Performance of Dynamic Modeling And Optimization Technique of Direct Coupled PV Water Pumping System

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Abstract: Due to insufficient of electricity and escalate diesel costs, the solar energy based water pumping system has emerged as a promising alternative to the conventional electricity. The diesel based water pumping systems used in urban, rural and remote regions to pump water for irrigation purpose and community water supplies. Solar PV water pumping system can provide drinking water without a need for any kind of fuel or extensive maintenance as required by the diesel pumps. Permanent Magnet (PM) Brushless DC (BLDC) motors have been widely used in industrial drives due to their high performance, high torque density and low acoustic noise. The aim of this paper is to develop a dynamic modeling for the design of a PV water pumping system by combining the models of the water demand, the solar PV power and the water pumping system. Solar water pumping is found to be economically viable in comparison with diesel or electricity based systems for the purpose of irrigation needs and water supplies in urban, rural and remote regions. The complete model is simulated using MATLAB/SIMULINK and HARDWARE. The simulated results emphasize the significance of the proposed method to attain the maximum power from PV with minimum motor losses. This paper explains how solar powered water pumping system works and what the differences with the other energy sources.

KEYWORDS – SOLAR PV PANEL, DC-DC BOOST CONVERTER, PMBLDC MOTOR AND WATER SOURCE.

I. INTRODUCTION

A solar-powered pump is a pump that should be running on the electricity generated by the PV panels or the radiated thermal energy available from using solar energy as a power source, such solar water pumps are basically consist of collected sunlight as opposed to grid electricity.

A solar energy-powered water pump is a water pump that will run on the electricity that is generated by the solar photovoltaic modules.

Using solar energy as power source, the solar water pumps are basically consists of three main components:

1) The water pump

2) Solar photovoltaic modules

3) DC-DC boost converter

A water pump basically is an electro-mechanical device that moves water by mechanical action and powered by an electricity generating source, which can be manifold, such as diesel engines, wind power or solar energy. According to water table level, distance to move from the water and the pumping quantity requirements, different type sizes of water pumps should be apply.

The most common and the different types of pumps we use are basically surface-mounted pumps and submersible (deep-well) pumps – as shallow-well water pumping requirements are different from those for deep-well water pumping. In latter situations of wells deep in the ground, it makes much more sense to put the water pump near to the well source in order to basically push up the water.

The water pumping amount requirements, electricity supply and sun irradiance conditions determine the overall size of the PV system and thus the output power and quantity of solar photovoltaic modules needed.

The pump controller is the most important component of the system. It matches the input and output power of the pump and solar panels and it also provides the voltage protection. With the pump controller the operator adjusts the pump pressure, frequency, flow, operational times etc. According to the end user requirements, there are various categories of pump controllers to choose from, depending on the solar pump motors (AC or DC).
Advanced pump controllers come together with the integrated inverter functions and is needed for AC solar pump motors, as well as for network communication functions, which enable off-site supervision and operational adjustment of the solar water pump.

The boost converter is used to improve the output power of the solar panel. The boost converter gives higher output voltage compared to input voltage. Boost converter is a switch mode power supply that contains a transistors and a diode with one energy storage element, capacitor.

II. CIRCUIT DIAGRAM

III. DESCRIPTION

BLOCKS IN THE CIRCUIT
1) Solar panel
2) Boost converter
3) Permanent magnet brushless dc motor

3.1 Solar panel:
A solar panel works by allowing the photons, or particles of light, to knock the electrons free from the atoms, for generating a flow of electricity. Solar panels are actually comprise many, smaller units are as called photovoltaic cells. (Photovoltaic means they convert sunlight into electricity.) Many cells linked together to make up a solar panel.

3.2 Boost converter:
A Boost converter is a switched mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called as step up converter. The name step up converter comes from the analogous to step up the transformer input voltage is stepped up to a level greater than the input voltage.
3.3 Permanent magnet brushless dc motor:

A brushless DC motor is a permanent magnet synchronous electric motor which is driven by the direct current and it accomplishes electronically the controlled commutation system instead of that a mechanically commutation system. Brushless dc motors are also referred as the trapezoidal permanent magnet motors.

Unlike conventional brushed type DC motor, wherein the brushes make the mechanical contact with the commutator on the rotor part so as to form an electric path between the rotor armature windings and a DC electric source, BLDC motor employs electrical commutation with the permanent magnet rotor and a stator with a sequence of the coils. In this motor, permanent magnet will rotates and current carrying conductors are fixed.

The armature coils are switched electronically by a silicon controlled rectifiers at a correct rotor position or by the transistors in such a way that armature field is in space quadrature with the rotor field poles. Hence the force is acting on rotor then it causes it to rotate. Rotor encoders or hall sensors are most commonly used to sense the position of the rotor and are positioned around the stator. The rotor position feedback from the sensor helps it to determine that, when to switch the armature current.

This electronic commutation arrangement eliminates the brushes in a DC motor and commutator arrangement and hence more reliable and less noisy operation is achieved. Due to the absence of brushes brushless DC motors are capable to run at high speeds. The efficiency of brushless DC motors is typically 85 to 90 percent and brushed type DC motors are 75 to 80 percent efficient. There are wide varieties of brushless DC motors are available ranging from small power range to fractional horsepower, large power ranges and integral horsepower.

![Simulation Diagram of PMBLDC Motor](image)

3.4 SIMULATION RESULTS:

![Simulation Results Graphs](image)
IV. HARDWARE MODEL

4.1 Solar panel working and generation of electricity:

A standard solar panel consists of a layer of a metal frame, silicon cells, a glass casing and various wiring to allow current to flow from the silicon cells. Silicon is a non metal with the conductive properties that allow it to absorb and converts sunlight into the electricity. When light interacts with the silicon cell, it causes electrons to set into motion, which initiates a flow of electric current. This is known as the “photovoltaic effect,” and it explains the general functionality of solar panel technology.

The general photovoltaic process, as described above, it works through the following steps:

1) The silicon photovoltaic solar cell absorbs solar radiation.
2) When the sun’s rays interact with the silicon cell, electrons begin to move.
3) Moving electrons creates a flow of electric current, captured by nodes and wiring in the panel.
4) Wires feed this direct current (DC) electricity to a solar inverter to be converted to alternating current (AC) electricity.

In addition to silicon solar cells, a solar panel includes a glass casing that offers durability and protection for the silicon PV cells. Under the glass exterior, the panel has a protective back sheet and a layer of insulation, which protects against heat dissipation and humidity inside the panel. The insulation is important because it will increases in temperature and will lead to a decrease in efficiency, resulting in a lower of a solar panel performance.

Solar panels have an anti-reflective coating that increases the sunlight absorption and it allows the silicon cells to receive maximum of sunlight exposure. Silicon solar cells are manufactured generally into two cell formations: mono crystalline or polycrystalline. Mono crystalline cells are made up of a single silicon crystal and polycrystalline cells are made up of fragments or shards of silicon. Mono formats can provide more space for electrons to move around it and thus offer a higher efficiency solar technology than polycrystalline, though they are typically more expensive.

4.2 Operation of boost converter:

The main working principle of boost converter is the inductor in the input circuit it resists sudden change or variations in input current. When switch is OFF the inductor stores the energy in the form of the magnetic energy and discharges it when the switch is closed. The capacitor in the output circuit is assumed as large enough that the time constant of the RC circuit in the output stage is so high. The large time constant is compared to switching period it ensures a constant output voltage \( V_0 (t) = V_0 \) (constant).

4.3 Operation of brushless dc motor:

BLDC motor works on the principle similar to the conventional DC motor. The Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it will be experiences a force. As a consequence of reaction force, the magnet will experience an equal and the opposite force. In case of brushless dc motor, the current carrying conductor is stationary while the permanent magnet moves.

When the coils of the stator are electrically switched by a supply source, then it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between permanent magnet rotor and electromagnet stator, the rotor continues to rotate.

4.4 HARDWARE RESULTS
CONCLUSION:
A review of this project status of solar PV water pumping system technology research and applications is presented. The study focuses on solar PV water pumping technology, optimum sizing techniques, performance analysis are carried out worldwide, economic valuation, degradation of PV generator supplying power to pump, environmental aspects and efficiency improvement of photovoltaic technology and experience of using solar PV pumps worldwide. Based on the study main conclusions are as follows:

- PV water pumping technology is reliable and economically viable alternative to electric and diesel water pumps for irrigation of agriculture crops.
- PV water pumping for urban, rural and community water supplies and institutions, is another potential feasible sector but is not still widely utilized. The remote in accessible locations with no grid electricity also require a special attention. These sectors still depend on conventional electricity or diesel based pumping system resulting in increased recurring costs to the users.
- Keeping in view the high installation costs of solar water pumps especially for large irrigation and water supplies, more incentives are required to be provided by government to make the technology further attractive to diesel and electrical water pumping.
- Factors affecting the performance and efficiency improving techniques, use of highly efficient PV modules including bifacial modules and degradation of PV generator are areas for further research for lowering the cost, improving the performance and enhancing pumping system life time.

REFERENCES
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