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Survey on Photovoltaic Microgrid with MPPT

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***Abstract*—** Improving the efficiency of MPPT is the major concern with the Photovoltaic (PV) power system. This paper reviews 18 contributions on PV power generating system under MMPT algorithm. The review follows on three categories: Methodology, Performance measure and best performance measure. All these parameters are validated and specified under diagrammatic representation and tabulations.

Keywords*—PV power system; MPPT; MPP; Efficiency; PV energy*

Nomenclature

Acronym	Description
MPPT	Maximum Power Point Tracking
PV	Photovoltaic
GCPVS	Grid-connected PV System
BOS	Balance of System
MPP	Maximum Power Point
THD	Total Harmonic Distortion
ZAP& O	Zero-oscillation, Adaptive step Perturb and Observe
HPO	Human Psychology Optimisation'
MBA	Model Based Algorithm
AMPPT	Analog Maximum Power Point Tracking
FLC	Fuzzy Logic Controller
DLFVR's	Double Line-Frequency Voltage Ripple
SEPIC	Single-Ended Primary-Inductor
GMPP	Global Maximum Power Point
DE	Differential Evolutionary
PSO	Particle Swarm Optimization
DANC	Direct Adaptive Neural Control

I. INTRODUCTION

Solar PV is emerged as a major source on the future energy mix. The modules cost has determined sharply on the last few decades and recently the PV power plants along capacity of MW are considering as the norm in different countries. In spite of this focusing trend, the PV energy per-watt price is yet considerably expensive than the fossil fuel counterpart. Here, the reason is very clear and the capital investment for PV project (with respect to dollar per watt) is mainly greater than the latter. Certain exadditional research works and enhancment efforts are there to enhancing the solar cell performance efficiency. In a GCPVS, PV power [19] [20] [21] deviates with operational constraints, including irradiance, temperature, reduction of sunlight transmittance, light incident angle, on glass of module, as well as shading. The respective factors has examined in detail and the authors from many research work has presented diagnosis models for estimating the minimization of PV power. The more economical manner for enhancing the performance of the PV system.

The installation of PV is concerned as the components of BOS specifically, the respective power converters. The most vital easy way of enhancing the performance is by enhancing the MPPT algorithm. It works because the MPPT includes the software codes, which could be embedded inside of the power converter firmware, in the sense, without any further cost. This algorithm automatically positions the MPP, which are the required operating voltage MPP or current MPP for attaining the maximum output power MPP. Further, the tracking process should be dynamic, which means, the points of operating should be continuously altered with the responsible to the measured irradiance along with the constraints of temperature. Hence, the positioning of MPP is a tedious process since the environ constraints are constantly altering, meanwhile, the curve, P–V proclaims the non-linear characteristics. However, the major drawbacks with this algorithm are oscillations over the optimal operating point as well as the need of array current measurement. Subsequently, sometimes, the researchers have concentrated on the enhancement of MPPT control as well as the minimization of THD. This

paper makes a short review on MPPT PV power generation. 18 papers are reviewed with different parameters like methodology, performance measure and best performance. The rest of the paper is arranged as follows: Section II reviews the literature work. Section III explains the clear research gaps and challenges. Section IV concludes the paper.

II. LITERATURE REVIEW

A. Related Works

In 2013, Paz and Martin [1] have developed and discussed the MPPT algorithm along slope tracking as well as zero oscillation for addressing some technical issues. The developed model has combined 3 models for enhancing the steady-state behavior along with the operation of transient: 1) idle operation on the Maximum Power Point (MPP), 2) Finding irradiance alteration via natural perturbation and 3) a simple multi-level adaptive tracking phase. They have investigated two key elements that figure the basis of developed solutions. Further, ZAP& O model was adopted on the proposed mechanisms for identifying the related data and grants effective gains. the results have shown that the proposed combinations have made the performance very effective with simple implementation.

In 2017, Lei *et al.* [2] have stated that the step-size, was the main factor that defines the performance of MPPT algorithm, which was often intended for the exacting system along some working strategies. In order to solve this, the research work has developed an optimisation algorithm that could automatically adjust the step-size. In this, the tracking process could be transmitted into the maximum series, which was solved through various iteration algorithms. The research work has granted a simple as well as efficient manner on attaining the optimal step-size. After choosing the iteration method, they have decided the MPPT performance. Moreover, the authors have analyzed in terms of convergence order, convergence, as well as stability. Finally, the results have shown that the developed method could grant better stable as well as dynamic characteristic.

In 2017, Caporal *et al.* [3] have developed a grid connected photovoltaic system, which has two phases. the initial phase was the MPPT strategy that was on the basis of variable-step along predictive current control. Then, in the next phase, an reactive/active power control was used for controlling a multilevel inverter for the connection of grid. They have developed the system in Matlab as well as simulated on Simulink to do the validation.

In 2017, Nishant *et al.* [4] have introduced a rapid, effective as well as single sensor based MPP tracking MPPT for partially shaded solar PV system. The authors have proposed a new HPO that was on the basis of psychological states as well as mental states of determined person. Further, the aim of HPO algorithm was the greatest power extraction from PV panel, and the effective supplying of power to the load. The research work has tested through the use of HPO and under MATLAB simulation and has established on the proposed prototype of PV system. Further, as the single sensors were used, the MPPT cost was minimized and because of HPO, the computational saddle was also reduced. Hence, the developed system could be simply executed on the low-cost microcontroller.

In 2017, Berclin and Immanuel [5] have used the MBA as the existing slow iterative MPPT algorithms DMMPPT have failed under the quick deviations in various constraints. This was because of the character leaning nature as well as swift tracking. With the identification of actual behavior of every module, they have implemented a new MBA in compensation power DC-DC converter. Further, they have used a Flyback converter that was on the basis of CPDC converter, which has granted the current compensation or voltage compensation. This was utilized for module operation in its own MPP that was happened even in the mismatching constraints or partial shaded constraints. Since the distinctive module parameters was utilized in MBA were assessed while installation, the avoidance of costly great precision measure was insight in under consumer site. Further, because of the centralized control that was on the basis of LabVIEW , the MBA updating has become more simpler without the alterations in distinctive controllers of PV farms. Finally, the developed model has proven the effective performance.

In 2016, Ramdan *et al.* [6] have proposed a novel maximum-power-pointtracking approach for the PV system, which was on the basis of Lagrange Interpolation Formula. they have also proposed the particle swarm optimization approach. Here, the developed scheme has eradicated the issues of existing approaches through the utilization of easy arithmetical evaluation. This was done for the initialization of the particles over inclusive maximum power point. Thus, the proposed approach would use only less iterations for reaching the greatest power point. next to this, the developed algorithm was analysed with the real world OPAL-RT simulator. At last, the results have shown that the developed algorithm could efficiently improve the stability as well as fast tracking ability.

In 2011, Ahmed *et al.* [7] have developed a modified P&O MPPT approach, which was applicable for PV systems. In this, the introduced technique achieves: adaptive tracking, no steady-state oscillations on MPP, finally the system-dependent constants, so that it could grant generic design core. They have also introduced a

design example through the investigational completion. Finally, the experimental outcomes at various irradiance levels have validated the developed technique.

In 2012, Yang *et al*. [8] have developed a compact-size AMPPT model to grant great power efficiency in PV system. With the combination of conventional MPPT models, the authors have developed a quick as well as accurate tracking performance. Further, they have implemented a wide-range current multiplier that tracks the MPP in power system (solar), which was for identifying the power slope constraints of solar panel. At last the investigational outcomes have proven that the developed technique could quickly track the MPP at high accuracy rate of 97.3%.

In 2010, Fahim *et al*. [9] have proposed an artificial intelligence-based fuzzy logic control approach for the tracking of MPP of a solar PV system on variable temperature as well as insolation constraints as well. The proposed model has used a FLC that has concerned to the dc–dc converter device. The various phases of controller design were offered together along the simulation work. At last, the simulation outcomes of proposed model were compared to others that were attained through the perturbation as well as observation controller. Finally, the outcomes have reviewed that the FLC could exhibit better behavior.

In 2007, Sachin and Vivek [10] have proposed a single-stage inverter topology, greatest performance for PV systems (grid connected). Here, the developed configuration could boost the common less PV array voltage and also has converted the solar dc power to feed into the grid. This was happened during the greatest PV array power. Further, the current's Total harmonic distortion that feed was controlled according to the IEEE-519 standard. The developed topology has various attractive features including best usage of PV array, greatest efficacy, minimum cost as well as size of compact. Furthermore, because of the nature of developed topology, the model has appeared the PV array as the floating source. They have presented detailed investigations by comparing the conventional methods. At last, the total simulation as well as investigational outcomes has also presented.

In 2007, Karlis *et al*. [11] have stated that the MPPTs play a significant role in PV systems as they have maximized the output of power from the system under certain constraints. This could increase the efficacy of array. The research work has developed a new MPPT approach that was on the basis of fuzzy cognitive networks (FCN). Here, the novel approach has granted a best maximum operation of power of any PV array on various constraints including insolation changing as well as temperature alteration. Finally, the outcomes have proven the superiority of developed algorithm.

In 2015, Ahmed and Zainal [12] have developed a new approach for enhancing the efficacy of P&O MPPT through minimizing the steady state oscillation as well as eradicating the prospects of algorithm for losing its track directions. They have also employed a dynamic perturbation step-size for minimizing the oscillation; meanwhile they have introduced the boundary constraints on preventing it from differing away from the MPP. In order to prove the efficiency, the comparison was made with the developed and conventional P&O through the utilization of irradiance tests. Additionally, the performances were assessed on the basis of one-day (10 h) irradiance and the profile of temperature. Then, the algorithm was applied on a buck-boost converter. Finally, it was evident that the developed algorithm could not need any additional hardware components rather could require only few software codes.

In 2011, Tsai *et al*. [13] have presented a power loss comparison work of single as well as two-stage grid-connected PV systems that was on the basis of DLFVR's loss factors. The respective loss factors would produce the deviations in power from MPPs. Here, the authors have considered both the single-stage as well as two-stage grid-connected PV systems. Total impacts on two-stage system were unimportant because of additional MPP trackers, however, the tracker would minimize the effectiveness of system efficiency that to about 2.5%. Finally, the simulation outcomes have confirmed the performance analysis.

In 2008, Jan [14] have presented an impression of the vital research outcomes. The research work has concentrated the operation as well as the stand-alone power systems modeling along PV generators. The PV array–inverter systems along assemblies were discussed and the simulation outcomes that were attained through renewable energy power system were also offered. The respective outcomes have demonstrated that the simulation was the effective step in the process of system development and the respective PV power generators could compose the expensive energy source. The model has the capability on balancing the energy as well as it could supply best power quality. Further, it was reviewed that when the PV array– inverters were operating under stand-alone applications, the model would does the voltages' controlling task as well as the power system frequency. The switching mechanism; the master function among PV array–inverter as well as diesel generator that assembled in stand-alone power system was developed and examined. At last, certain investigational outcomes on real-time system were compared with the simulation outcomes and have confirmed the helpfulness of developed model with the enhancement of renewable energy systems.

In 2013, Ahmad *et al.* [15] have introduced a type-2 FLC the MPPT that could handle the rules uncertainties on greatest deviations in weather constraints. The MPPT engaged SEPIC converter. Further, the novel controller enhances the MPPT search approach by fuzzifying rules. They have offered an accurate as well

as rapid convergence for MPP by the type-2 fuzzy tracker at the time of steady-state as well as deviating weather constraints when compared over existing fuzzy MPPT approaches. Finally, the performance of developed model was established in MATLAB simulation under various operating constraints.

In 2009, Davide *et al*. [16] have presented a batteryless solar-harvesting circuit, which was tailored on the requirement of low-power applications. The harvester does MPPT of solar energy collection on non-stationary light constraints along greatest efficacy as well as minimal energy cost that has exploited miniaturized PV modules. They have characterized the circuit performance in terms of simulation as well as widespread testing under different charging as well as discharging constraints. More attention has prearranged on identifying the loss of power of various circuit components. Finally, the outcomes have shown that the proposed system could attain less power consumption along maximized efficacy and cheapest implementation as well. They have also discussed the enhancement over other conventional models. Along with this, they have analyzed the supercapacitors' behavior.

In 2015, Mohammadmehdi *et al.* [17] have stated that in PV power generation, the partial shading was the inescapable complication, which could effectively minimize the efficacy of general system. In such circumstances, the PV system grant a multiple-peak function. Hence, the reliable technique was needed for tracking the GMPP in a suitable time. The research work has aimed in employing a hybrid evolutionary algorithm named DEPSO model, which was the arrangement of DE as well as PSO for identifying the MPP on limited shading constraints. Here, the research work has started with a deep description under the PV system behavior on partial shading constraint. Then, they have given the detailed description about DEPSO model with MPPT. At last, they have verified the investigational outcome under the proposed model with various partial shading constraints. the outcomes have proven the superiority of proposed model in terms of system-independence, reliability, as well as accuracy in GMPP tracking on partial shading constraints.

In 2015, Anastasios *et al*. [18] have proposed a new DANC approach for MPPT of PV systems. They have concerned a DC/DC buck converter for regulating the PV's output power. This has operated on MPP and has enhanced the solar energy conversion performance even effectively. Further, the online adaptation processes was done on the basis of d rule learning law and the system output error was needed. The major aid of this research work was the simple as well as efficient MPPT solution. They have assessed the direct adaptive neural controller's performance with various characteristics. Finally, the outcomes have shown the efficiency of DANC over other methods.

B. Algorithmic Analysis

This section explains the reviewed methodologies from various contributions. In [1], the authors have developed MPPT algorithm with zero oscillation and slope tracking model. Then in [2], the authors have developed optimisation algorithm for effective PV system. variable-step with predictive current control is in [3]. Single sensor based MPP tracking is the model used in [4]. DMMPPT is proposed in [5]. Lagrange Interpolation Formula is contributed in [6]. Modified P&O is in [7]. The method like AMPPT technique is developed in [8]. Fuzzy logic control scheme is contributed in [9]. Single-stage inverter topology is the main model of [10]. The authors in [11] contributed fuzzy cognitive networks (FCN). Improved P&O is developed in [12]. In [13], single-stage and two-stage grid-connected PV systems are the developed model. In [14], the authors have proposed slave-and-master modes. Type-2 FLC is developed in [15]. In [16], the battery less solar-harvesting circuit is adopted. The hybrid evolutionary algorithm called the DEPSO technique is developed in [17]. A novel DANC method is developed in [18].

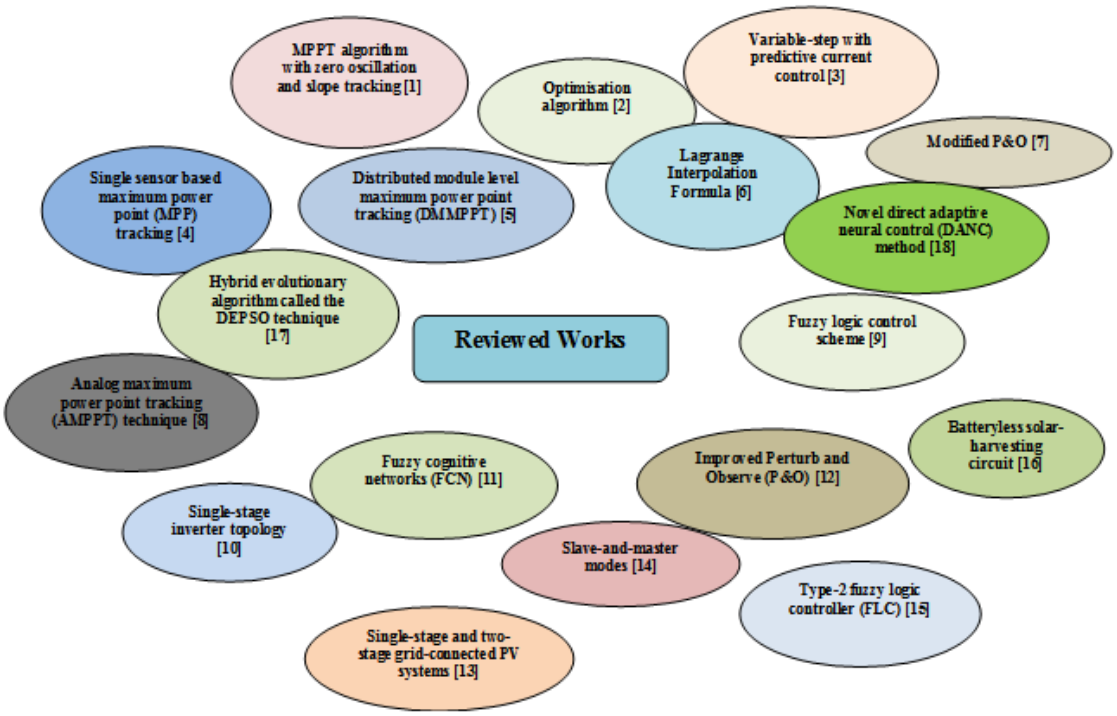

Fig. 1: Algorithmic analysis

C. Performance Measure

The used performance measure of reviewed works is tabulated in Table I. From the table, it is evident that the power measure has used by 60% of total contribution. The stability is the measure that used by 5.55% of the total contribution. The voltage measure is used by 26.66% of total contribution. 20% of contributions have used the charging current measure. Then, the power gain is used by 5.55% of total contribution. The efficiency has been used by 33.33% of total contribution. Irradiance variation measure is used by 5.55% of total contribution. Then some other measures has been used by 26.66% of total contribution

TABLE I. **PERFORMANCE MEASURE**

Citation	Power	Stability	Voltage	Charging current	Power gain	Efficiency	Irradiance variation	Others
[1]								
[2]	✓	✓	✓					
[3]			✓	✓				
[4]	✓			✓				
[5]	✓				✓			
[6]						✓		
[7]								✓
[8]								✓
[9]	✓							✓
[10]								
[11	✓							
[12]	✓					✓	✓	
[13]								
[14]	✓		✓					
[15]	✓		✓	✓				
[16]	✓					✓		
[17]						✓		✓
[18]						✓		

D. Best Performance

The attained best performance measure is given in Table II. From the table, it is evident that the best control efficiency is 62.049, best voltage attained is 19.2V. The best power attained is 1114.72. The output power that attained is 59.09. The best efficiency value is 99.94%. The attained best tracking accuracy is 97.3%, the reduced error rate is 2.5818%. the best panel power is 51.99, respectively.

TABLE II. **BEST PERFORMANCE MEASURE**

Voltage	19.2V
Control efficiency	62.049
Time	1.01,
Power	1114.72
Output power	59.09
Power gain	high
power interrupt	no
Efficiency	99.94
Tracking accuracy	97.3%
Error	2.5818%
Panel power	51.99

E. Invertor Topology

The inverter topology analysis from the reviewed works is clearly represented in Fig 2. From the Fig 2, it is evident that the 73.33% of contributions have worker under the inverters in power generation system and 46.66% of contributions have not worked under inverters in enhancing the PV power system generation.

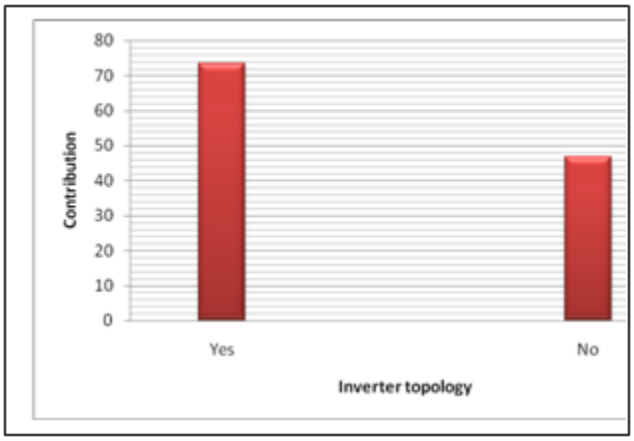

Fig. 2: Inverter Topology analysis

III. RESEARCH GAPS AND CHALLENGES

Even though the advantages of PV system with MPPT tracking concept is reviewed, still some extension is needed in case of tracking huge count of input parameters that are deviating in terms of time like system parameters deviations. To attain accurate MPPT point, the new arithmetical algorithms like Z-infinity algorithms must be implemented. The works under DC-DC converter is restricted only through the concerning of high switching frequency. However, the THD values' output voltage is not enhanced much, and hence some advanced work is needed in this field. Moreover, the filter circuit's configuration must be enhanced in a effective manner. In terms of inverter circuits, most of the problems are suffered on grid tied inverters with respect to grid fails and so on, the customer might not get any supply although there has the generation of power from PV system. This is actually a serious issue and further research work must be takes place in this area.

Further, the models often need the usage of some heuristic algorithm that helps in selecting the optimal parameters as well. Moreover, tracking larger input parameters might comes under the concept of optimal tracking. Advancement in the optimization will be a major constraint in the future work.

IV. CONCLUSION

This research work has contributed a review on 18 papers under the PV power system on MPPT algorithm. The review categorization was done under three aspects: Methodology, Performance measure and

best performance. Some graphical, diagrammatical representations have been made. The values were tabulated as well. Further, a clear research gaps and challenges on reviewed works have also been given.

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