

A review on development of photovoltaic water pumping system



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ABSTRACT

Photovoltaic (PV) water pumping system has been becoming increasingly important in remote, isolated, and non-electrified population, where either accessibility to the grid is difficult to establish or implementation cost is indeed very high. In such location, PV water pumping application is significant area of interest for sustainable development. In this article, DC and induction motor as part of multi and single stage water pumping system has been reviewed. The maximum power point (MPP) at which PV system is to be operated is tracked by peak power tracker to utilize solar power. Therefore, the peak power tracking algorithms with voltage, current, duty cycle, and frequency as perturbation parameters under uniform and non-uniform insolation are also presented. Review reports on PV emulators used for evaluation of new MPPT control techniques, and microcontroller based implementations of MPPT controller are also presented. Thus, this article becomes reference document for developing DC/AC PV water pumping system.

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1. Introduction

The solar energy is fast gaining importance due to climate change mitigation policies, programmes, and rapid depletion of conventional sources of energy. Government of India, in its Jawaharlal Nehru Solar Mission toward building SOLAR INDIA proposes off-grid solar applications up to 200 MW (2010–2013) in Phase I, 1000 MW (2013–2017) in Phase II, and up to 2000 MW (2017–2022) in Phase III [1]. Environment friendly solar energy is abundant in nature, and most parts of India receive 4–7 kWh of solar radiation per square meter per day with 250–300 sunny days. The solar energy is utilized either in its thermal form or in photovoltaic form. Applications which use the thermal form of solar energy are cookers, water heaters, dryers, water purifiers, etcetera. The lanterns, street lighting, home lighting, and water pumping are few applications which use the photovoltaic form of energy.

Photovoltaic (PV) systems are modular and have a low running cost as no moving parts are involved. PV modules have a comparatively long life and the balance of system (BOS) requires minor maintenance. However, PV systems suffer from a high initial investment cost, low solar-to-electric power conversion efficiency, and non-linear voltage-current ($V-I$) characteristics. Notwithstanding these drawbacks, PV systems have emerged as one of the most potent alternative energy source to grid power supply for feeding stand alone applications.

The major interest in the subject is in reducing the pay-back period in terms of improved efficiency and performance, as well as, reducing the number of components to decrease overall cost. Therefore, researchers have been focusing on three major areas,

- Manufacturing process of solar arrays: many research efforts have been taking place to improve the manufacturing process of PV cells and its material [2–4].
- Controlling the insolation input to the PV arrays: The intensity of insolation impinging on the surface of the PV array is maximized by using sun-tracking solar collectors [5], [6] or by rearrangement of solar cells configuration of PV array corresponds to changes in environmental conditions [7], [8].
- Utilization of output electric power of the solar arrays: efforts are being made to improve effective utilization of solar energy in off-grid / on-grid PV stand alone applications [9–21].

The reasons for reviewing PV water pumping systems in particular are that the grid power supply fed pumps used for potable and irrigation purposes experience four important problems; a. Cost of motor burn outs and its repair due to voltage fluctuations, b. Lower crop yields due to irrigation activities affected by shortages in the supply of electricity, c. Transmission & distribution losses and d. This has been made affordable by utilizing the government subsidies which affects growth in developing countries. Moreover, advancements in design of motors, availability of cost effective high speed digital signal controllers, decrease in the cost of photovoltaic modules, rapid developments in the state-of-art power conversion devices, as well as, topologies of power circuit, and more significantly, the policies of the government have accelerated the growth of PV applications.

PV water pumping system [22–24] is broadly classified as DC and AC motor pumping systems [25]. The DC motor based PV water pumping systems consist of a PV array, with or without an intermediate converter, and a motor coupled with a pump. The AC motor water pumping systems requires a DC-AC inverter for converting intermediate converter output voltage or directly PV voltage in to a variable voltage / variable frequency power source. The intermediate converter employed with a peak power tracking algorithm matches the load impedance to the optimum internal

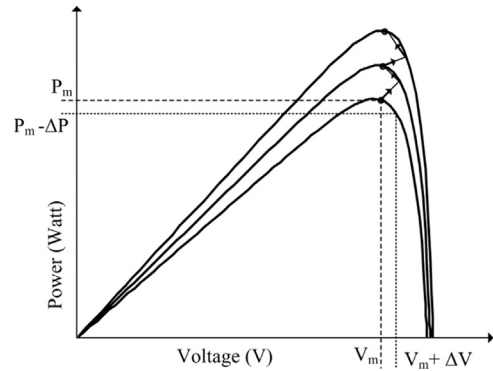


Fig. 1. Effect of perturbation on V-P characteristics and MPP variations.

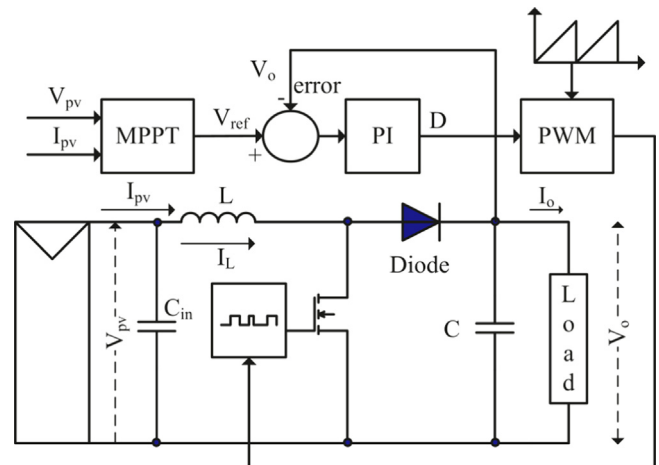


Fig. 2. MPPT Tracking using a DC-DC converter in Voltage Mode Control.

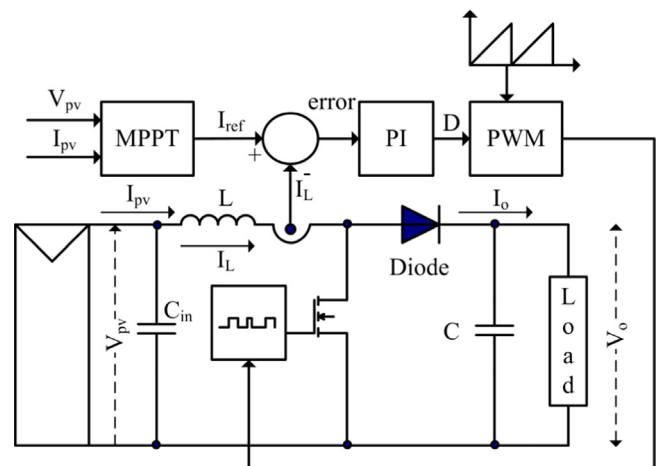


Fig. 3. MPPT Tracking using a DC-DC converter in Current Mode Control.

impedance of the PV array in order to utilize the optimum solar power. The point at which this occurs is called the maximum power point (MPP). The MPP varies for changing insolation and temperature in addition to wind, dirt, etcetera. The dynamic adjustment of the MPP at which the PV system is to be operated to extract the maximum power is called maximum power point tracking (MPPT). This controller is called MPPT controller, and it is implemented invariably with a DC-DC converter and a peak power tracking algorithm. In a parallel development, the induction motor based water pumping system which is referred here as AC water pumping system has found much interest among researchers due

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