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Assessing Productivity for DC Converters in Photo Voltaic Systems

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Abstract - *The Amount of electrical energy generated using Photovoltaic (PV) systems is drastically high when studied. Certain changes may occur in PV arrays when calculated under array configuration, shading effect, solar reflections and temperature control. So, the need to increase the efficiency of power production can only be attained using Maximum Power Point Tracking (MPPT) techniques. Therefore, high productivity of Photovoltaic energy conversion can only be achieved using the proper use of solar arrays and panels must be operated using MPPT. At this level, the solar based panels produce electrical energy at negligible losses and utmost efficiency. This research deals with the behavior of maximum power point tracking over PV based energy systems, linking techniques between buck-boost DC/DC converter and solar panels, and thirdly the performance evaluation of PV generators in severe sunlight and cloudy situations.*

Key Words: Maximum Power Point Tracking Techniques, P&O Algorithm, Solar Panels, Solar Arrays, Power Production Systems, DC-DC Power Converters.

1. INTRODUCTION

To achieve peak power generation and attaining maximum productivity using PV panels is a vital research area [1], [2]. Generally, we know that solar based cells produce variable amount of voltage and current characteristics, and therefore the maximum power point value is solely dependent on environmental temperatures and solar exposures. MPPT techniques are industrialized to record determined power values in flexible climatic changes [3], [4]. Furthermore, PV based panels deploy mono crystalline structure that is organized in a one by one configuration forming 10 W of solar array power. The output power generated using arrays are transformed to DC power when buck-boost converters are connected to it. Also, the DC/DC types of converters are greatest significant devices that are dependent on PV systems, which ultimately convert the DC power output for direct current loads and battery charge.

Interestingly, each and every topology deployed here utilize conjoint DC/DC converter, but with dissimilar MPPT arrangement. Initially, both PV panels were coupled to an integrated MPPT type of buck-boost converter. Secondly, every circuitry section was coupled to a MPPT buck-boost converter in the equivalent PV array alignment.

For evaluating the effects of several connecting types of PV panels, the Photovoltaic panels were smeared by the light rays from a halogen spotter. The halogen spotter in this circumstance was utilize to embody light rays, while the case where particular area of the PV is shielded with a dark entity, this is to signify the cloudy situation. After studying both cases, the voltage and current variations were witnessed. Therefore, final results were matched to outline the MPPT unit layout with precise DC/DC converter for an ideal situation. This research paper evaluates the variations in steadiness, productivity and quality of energy transformation for solar systems in unstable conditions. Specifically, the properties of unreliable irradiation above PV arrays were perceived on two unconventional modeled systems for defining which topology accomplished better output in mutable circumstances. In order to achieve it, two solar energy conversion panels were simulated. By deploying simulation over MATLAB, the effects of MPPT in PV energy conversion were evaluated.

2. THEORITICAL BACKGROUND

When the solar reflections hit the upper surface of Photovoltaic cells, photocurrent and photo-voltage begins to act as a forward diode on an outsized surface. The expression for the current generated as an outcome of the sun light touching on the cell is given as (1) [5].

I = IPH – IS x{exp[q/AkT (V+IRL)]-1}- V+IRS/RSH ....(1)

From the above formula, we imply that parallel circuit resistance, saturation current, photo-current, temperature of PV panel, terminal voltage, load resistance, series equivalent circuit resistance, Bolltzman's constant, load current and diode ideality factor, are indicated by RSH, IS, IPH, T, V, RL, Rs, k, I, and A respectively. The corresponding circuit diagram for a solar panel circuitry is shown in Fig. 1.

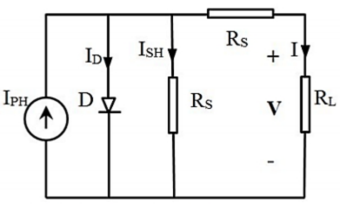

Fig -1: Equivalent circuit diagram for solar panel.

Photovoltaic designed panels, which are embedded with parallel or series coupled solar panels, are electrically encompassed of parallel diodes, current source, parallel, and series resistances.

Furthermore, the phenomenon occurring between the voltage of solar cells and current transferred on the load explains P-V and I-V characteristics of the panel. Relatively, these two characteristics provide imperative suggestions concerning the required conditions for the power assimilated from the panel to spread its maximum level.

Attaining the peak power and accomplishing utmost efficiency level in these panels is an imperative research subject. Generally, solar panels perform like a actual current source whereas, from a definite point of angle, they behave like a voltage source. The value of current accomplished from a solar based panel is well recognized in short circuit.

The determined power point fluctuates based on atmospheric conditions such as; insolation amount and ambient temperature. Most photovoltaic solar panels produce maximum power point at about 25 °C. Insolation value is determined as the sunlight power per unit area. Parameters related to electricity generation in PV panels replicated and evaluated in this research are given in Table 1 and Table 2. Furthermore, Figure 2 also clarifies the P-V and I-V characteristics of this PV panel.

Table 1: Parameters of Proposed PV Array

Module Specification using STC	Parameters Defined
Short Circuit Current (Isc)	5.45A
Open Circuit Voltage (Voc)	22.2 V
Voltage at Pmax (Vmp)	17.2 V
Current at Pmax (Imp)	4.95A
Maximum power at 1000W/m2(Pmp)	85 W

Table 2: Parameters in Practical Setup of PV Array

Module Configuration for STC	Parameters Proposed
Short Circuit Current (Isc)	0.66A
Open Circuit Voltage (Voc)	21 V
Voltage at Pmax (Vmp)	16.8 V
Current at Pmax (Imp)	0.60 A
Maximum power at 1000W/m2(Pmp)	10 W

To gain determined efficiency the solar panel has to be utilized at that point. Peak power formula can be stated by Buck-boost converter, as the name suggests, is a configuration in which voltage declines and upsurges.

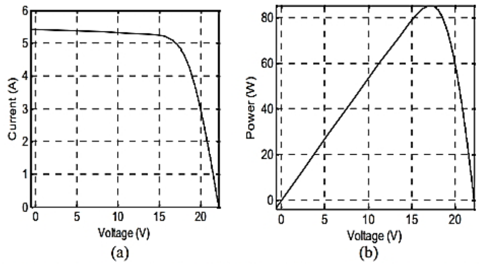

Fig -2: Distinctive characteristics of counterfeit PV array: a) I-V curve, (b) P-Vcurve.

Correspondingly, near the boost converter there seem to be two thump relocations of energy, from the power generator to the electric capacity. The abridged circuit diagram is presented in Fig. 3. Here, input voltage is defined as VS, whereas the output voltage of panel is VO, and is also the load voltage and d is duty cycle, as outlined in Fig.3 [6], [7].

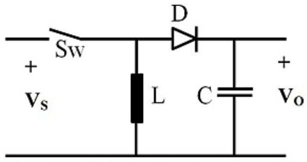

Fig -3: Circuit overlay for Buck-Boost DC/DC converter.

Throughout the switching mechanism; MOSFET module is kept ON, while the inductor receives energy from the input source making the reverse-biased diode disconnected with the load source. In this approach the load energy is delivered by the output capacitor alike the boost converter. When we turn this OFF, the diode (D) becomes forward biased and adopts the inductor current and the saved energy of inductor is conveyed to the load. As the inductance current is in reverse direction, the load too accepts the output current in the reverse direction, dissimilar to the previously acquainted converters. Therefore, the final the buck-boost converter voltage will drive reverse direction in contrast with its input. The transformation of voltage ratio is attained by relating the voltage time balance rule that is expressed from the given equation.

3. PERTURBATION & OBSERVE ALGORITHM

The algorithm Perturbation and Observe (P&O) is widely used in real-world experiments due to its effortlessness benefits. It expedites to mark an assessment via exploring the variations in output power ensuing experimental voltage decrease and increase in PV system. This algorithm is renowned as ‘hill climbing’. P-V curve is utilized in this type of algorithm. The quantity of power change (ΔP) in photovoltaic panel is noticed after a negligible rise. If in the case, the power change (ΔP) value is progressive then functional voltage is amplified once more, enabling the PV panel functioning point to reach its utmost power point. This implies, the final voltage throughput is examined persistently and it is analyzed whether to increase or decrease orientations subsequently when the correlation between power actions and control variable is established. This algorithm and varying values are prearranged in Table 3 [8].

Table 3: P & O Algorithm

Perturbation	Power Change	Next Perturbation
Positive	Positive	Negative
Positive	Negative	Negative
Negative	Positive	Positive
Negative	Negative	Positive

The PV operational point is agitated intermittently by varying the PV system voltage, and therefore by using every perturbation, the control algorithm re-counts the power rates by the PV, prior and afterwards the perturbation. Henceforth, with this technique PV power has drastically improved, leading to better performance of operating point along with MPP. As a result, the succeeding perturbation levied to the voltage will have the similar indication as the former one [9]. The block diagram for employing the Perturb and Observe algorithm for Photovoltaic system is shown in Fig. 4.

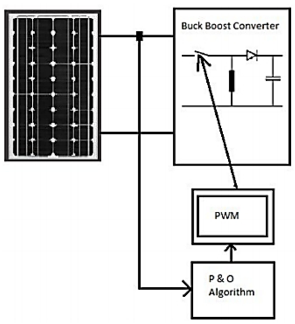

Fig -4: Block for implementing the P&O algorithm in PV system.

Consequently, the terminals of updated voltage perturbation system are found to be reversed; the modification in converter is developed to determine the perturbation of the PV panel's functional voltage.

The elementary P&O structure can be pragmatic for the switching component and for transmitting the PV panel voltage disconcertion. In initial case, it deals with uninterrupted discomposure of the duty ratio of the DC/DC converter power. For second case, the perturbation is investigated with orientation voltage of the duty cycle. Results for this can be perceived from Fig. 4. In this circumstance, the buck boost converter functions in open-loop subsequently in every duty cycle trepidation. Figure 5 explains the flowchart of the P&O algorithm using. The elementary variation of the P&O algorithm operates a steady phase amplitude Δx, which is preferred on the basis of action altercation between constant state and temporary upsurge time [10].

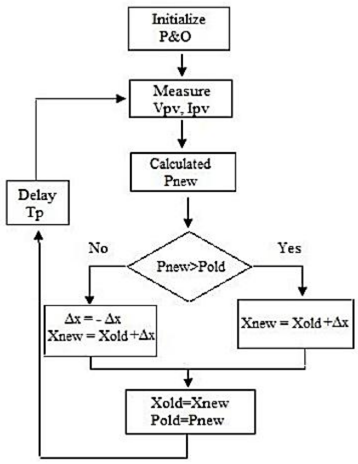

Fig -5: Elementary flowchart for the P&O algorithm [10].

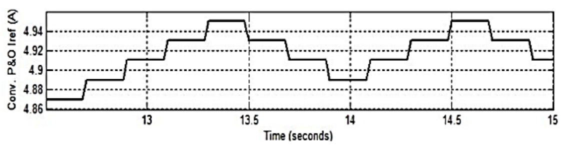

Fig -6: PV training points subjected by the P&O algorithm.

Figure 6 explains the functioning points of the PV field that are laid open to step by step by the P&O algorithm with the same MPPT and perturbing form of the P&O algorithms. Furthermore, The P&O algorithm can be unclear and the functioning point can appear indecisive, irregular or even muddled form [11].

4. STUDYING MPPT EFFICIENCY

Dissimilar preliminary radiation standards were studied for two altered functioning points during the simulations. Firstly, the performance evaluation for persistent reference current was executed without the deploying MPPT. Secondly, the assessment between productivity and output power has been completed with the equivalent case study deploying

MPPT unit. Every simulation is conceded using Simulink model [5] as shown in Fig. 7.

4. 1 Case A - Operating of System without MPPT

It is promising to customize the identical model by interchanging component on-off conferring to the cases using MPPT and those devoid of MPPT. Initially, simulation without MPPT jolts with an illumination value of 1000 W/m2 and then improved to 1050 W/m2 at 50th second. The output results of the simulation without MPPT are shown in Fig. 7.

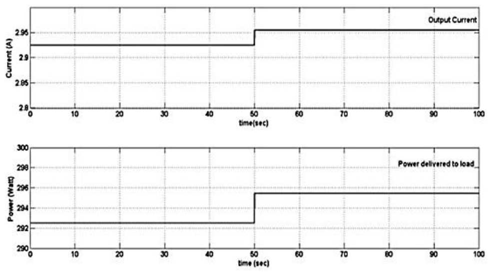

Fig -7: Power and Current Output without MPT.

4. 2 Case B - Operating of System with MPPT

In similar circumstance of anaysis, output currents and powers are evaluated in accordance to current that can be altered using radiance level along with MPPT. P&O algorithm is demonstrated in Matlab coding and the results are displayed in Fig. 8.

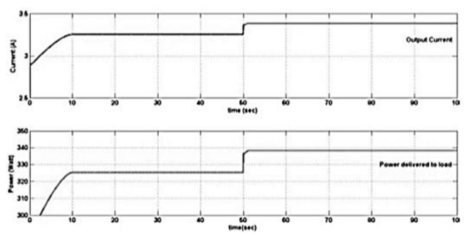

Fig -8: Power and Current Output with MPT.

The assessment of output powers delivers better appreciative results. Primarily, in case of 1000 W/m2 radiance value, load captivated was 292.5 W without MPPT and 325.3 W with MPPT. At 50th second when illumination value was amplified by 50 W/m2; load absorbed 295.5 W without MPPT and 338.2 W with MPPT,

By apprehending the difference in efficiently, final results at dissimilar illumination standards are examined and output is shown in Table 4.

TABLE 4: Output at Various Illumination Ranges

W/m2	Pout No MPPT	ΔPout No MPPT	Pout with MPPT	ΔPout With MPPT	Δ
1000	292.5		325.3		32.8
		3		12.9	
1050	295.5		338.2		42.7

At illumination rate of 1000 W/m2, the difference amongst obtained power with without MPPT is equal to 32.8 W. Subsequently, by growing illumination rate by 50 W/m2, the difference obtained is 42.7 W. The utilization of MPPT surges the productivity as illumination value upsurges.

5. SUGGESTED METHOD

This suggested method comprises of two phases: initially two panels are joined on buck boost DC/DC converter with MPPT [12]. In succeeding stage, every panel is linked to single MPPT and DC/DC converter [13], as shown in Fig. 11. Every stage is organized by P&O algorithm beneath light-available and spectral conditions. The tentative arrangement comprises of four parts. The principal part of the PV panel creates DC energy from temperature and emission. The buck boost DC/DC converter and MPPT yield high power using P&O algorithm. The LED strings utilized for loading in the system is seen in Fig. 9.

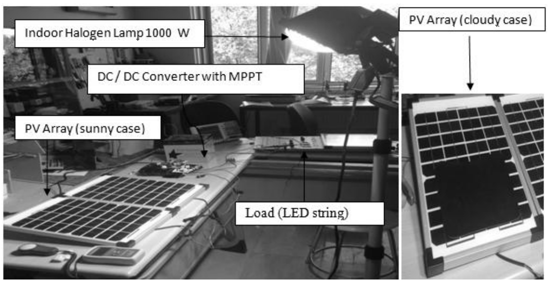

Fig -9: Setup utilizing for observing the final DC power from PV panels under dissimilar lighting circumstances.

6. INTEGRTED DC SYSTEM USING BUCK-BOOST CONVERTER

In main model, the consolidated single MPPT comprising buck-boost converter was associated resolving two PV panels. Here, two PV panels were linked in series. Final power acquired from converters has been attained through two serial coupled panels and LED strings were recovered as a load.

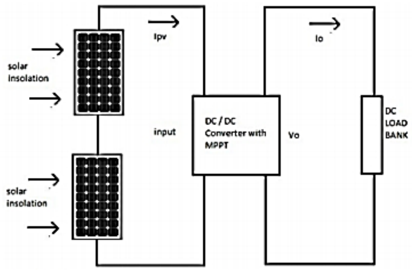

Fig -10: Buck-Boost converter using centralized MPPT.

By observing the final power, the oscilloscope was profited. The topology presented in the figure was showed results for centralized DC with distributed DC system in PV energy generation.

7. DISSEMINATED DC SYSTEM USING BUCK-BOOST CONVERTER

In this phase, the second model was utilized. Nevertheless, there is a one crucial variance in this system every panel was connected to buck-boost converter using MPPT. Final power of this system, with the MPP being presented at every panel, was systematized in the similar pattern as in the first case as displayed in Fig. 11.

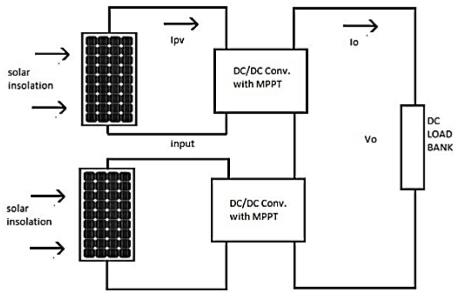

Fig -11: Distributed MPPT with Buck-Boost converter.

To distinguish the variations in the output power of each PV sheet, an obscure object was used, which provided shadowing condition.

8. RESULTS OBTAINED

The employment of the irradiation enacted on each method in discrete light levels, we found that the systems in question were incompatible and therefore evaluated. The final voltage generated by each model is specified in Fig. 12 and Fig. 13.

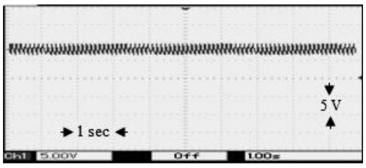

Fig -12: Final voltage for centralized-DC system under sunny condition.

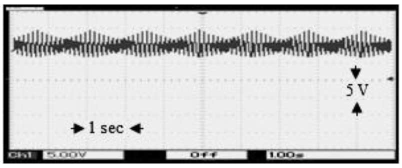

Fig -13: Final voltage for distributed-DC system using PV energy conversion under sunny condition.

Observing two phases of the sunny conditions; it becomes vibrant that the waveforms acquired from either system accomplish a similar tendency. The centralized DC system would be able to react to small and sensitive changes in sunlight during the daytime, without negative enactment problems incurred from sporadic clouding. All experimental cases deployed continuous type of converters as shown in Fig. 12 and Fig. 13.

In cloudy case, each panel was apprehended moderately by an obscure object. Figure 14 and 15 displays the outcome for both systems under the similar conditions. The difference achieved between both systems is remarkable when equated with the sunny environment. Final power of the PVs is typically generated on the irradiation conditions, and the irradiation levels on every panel are different. Every single MPPT unit is to execute according to the MPP of the panel. The oscilloscope views specified in Fig. 14 and Fig. 15 demonstrate that distributed DC system unveils a greater performance when compared to centralized DC system.

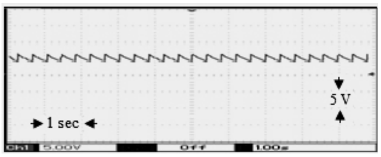

Fig -14: Final voltage for centralized DC system, cloudy situation.

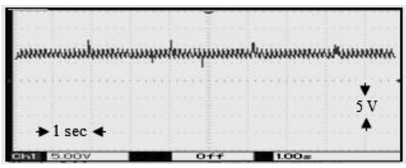

Fig -15: Final voltage for distributed DC system, cloudy situation.

The distributed DC/DC converter when used along MPPT system retorts improvement for changes in the source current of its panels, where every panel reins its final power independently. This point towards enhanced system strength, as possessing a reliable output will protect the other components of the system efficiently.

The Fig. 16 shows both types of unfiltered systems. A more concise vision of the situation enlightened above is demonstrated by both curves fetched together.

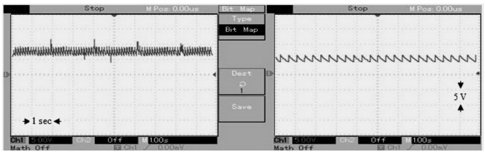

Fig -16: Figure of unfiltered MPPT voltages throughout cloudy condition (a) distributed (b) centralized system.

9. CONCLUSIONS

In this study; MATLAB simulation of adept PV generators, that generates altered output powers, are utilized. In this simulation final power generated is measured and DC/DC converter is made efficient by deploying MPPT and without MPPT. The utilization of MPPT in PV energy conversion systems escalates output power and efficiency. This affects in usage of rarer amounts of panels and cheap cost. The systems for photovoltaic panels, a DC/DC buck boost converters with MPPT, and a variable lighting halogen lamp were experimented. Usage of these tools in two systems was assessed. In the first case, distributed and centralized DC systems were evaluated under mock sunny condition. The results acquired from this case exhibited that distributed DC system had an insignificant advantage over centralized DC system in terms of power generation. However, this negligible difference is to be ignored because distributed DC system would entail more of converters, which would typically require high budget. In the second case, an artificial cloudy condition was generated by the use by using a dark object as a way to cover some part of the PV panel. The results acquired in this situation speckled massively in relation with the first case. The distributed DC system was noted to have a great benefit over the centralized DC system as the output power is dependent on the irradiation level altered on each PV panel.

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