted, to evaluate the performance of the proffered tracking MPPT algorithm under unsought irradiance. The PV panel converts solar energy into electrical energy by the use of principle photovoltaic effect. The DC-DC converter and its output voltage regulation are driven by MPPT controller. The result and performance of the proffered algorithm is evaluated under uniform and non-uniform irradiance respectively.

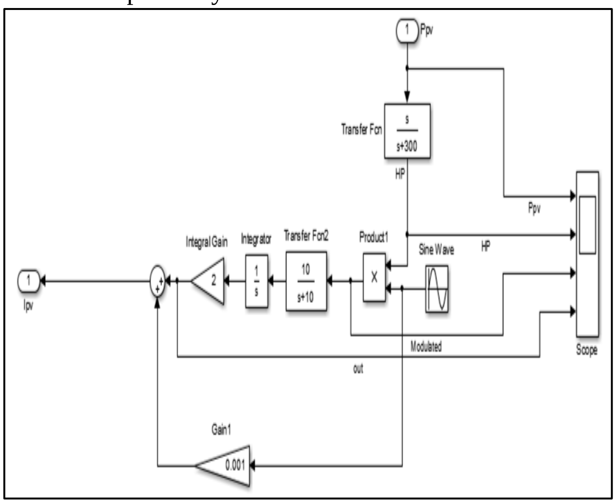

Fig. 3: Shows Esc Mppt simulation block

A. Tracking Performance Under Uniform (Ossified) Irradiance

The tracking performance of the proffered controller under uniform irradiance is mediated in this section. The simulations of the enhanced extremum seeking control algorithm have been carried out in MATLAB/ Simulink.. Fig 3 show that proposed MPPT matlab model. In this model 6 pv module is used connected in parallel. Each module have 85 watt power. The total power is 510 watt. There is ESC MPPT technique is used for traking maximum point tracking.Boost converter is also used for increase the efficiency. The output converges to the maximum power point. In the stabile state, the output power is 505 W, while 510 W is the topmost power of photovoltaic module. The tracking efficiency of the simulated enhanced extremum seeking algorithm is about 95.5 %.

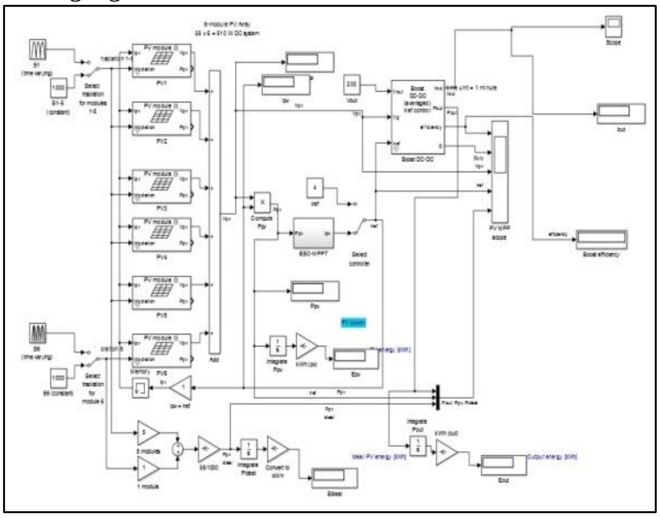

Fig. 4: Proposed MPPT MATLAB model

The tracking performance of the proposed and the existing MPPT methods have been correlated in terms of convergence time and tracking performance. In the existing ES MPPT method forfeit only 92% of efficiency and its convergence is more than 6 seconds, but in the proposed MPPT ie. enhanced Extremum seeking control technique 95.5% of efficiency can be achieved with convergence time less than 5 seconds.

B. Tracking Performance Under Non-Uniform (Non - Ossified) Irradiance

In this section, under non-uniform irradiance the tracking performance of the proffered algorithm with abrupt changes is accessed. In order to demonstrate the effectiveness of the suggested MPPT system more instinctively, the statistical comparison betwixt the existing extremum seeking and the proffered extremum seeking algorithm is shown in Fig 5and Fig 6. Shows the output graph of ESC MPPT sub block.

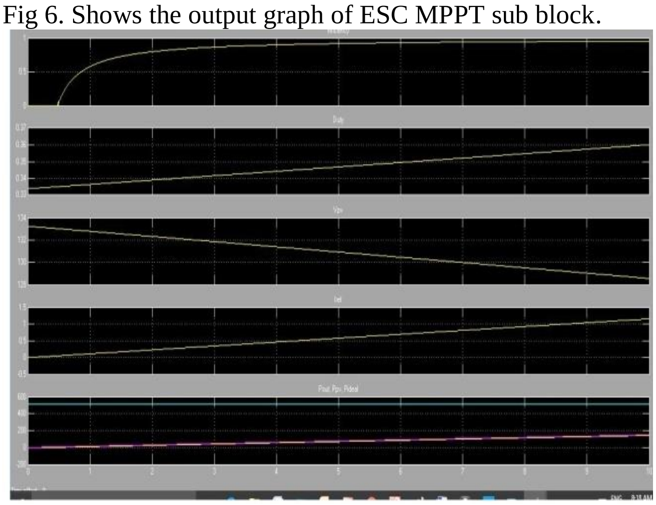

Fig. 5: Output graph of overall model

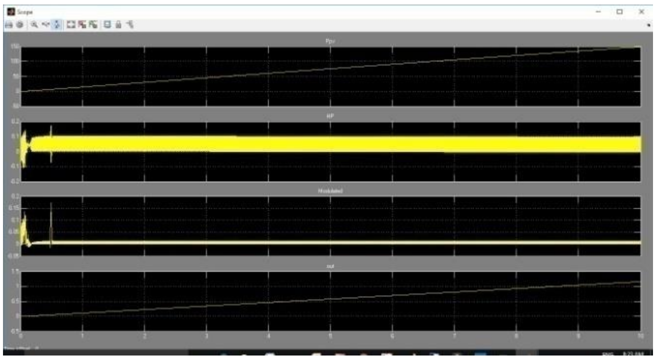

Fig. 6: output of ESC MPPPT block

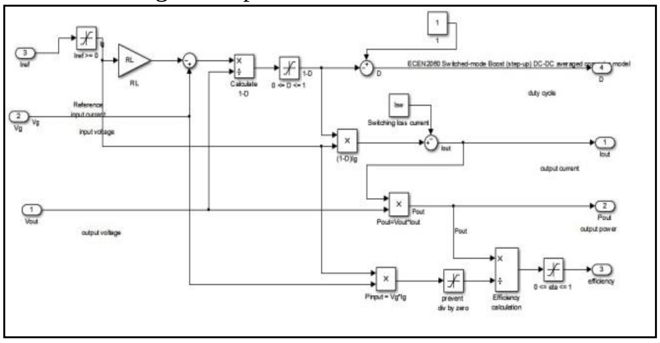

Fig. 7: Simulink model of boost efficiency circuit

VI. CONCLUSION

Extremum seeking is a promising extraction maximum power point from photovoltaic module. In this paper, we suggested an improved enhanced extremum seeking MPPT for PV system. The proffered algorithm will not call for power map knowledge, and it possess an advantage of good tolerance of convergence rate and stochastic fluctuations. The convergence and stability of the enhanced extremum seeking MPPT algorithm is proved strictly. The application related topics like PV module ageing and effect of partial shading are also explained. The result provided for tracking efficiency and convergence time of the proffered MPPT algorithm proves its efficacy. (Fig 8 showing Iout ie output current after boost circuit)

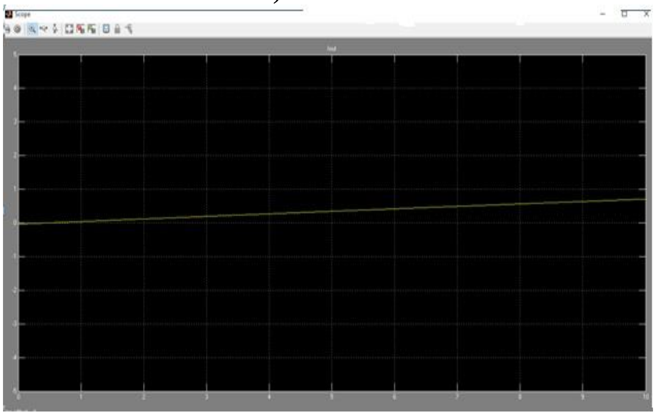

Fig. 8: Sshowing Iout ie output current after boost circuit

VII. FUTURE SCOPE

The proposed MPPT technique lays foundation for use of power from PV panels in the form DC only for those applications where we find that conversion of DC into AC is useless (ie in remote areas ,in street lights etc .) One such example is in those places which are isolated from main grid(eg Islands, river basins as in some parts of Godavri and Madhipura districts).Further now a days most of the NGO's are providing only DC based help to isolated areas so that with cheaper rates more and more villages get coverd easily. Also solar E rickshaw can also be considered as one such example, these rickshaws with the help of solar irradiations charges the Dc battery bank and with the help of DC drives movement of vehicles is achieved. Further now a days research is also taking place on pv traction drives. As we know that not only in India but most of the countries in the world the trains move on DC drives and on every track we need to convert HVAC to dc and then movement is achieved.

Thus we can say that the suggested simulation proves to be the basics for most of the pv applications.

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[19] ESC for mppt Recent Advances on Energy, Environment, Ecosystems, and Development A.Senthil Kumar1 , K. Kirubasankar2, Thomas Cermak3 and Stanislav Misak4 1,3,4 Energy for Utilization of Non-Traditional Energy, VSB-Technical University of Ostrava, Ostrava- Poruba, Czech

