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Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies

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ABSTRACT

The deficit in electricity and high diesel costs affects the pumping requirements of community water supplies and irrigation; so using solar energy for water pumping is a promising alternative to conventional electricity and diesel based pumping systems. Solar water pumping is based on photovoltaic (PV) technology that converts solar energy into electrical energy to run a DC or AC motor based water pump. The main objective of the study is to present a comprehensive literature review of solar pumping technology, evaluate the economic viability, identify research gaps and impediments in the widespread propagation of solar water pumping systems and technology. The study focuses on update on solar water pumping technology, performance analysis, optimum sizing, degradation of PV generator supplying power to pump, economic and environmental aspects and advances in PV materials and efficiency improvements. An update on the current state of research and utilization of solar water pumping technology is presented. Factors affecting performance of PV water pumping system, degradation of PV modules and efficiency improving techniques of PV water pumping systems are identified. Solar water pumping is found to be economically viable in comparison to electricity or diesel based systems for irrigation and water supplies in rural, urban and remote regions. The investment payback for some PV water pumping systems is found to be 4–6 years. The recent Indian incentives for PV pumping and policy initiatives for the promotion of solar water pumping in developing countries are also discussed. Potential follow-up research areas are also identified.

Contents

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1. Introduction

Water pumping worldwide is generally dependent on conventional electricity or diesel generated electricity. Solar water pumping minimizes the dependence on diesel, gas or coal based electricity. The use of diesel or propane based water pumping systems require not only expensive fuels, but also create noise and air pollution. The overall upfront cost, operation and maintenance cost, and replacement of a diesel pump are 2–4 times higher than a solar photovoltaic (PV) pump. Solar pumping systems are environment friendly and require low maintenance with no fuel cost [1]. Keeping in view the shortage of grid electricity in rural and remote areas in most parts of world, PV pumping is one of the most promising applications of solar energy. The technology is similar to any other conventional water pumping system except that the power source is solar energy. PV water pumping is gaining importance in recent years due to non-availability of electricity and increase in diesel prices. The flow rate of pumped water is dependent on incident solar radiation and size of PV array. A properly designed PV system results in significant long-term cost savings as compared to conventional pumping systems. In addition, tanks can be used for water storage in place of requirement of batteries for electricity storage [2].

Agricultural production in developing countries is largely dependent on rains and is adversely affected by the non-availability of water in summers. However, maximum solar radiation is available in summers as such more water can be pumped to meet increased water requirements. Urban water supply systems are also dependent on electricity to pump water in towns. There is a wide scope to utilize PV pumping systems for water supplies in rural, urban, community, industry and educational institutions.

In this study, a review of current state of research and utilization of solar water pumping technology is presented. The study focuses on recent advancement of the PV pump technology, performance evaluation, optimal sizing, modeling and simulation, degradation of PV generator supplying power to pump, economic and environmental aspects, and viability of PV water pumping systems for irrigation, livestock and community water supplies in rural, urban and remote regions. The research findings of solar photovoltaic water pumping systems of different configurations are presented for further follow-up research. The main objective of the study is to present current research status, and identify research gaps and impediments in the widespread propagation of solar water pumping technology. The strategy and policy issues for the promotion of PV water pumping are also presented.

The paper is organized as follows: current state of solar water pumping technology is described in Section 2; the literature survey of PV water pumping system studies and research findings are given in Section 3; in Section 4 the viability and initiatives taken are presented. Results and discussion are presented in Section 6. Conclusions are given in Section 7.

2. Solar photovoltaic water pumping technology

2.1. Current state of technology

A SPV water pumping system consists of a PV array, a DC/AC surface mounted/submersible/floating motor pump set, electronics. The PV Array is mounted on a suitable structure with a provision of manual or automatic tracking. Water is pumped during day and stored in tanks, for use during day time, night or under cloudy conditions. The water tank acts as storage and generally battery is not used for storage of PV electricity; however, for specific reliable requirements it can be used. The components

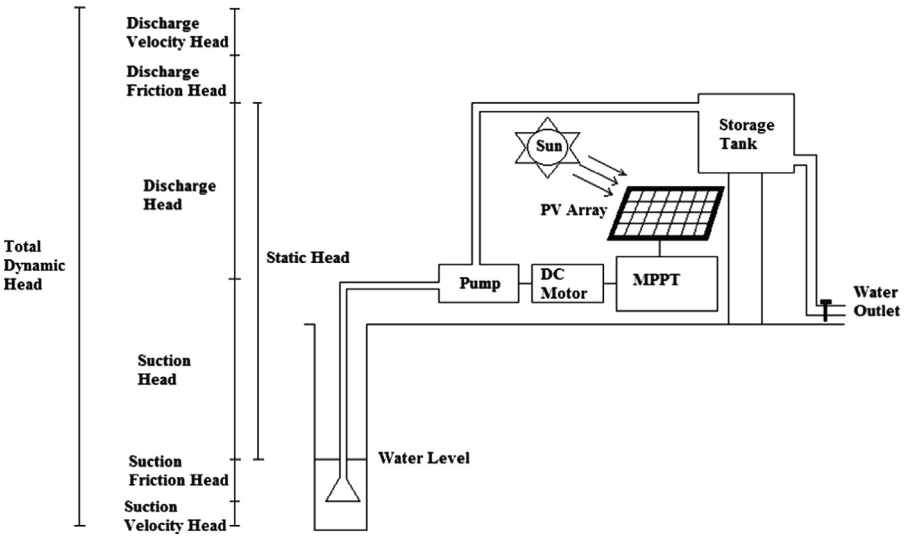

Fig. 1. Schematic of a direct coupled solar photovoltaic water pumping system with MPPT.