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Global MPPT based on flower pollination and differential evolution algorithms to mitigate partial shading in building integrated PV system

Ahmed A. Zaki Diab [b], Hegazy Rezk [a,b,*]

[a] College of Engineering at Wadi Addawaser, Prince Sattam Bin Abdulaziz University, Saudi Arabia
[b] Electrical Engineering Department, Faculty of Engineering, Minia University, Egypt

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ABSTRACT

The implications of partial shading condition (PSC) on building integrated photovoltaic power system (BIPVPS) and its mitigation is introduced. Tracking global maximum power point (MPP) for BIPVPS during PSC based on the traditional maximum power point tracking (MPPT) algorithms like hill climbing, and perturb & observe is incompetent. Therefore, a global MPPT based on meta-heuristic optimization techniques is an important point of research to increase the performance of partially shaded BIPVPS. This work presents a powerful technique called Flower Pollination Algorithm (FPA) to mitigate PSC in BIPVPS. The feasibility and effectiveness of FPA technique for extracting global MPP are validated with various shadow patterns. For illustrating the capabilities of FPA method, it is compared with other optimization techniques such as differential evolution and particle swarm optimization. The results confirm that FPA ensures exact catching global MPP under different PSC patterns. Moreover, FPA has best performance when compared with the other two optimization techniques.

1. Introduction

Nowadays, looking for different but environmentally friendly resources of energy becomes a must. This is because of the dramatic drawbacks of the conventional fossil fuel energy. Gases, such as CO and CO2, which emitted from the combustion of fossil fuel is negatively affecting the living organs. These gases also deteriorate the Ozone layer, which in turn changes the climate and increases the temperature of the Earth. Additionally and most importantly, its bad effect on the human health especially the pulmonary system. Because of the above, one of the national research projects in worldwide is the field of Renewable Energy. Solar Energy is definitely one of this type. Photovoltaic power system (PVPS) has many merits, such as: pollution-free, little maintenance and noise-free (Rezk and Dousoky, 2016; Rezk, 2016).

For supporting grid-connected PVPS in the world the Feed-in-tariff system (FITS) is created. FITS aimed to encourage investment in renewable energy sector. It is designed for providing price certainty to renewable electricity generators (Murphy and McDonnell, 2017). Fig. 1 illustrated the electricity costs and FIT in Germany as an example. From the figure, it can be see that the feed-in-tariff for PV rooftop up to 10 kW is decreased by 8.9% during the period form 2000 into 2015. In addition FIT for PV free-standing is decreased by 11.2% for the same period.

Recently, there is an increasing interest in using building integrated photovoltaic system (BIPVPS) as a new source of electrical energy. BIPVPS provides energy to buildings. Furthermore, PV panels have been used as structural elements for the buildings. Accordingly, it decreases concentrations of additional weight above ceiling. On the other hand, under implementation feed-in-tariff program, BIPVPS produces enough revenue for paying back cost of PV system (Salam et al., 2015). The Energy Payback Time (EPBT) for a grid-connected BIPVPS system, including PV modules, inverter, and cables, varies based on the type of system and location it is installed in. For monocrystalline panels it ranges from under one year to just above 2 years. Due to more efficient production methods, the EPBT has been cut to less than half of its 1990 figures as illustrated in Fig. 2 (Bhandari et al., 2015).

The problem of how can increase the efficiency of PVPS, has more interesting from the researchers. Moreover, developing materials which can offer a high conversation efficiency at low cost under research. There is a wide range of PV solar cell technologies. Such technologies include; crystalline silicon, thin-film and multi-junction solar cells. The crystalline silicon like mono-crystalline, poly-crystalline, multi-crystalline and ribbon multi-crystalline. The thin-film technologies like amorphous silicon, cadmium telluride (CdTe) and copper-indium-gallium-diselenide (CIGS). Every

* Corresponding author at: College of Engineering at Wadi Addawaser, Prince Sattam Bin Abdulaziz University, Saudi Arabia.
E-mail address: Hegazy.hussien@mu.edu.eg (H. Rezk).

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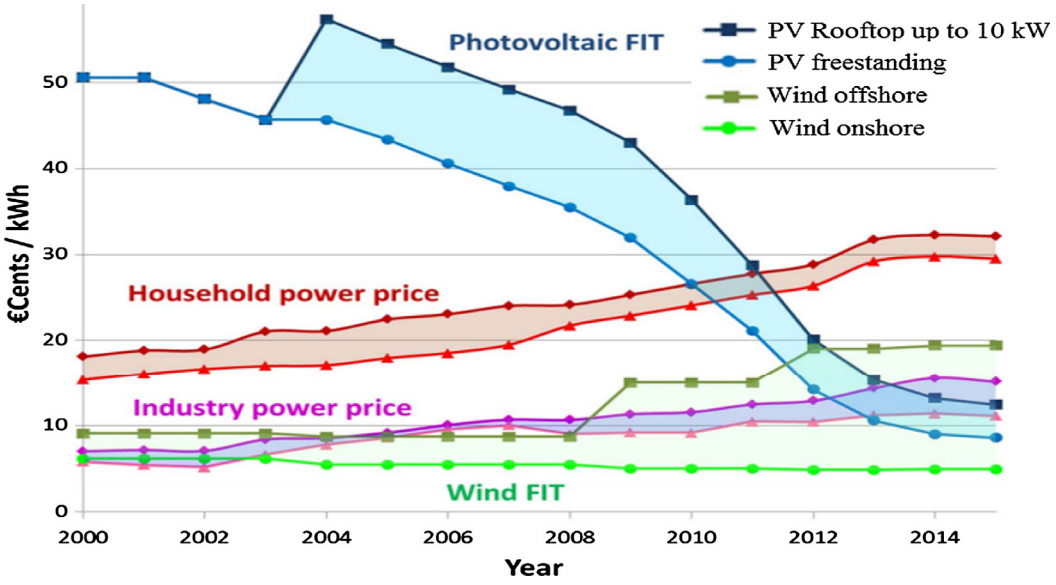

Fig. 1. Electricity costs and Feed-In Tariffs in Germany.

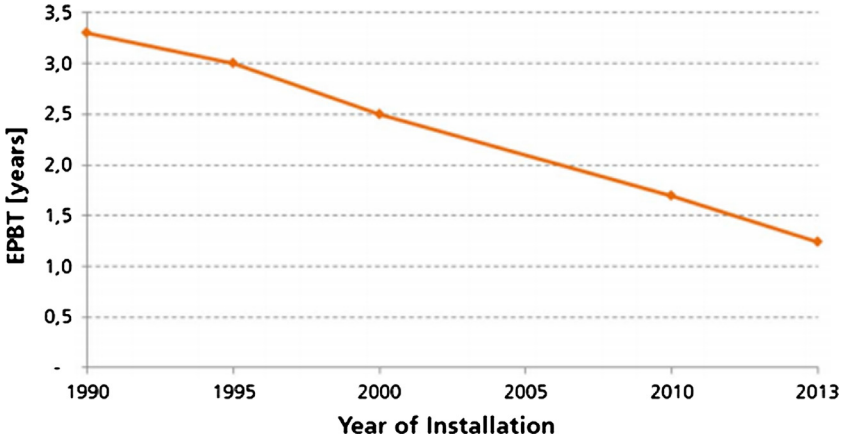

Fig. 2. EPBT of multi-crystalline PV rooftop systems installed in Southern Europe.

technology have different material and processing requirements, leading to distinct emission profiles. Fig. 3 shows the development of solar cell efficiencies during the period from 1993 into 2015 (Green et al., 2016).

Under uniform solar irradiance, the voltage-power curve BIPVPS contains only one maximum power point (MPP) and such point can be easily tracked by any conventional maximum power point tracking (MPPT) method without any problems (Ahmed and Salam, 2014). Many efficient traditional MPPT techniques was conducted to improve the conversion efficiency of BIPVPS without taking the problem of partial shading condition (PSC) into consideration (Ma and et al., 2013). These algorithms include; hill climbing, incremental conductance (INC), incremental resistance (INR), fuzzy logic control, perturb & observe (P&O), and neural network (NN) (Rezk and Eltamaly, 2015; Rezk and Hasaneen, 2015; Rezk, 2016; Salah et al., 2008). The problem occurs under PSC as voltage-power characteristic contains multiple local MPPs and only one global MPP. Therefore, the tracking of the MPP is difficult and the conventional techniques fail in tracking global MPP since they cannot differentiate between global and local peaks. Accordingly, overall efficiency of the BIPVPS decreases. To solve this problem MPPT based on optimization algorithms is required.

The idea of using meta-heuristic optimization techniques for global search is proposed in Karlis et al. (2007), Liu and et al. (2012), Tey et al. (2014), Daraban et al. (2013), Phimmasone et al. (2010), Jiang et al. (2013), Chen et al. (2014), Sarvi et al. (2015), Mirhassaniet et al. (2015), Ishaque and Salam (2013), Liu et al. (2012), Salam and Saad (2013), Yang (2012), Abdelaziz et al. (2016), Rezk et al. (July 2017), Rezk and Fathy (2016), Fathy and Rezk (2016, 2017), Mao et al. (2017), Chao et al. (2015), Sundareswaran et al. (2015), Kumar (2017), Kumar et al. (2017), Koad and Zobaa (2017), Rahmani and Yusof (2014), Seyedmahmoudian et al. (2016), Dileep and Singh (2017), Sridhar et al. (2016), Kofinas et al. (2015), Ahmed and Salam (2015). Such algorithms include; genetic (Daraban et al., 2013) and particle swarm optimization (Liu et al., 2012). In addition, ant colony optimization and cuckoo search (Ahmed and Salam, 2014). They are developed to deal with global MPPT problem. Based on literature study, Flower Pollination Algorithm (FPA) didn't utilize in the field of tracking global MPP under abnormal conditions. FPA has been considered simple in implementation and faster to extract optimal solution in many engineering problems. This encourages us for proposing FPA for dealing with tracking global MPP. It is noticed from the previous studies that some works taken either only single