Ministry of Higher Education
Valley Higher Institute for Engineering &Technology
Electrical power Eng. Prog.

Design of a PV-Based Mobility Station for Irrigation Applications Considering Egypt's High Solar Potential

1. Overview:

THE RISING energy crises throughout the world and pollution of natural habitats have attracted considerable attention from engineering and science fraternity since a couple of decades. The knowledge for manifestation of renewable energy sources into a useful form has been developing rapidly. The advent of fast switching power electronic devices and the development in semiconductor technology have contributed majorly to energy conversion methods. The renewable energy utilization, which started from converting the energy of running water, has traveled across to convert solar energy to electrical energy directly today. Earlier solar photovoltaic (PV) energy converters have been inefficient, with efficiency as low as 5–6%, and highly expensive However, with the advancement in technological research, the efficiency of a PV array, at present, has reached 15–16%. In addition, the prices have been reducing gradually. Today, PV energy conversion is viewed as one of the promising alternatives to fossil fuel-based electricity generating systems, since there are no toxic emissions, no greenhouse gases emission, no fuel cost involvement, least maintenance cost, no water usage, and so on. However, the technology is in developing phase and many challenges need to be addressed, such as intermittency, high initial cost, and low efficiency. The solar water pumps are gaining popularity in rural areas, where the electricity is not available. Moreover, solar PV fed water pumps are favored in remote areas for irrigation, water treatment plant, and agricultural purposes. For a country like India, where 70% of the population depends upon agriculture, irrigation is necessary for good yield. There are a large number of water pumps in the world running with electricity or with nonrenewable energy sources. The acquisitions of solar PV based water pumping systems are more convenient compared to diesel-based water pumping systems considering the cost and pollution

The mobile solar-powered irrigation system represents an advanced engineering solution designed to enhance agricultural productivity through the integration of renewable energy technologies. This system addresses the increasing challenges associated with rising fuel costs, limited access to electricity in rural areas, and the growing need for sustainable water management practices. By utilizing solar energy as the primary power source, the system provides a clean, reliable, and cost-effective alternative to conventional diesel-based irrigation methods.

2. Concept of the Project:

The project aims to develop a fully mobile irrigation unit that operates using solar energy as its primary power source. The entire system is mounted on a movable platform such as a trailer, tricycle cart, or lightweight vehicle allowing it to be transported easily between multiple agricultural locations. This mobility enables farmers to utilize a single system for several plots of land, reducing operational costs and maximizing resource efficiency.

The system is engineered to pump and distribute water for irrigation without relying on fossil fuels or a national power grid, making it ideal for rural and desert environments where access to electricity is limited.

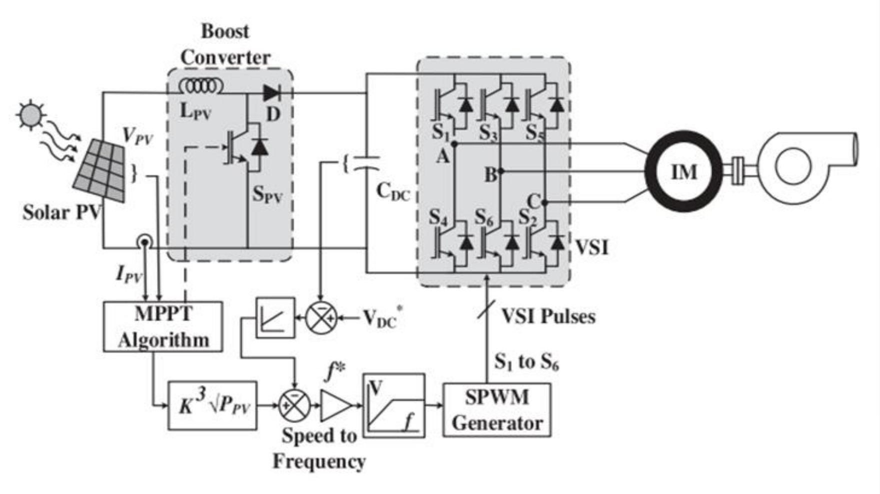
3. System Operation:

The operational process begins with the PV panels harvesting solar energy and converting it into electrical power. This power is directed either to the pump directly or through the battery-inverter unit, depending on the system configuration.

Once activated, the pump extracts water and delivers it through the irrigation network at controlled flow rates and pressures. Automated functionalities such as water-level sensors and programmable timers may be integrated to regulate irrigation cycles and enhance operational efficiency with minimal

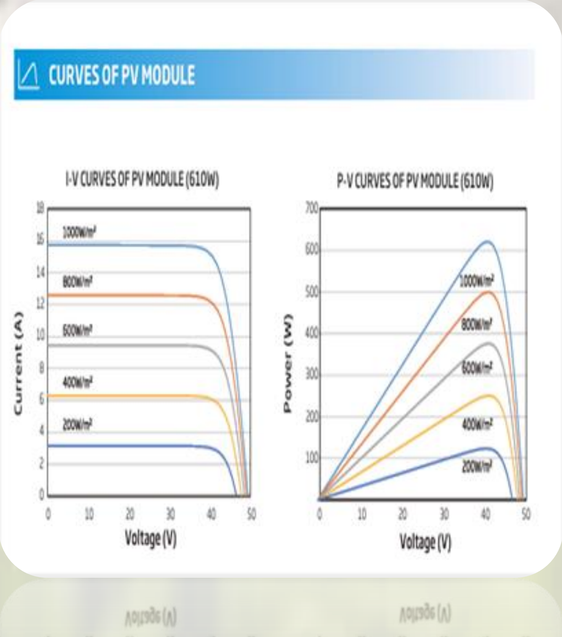
4. Design of System:

The system configuration of the PV water pumping system is depicted in Fig. 1. It consists of a PV array followed by a boost converter. A VSI is used to provide pulse width modulated voltage input to the motor and pump assembly. The power from the PV array is regulated using the O&P method to attain its maximum value with available radiation. The V/f control is used to give reference speed to Induction Motor Drive (IMD).



5.The Efficiency Comparison of Bifacial and Mono-facial Solar Module :

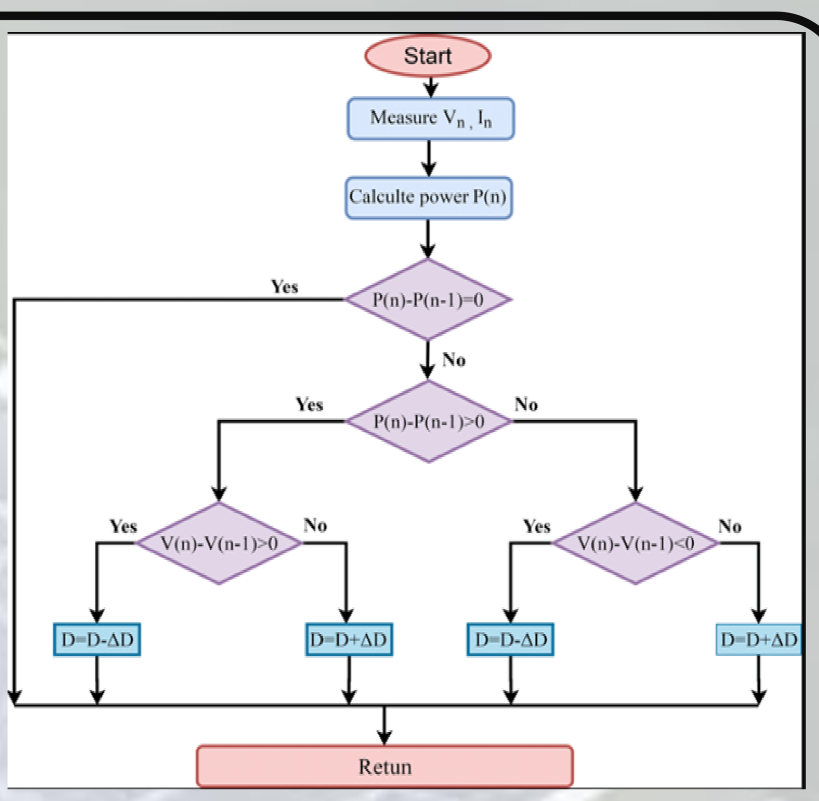
By definition, efficiency represents the measure of the solar cell performance in converting the total amount of incident sunlight into electrical energy. You may assume that bifacial solar cells are twice more efficient than mono-facial solar cells as the solar cell surface area is doubled in bifacial solar cells – but this is yet to be true. A 2018 study by LONGi Solar shows that the efficiency of bifacial solar modules increases only by **11%** over that of conventional solar modules. However, the efficiency of bifacial solar cells can be optimized by integrating a solar tracking system in the solar panel mount structure. This system tracks the sun's trajectory across the sky and continuously tilts the solar panels to maintain a perpendicular orientation for maximum exposure. Through this step, the efficiency may increase up to **27%.** Thanks to higher efficiency, only a few solar panels are needed to give you the same amount of solar power you obtain with a standard mono facial solar panel system. Considering the increasingly competitive bifacial solar panel price against mono facial solar panel prices, consumers with space constraints can go for bifacial solar panels that allow them to achieve maximum efficiency and energy with fewer panels The below table represents a summary of different solar cell efficiencies among the many solar panel options available in the market



6.Maximum Power Point Tracking (MPPT)

Perturb and observe (P&O) method:

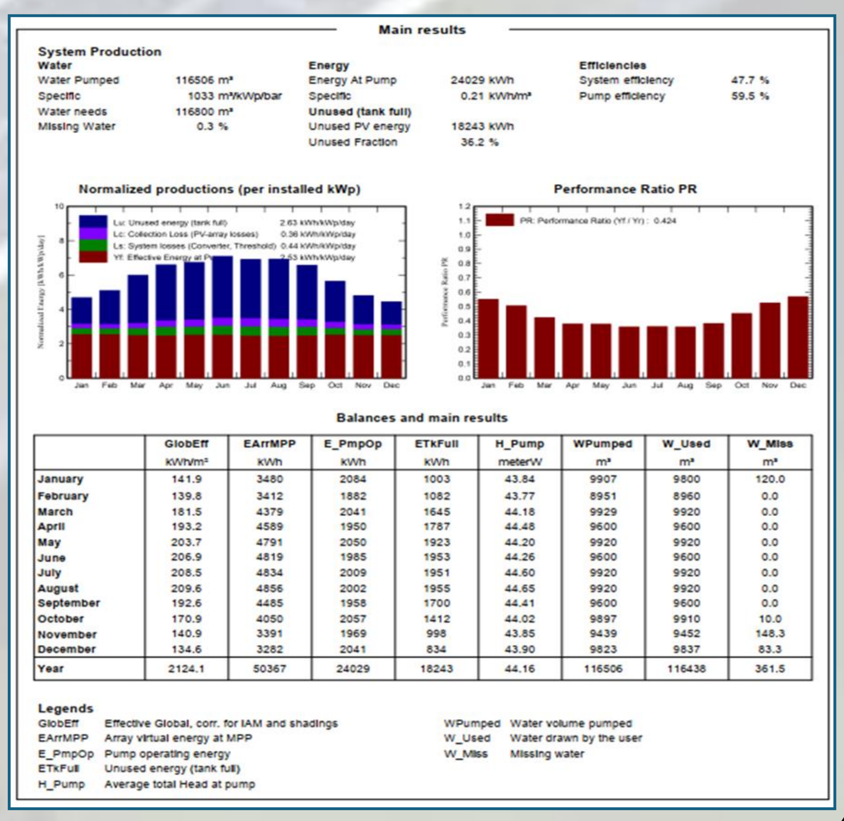
P&O algorithm iteratively perturbing, measuring and comparing the power generated by the PV module until it reaches the MPPT, the algorithm concept is perturbing the operating voltage of the PV array, then observing the effect of this change on the PV generated power. When dP/dV > 0, the operating point is considered to be at the left of the MPP and moving towards the MPPT so the direction of the perturbation is kept in the same direction to achieve the MPPT. When dP/dV < 0 the operating point is located at the right of the MPP and moving away from the MPPT so the direction of the perturbation should be reversed to achieve the MPPT, the MPPT is achieved when dP/dV = 0



7.The Result of PV Syst Program :

PVsyst is one of the most widely used software tools for the design and analysis of photovoltaic (PV) systems. the program is known for its accuracy, flexibility, and user-friendly interface, which makes it a key tool for engineers and professionals in the renewable energy sector.

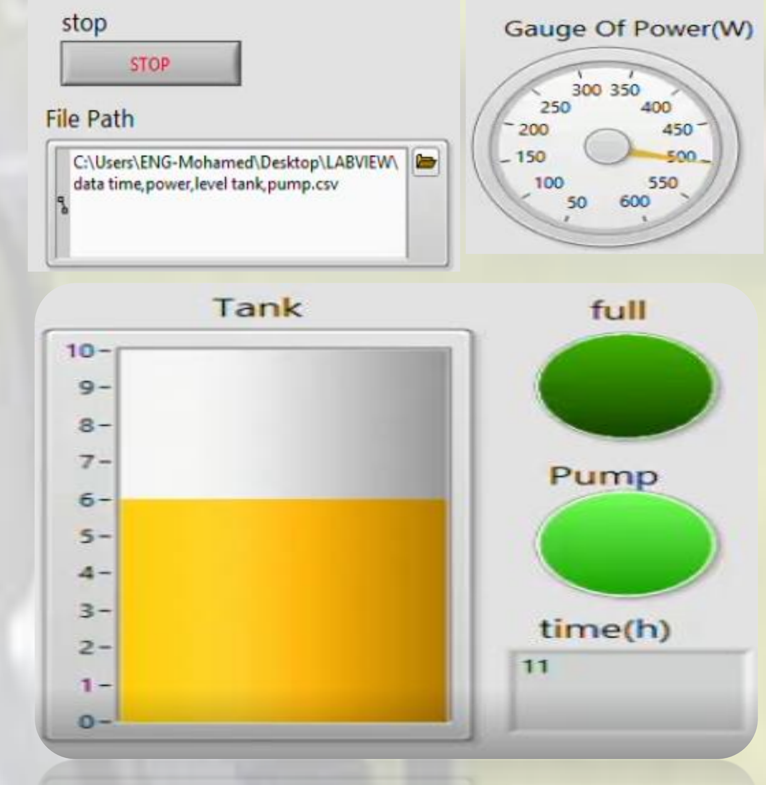
The software provides an integrated environment that allows users to study different types of PV systems, whether grid-connected or stand-alone. It enables the selection of suitable system components, the evaluation of expected energy production, and the assessment of how environmental and climatic factors may affect system performance. PVsyst also generates detailed reports that support technical assessments and feasibility studies with reliable and comprehensive data.



8.Smart Monitoring & Remote-Control using LabVIEW:

This section focuses on the User Interface (UI), sensor integration, and system interaction.

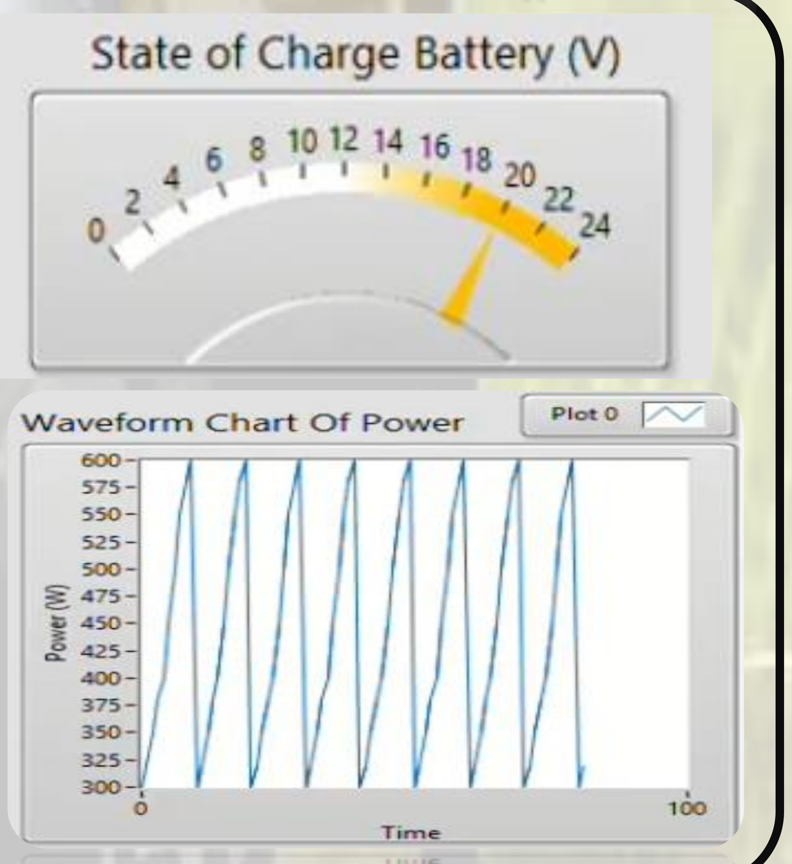
- •Water Resource Monitoring: Live visualization of tank levels to ensure supply continuity and eliminate resource waste.
- •Smart Energy Management: High-precision tracking of battery charge levels and pump status to guarantee safe and sustainable operation.
- •Electrical Instrumentation Panel: Real-time digital gauges for measuring Voltage, Current, and calculating Power **(P = V * I)** with high engineering accuracy.
- •Intelligent Alerts: Integrated LED signaling system providing instantaneous feedback on the system's operational health.



9.Engineering Analytics & Predictive Maintenance using LabVIEW:

This section focuses on the underlying software logic and the strategic value of the system.

- •Predictive Maintenance Algorithm: A smart counter tracks pump activation cycles to schedule maintenance before failures occur, significantly reducing emergency repair costs.
- •LabVIEW Core Integration: Leveraging advanced signal processing to ensure maximum data stability and measurement precision.
- •Consumption Efficiency Analysis: Comprehensive data logging of electrical loads to optimize system performance and reduce energy overhead.
- •Remote Management & Control: Full transparency and accessibility from any location, enhancing administrative efficiency by up to **40%.**



Current

Expected Future

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