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Freshwater Pinch Analysis for Optimal Design of the Photovoltaic Powered-Pumping System

Authors : Iman Janghorban Esfahani

Abstract : Due to the increased use of irrigation in agriculture, the importance and need for highly reliable water pumping systems have significantly increased. The pumping of the groundwater is essential to provide water for both drip and furrow irrigation to increase the agricultural yield, especially in arid regions that suffer from scarcities of surface water. The most common irrigation pumping systems (IPS) consume conventional energies through the use of electric motors and generators or connecting to the electricity grid. Due to the shortage and transportation difficulties of fossil fuels, and unreliable access to the electricity grid, especially in the rural areas, and the adverse environmental impacts of fossil fuel usage, such as greenhouse gas (GHG) emissions, the need for renewable energy sources such as photovoltaic systems (PVS) as an alternative way of powering irrigation pumping systems is urgent. Integration of the photovoltaic systems with irrigation pumping systems as the Photovoltaic Powered-Irrigation Pumping System (PVP-IPS) can avoid fossil fuel dependency and the subsequent greenhouse gas emissions, as well as ultimately lower energy costs and improve efficiency, which made PVP-IPS systems as an environmentally and economically efficient solution for agriculture irrigation in every region. The greatest problem faced by integration of PVP with IPS systems is matching the intermittence of the energy supply with the dynamic water demand. The best solution to overcome the intermittence is to incorporate a storage system into the PVP-IPS to provide water-on-demand as a highly reliable stand-alone irrigation pumping system. The water storage tank (WST) is the most common storage device for PVP-IPS systems. In the integrated PVP-IPS with a water storage tank (PVP-IPS-WST), a water storage tank stores the water pumped by the IPS in excess of the water demand and then delivers it when demands are high. The Freshwater pinch analysis (FWaPA) as an alternative to mathematical modeling was used by other researchers for retrofitting the off-grid battery less photovoltaic-powered reverse osmosis system. However, the Freshwater pinch analysis has not been used to integrate the photovoltaic systems with irrigation pumping system with water storage tanks. In this study, FWaPA graphical and numerical tools were used for retrofitting an existing PVP-IPS system located in Salahadin, Republic of Iraq. The plant includes a 5 kW submersible water pump and 7.5 kW solar PV system. The Freshwater Composite Curve as the graphical tool and Freashwater Storage Cascade Table as the numerical tool were constructed to determine the minimum required outsourced water during operation, optimal amount of delivered electricity to the water pump, and optimal size of the water storage tank for one-year operation data. The results of implementing the FWaPA on the case study show that the PVP-IPS system with a WST as the reliable system can reduce outsourced water by 95.41% compare to the PVP-IPS system without storage tank.

Keywords : irrigation, photovoltaic, pinch analysis, pumping, solar energy
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