GRID-Connected Solar PV-Based Water Pumping Using BLDC Motor

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***Abstract*— A grid-interactive Solar photovoltaic (PV) fed water pumping system enables a consumer to operate the water pump system using a BLDC motor at its full capacity regardless of the climate condition. To optimize the output power from solar panels MPPT is used. MPPT constantly tracks the Maximum power point of the solar panel and adjusts current and voltage to ensure the panel operates at maximum power point it also helps with power factor correction and improves the overall efficiency of the system. The energy supply from the solar cell or from a grid (in the absence of solar energy) feeds the BLDC motor through a Voltage source inverter (VSI). The VSI operated at the fundamental frequency, which minimizes the switching losses. Instead of the Induction motor, the BLDC motor is used in this system because of its high efficiency, high power density, higher torque at low speed and longer life span**

***Index Terms*— Power flow control; Solar photovoltaic; Brushless DC motor; Voltage source converter; Voltage source inverter; Maximum power point; Power quality; Power factor**

I. INTRODUCTION

Now the use of renewable energy sources is very important, the use of renewable energy sources can help to reduce carbon emissions and mitigate climate change. Renewable energy sources can provide a more secure source of energy than fossil fuel and this can help reduce dependence on non-renewable sources. Solar energy is an important part of the transition to a more sustainable and resilient energy system. It offers a sustainable source of energy that can help to improve energy security and lead to cost savings for consumers. The water pump has gained broad attention in the last few decades as a crucial application of PV energy. Initially, induction motors are used to drive the pump but the BLDC motor drive is used in this system because it offers high efficiency, low maintenance, and precise speed control. It is the type of motor that uses electronic commutation instead of brushes, making it more reliable and efficient than a brushed DC motor. BLDC motors are also able to provide high torque at low speeds, making them ideal for pumping applications. It has been determined that introducing this motor reduces the cost and size of PV panels in addition to improved performance and maintenance free working.

Being a standalone system, the BLDC motor driven water pumps fed by solar panel only. Due to its intermittency, the solar generation exhibits its major drawbacks, which result in unreliable pumping systems. In bad climate condition water pumping May interrupted, and the system is underutilized as the pump is not operated at its full capacity. Moreover, an unavailability of sunlight leads the shout down of the water pumping system.to overcome these difficulties a utility grid is connected to the system. BLDC motor is connected at the common DC bus of PV array and grid connected to the inverter. Here no battery storage is used; a service life of the system is thus improved. And maintenance and manufacturing cost are reduced. However, the developed control enables unidirectional power flow from grid to BLDC motor. So the system is a kind of hybrid power, in the absence of solar energy the supply fed from the utility grid so no interruption. It can also be converted to bidirectional system. The excess of energy during the pump is not working can be feed to the utility grid. But here concentrated in how the efficiency of the system improved and how solar energy can use effectively.

The MPPT (Maximum Power Point Tracking) of the PV array is achieved by the incremental conductance method. Incremental conductance is a popular algorithm used in MPPT systems. It helps to maximize the power output of a solar panel by varying the

voltage and current to find the optimal operating point (Maximum power point). The incremental conductance method algorithm works by comparing the current power output of the solar panel to the previous power output. If the current power output is higher than the previous power output, the algorithm increases the voltage slightly to see if the power output continues to increase. If the current power output is lower than the previous power output, the algorithm decreases the voltage slightly to see if the power output increases. If the power output remains the same, the algorithm stops adjusting the voltage the incremental conductance algorithm is able to track the MPP of a solar panel quickly and accurately, even in rapidly changing conditions. It works by calculating the derivative of the power output with respect to the voltage, or dP/dV. When dP/dV = 0, the solar panel is operating at the MPP. The incremental conductance algorithm constantly calculates dP/dV and adjusts the voltage to keep it close to zero.

The magnitude of stator current of BLDC at starting is controlled by operating the voltage source inverter in PWM (Pulse width modulation) mode for a predefined duration. However once the motor is started, the VSI is operated with the pulses of fundamental frequency resulting in a minimized switching loss and an enhanced conversion efficiency.

II. COMPARISON BETWEEN EXISTING SYSTEM AND PROPOSED SYSTEM

a. The main difference between existing system and proposed system is, in proposed system we using MPPT technique using Incremental method to improve the production of Solar energy.

b. Instead of Induction motor a BLDC motor used in proposed system so it reduces the cost and size of PV panels in addition to improved performance and maintenance free working.

c. In proposed system when the output of solar panel is below some certain (6 V), BLDC motor system is automatically connected to Grid

III. OBJECTIVES

a. The BLDC motor is connected to the Utility grid with proper bridge mechanisms in order to develop a reliable operation of the water pumping system.

b. By using MPPT is achieved by Incremental conductance technique, Maximum power output generated from solar panels and improved efficiency

c. The proposed system is designed and controlled such that it's also continuous to operate the BLDC motor and delivers water. in case of grid failure. The volume of water delivery then depends on the available solar radiation.

d. The three-phase VSI, feeding the BLDC motor is switched at the fundamental frequency. This results in a considerable reduction in the switching loss associated with the said VSI.

IV. PROPOSED SYSTEM

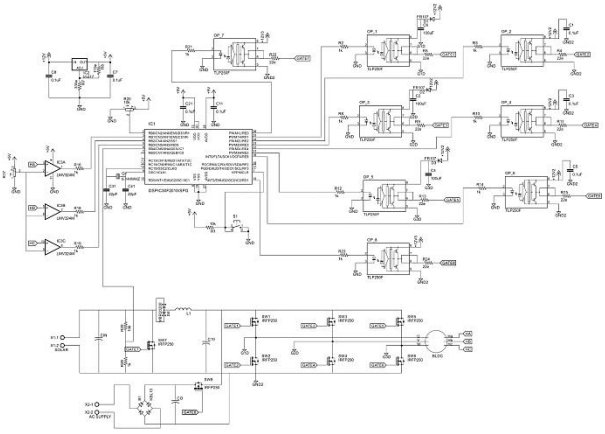

Fig.1 – Schematic Diagram of Proposed System

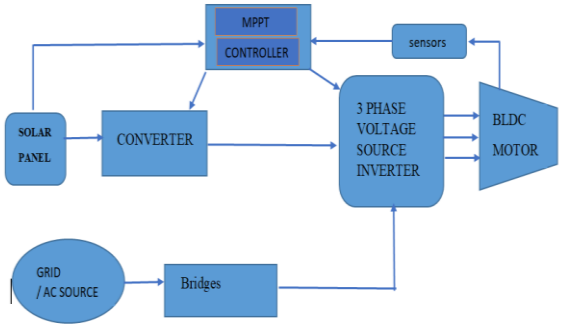

Fig. 2 – Block Diagram of proposed System

A. Solar Panel (PV)

Solar panels are a combination of photovoltaic cells, which convert solar radiation into electrical energy.

PV cells are made of materials that generate electrons when exposed to light. The electrons flow through a circuit and produce direct current (DC) electricity, which can be used to supply power to the BLDC motor. The output power of the PV panel depends upon solar radiation

B. MPPT Controller (Maximum Power Point Tracking)

Maximum PowerPoint Tracking is a technique used in photovoltaic (PV) solar systems to optimize the amount of power that is extracted from the solar panels. The maximum power point (MPP) is the point on the current-voltage (IV) curve of a solar panel where the panel can produce the most power for a given level of sunlight.

The MPPT technique involves continuously tracking the MPP of the solar panel by adjusting the voltage and current at which the solar panel operates, to ensure that it always operates at the optimal point for maximum power output. This is achieved through the use of a dedicated electronic device called an MPPT controller and its achieved by the incremental conductance method

C. Boost Converter

A boost converter (step-up converter) is an electronic circuit that converts a low-voltage DC input to a higher-voltage DC output. the conversion is achieved through the use of an inductor, a switch (MOSFET), and a diode. The boost converter works by first storing energy in the inductor when the MOSFET is turned on, and then releasing that stored energy to the output when the MOSFET is turned off. This process of energy storage and release causes the voltage across the inductor to alternate between positive and negative, creating a stepped-up voltage at the output.

D. Three Phase voltage source Inverter (VSI**)**

A three-phase voltage source inverter (VSI) for a brushless DC (BLDC) motor converts a DC voltage input to a three-phase AC voltage output which is used to drive a BLDC motor. BLDC motors require a specific sequence of three-phase AC voltages to be applied to their stator windings in order to generate a rotating magnetic field, which in turn causes the motor shaft to rotate. The three-phase VSI provides this sequence of voltages by switching the MOSFET on and off in a specific pattern at a high frequency

E. BLDC Motor

A Brushless DC Electric Motor (BLDC) is an electric motor powered by a direct current voltage supply and commutated electronically instead of by brushes like in conventional DC motors. The magnitude of the stator current of BLDC at starting is controlled by operating the voltage source inverter. the BLDC motor drives the pump impeller to create the necessary flow or pressure. The motor controller typically uses feedback from sensors such as Hall Effect sensors to determine the motor speed and position

F. Hall Effect Sensors

Hall Effect sensors are used to provide feedback on the rotor position and speed. sensors is typically mounted on the stator and detect the position of the rotor magnets as they pass by the sensor. The sensor provides an electrical signal that is used by the motor controller to determine the position of the rotor and control the commutation of the motor windings

V. WORKING OF THE SYSTEM

When sunlight hits the PV panels, it generates DC electricity that the inverter then converts into AC electricity to supply power to the BLDC motor. The motor operates the pump, which extracts water from a source such as a well, borehole, or reservoir and transports it to a storage tank or distribution system. The MPPT controller is used to optimize the power output from the solar panel by monitoring the voltage and current of the panels and setting an operating point that maximizes the power output. The Three-phase Voltage inverter is controlled by the controller circuit, which receives feedback from the BLDC motor. The system can also be connected to the grid to supply power to the BLDC motor when solar radiation is insufficient. To convert the AC grid power to DC, a bridge circuit with MOSFET

VI. ADVANTAGES, DISADVANTAGES

Advantages:

1. Energy efficiency: BLDC motors are more energy-efficient compared to traditional motors.

They can deliver the same flow rate with lower power consumption, resulting in lower energy bills

2. Higher reliability: BLDC motors are brushless and have fewer mechanical parts, leading to increased reliability and reduced maintenance costs
3. Variable speed control: BLDC motors provide precise speed control, which is essential for water pumping applications. The motor speed can be easily controlled by adjusting the voltage and current supplied to the motor
4. Reduced carbon Emissions: Solar-based water pumping systems are powered by clean energy, reducing the carbon footprint of the pumping system. This is especially beneficial for remote areas where diesel generators are often used to power traditional pumping systems
5. Lower operating costs: Grid-connected solar-based water pumping systems have lower operating costs than traditional systems, which rely on electricity from the grid or diesel generators. The cost of solar energy is decreasing rapidly, and the maintenance cost of a solar-based water pumping system is lower compared to a traditional pumping system

Disadvantages:

1. High initial cost: The initial cost of installing a grid-connected solar-based water pumping system with BLDC motors can be higher than traditional AC or DC motor-powered pumping systems, although the cost is decreasing as technology improves and becomes more widely adopted
2. Dependence on weather conditions: The performance of solar-based water pumping systems is dependent on weather conditions, particularly sunlight availability. In cloudy or overcast weather conditions, the system's performance may be reduced, which can impact the water pumping capacity
3. Maintenance requirements: While BLDC motors are more reliable than traditional motors, they still require maintenance and if not properly maintained, they may not operate at their optimal efficiency. Additionally, the solar panels require periodic cleaning to ensure maximum efficiency
4. Complex system design: Designing a grid-connected solar-based water pumping system with BLDC motors requires specialized expertise in solar power, motor control, and electrical engineering. This can make the system design more complex than traditional systems, and it may be more challenging to find qualified technicians to maintain the system

VII. APPLICATIONS

1. Agricultural irrigation: Solar-powered water pumping systems using BLDC motors are widely used in agricultural irrigation, providing a reliable and efficient source of water for crop irrigation
2. Drinking water supply: Solar-powered water pumping systems can be used to provide a source of drinking water for rural and remote communities. The system can pump water from a well, borehole, or stream and supply it to a water treatment system or storage tank.
3. Industrial applications: Solar-powered water pumping systems can be used in a wide range of industrial applications, such as pumping water for cooling systems, wastewater treatment, and mining operations.

VIII. RESULT AND DISCUSSION

Simulation in MATLAB tool for understanding the behaviour of the Grid connected Solar based Pumping system using BLDC Motor Drive, predicting their response to inputs and conditions, and optimizing their performance

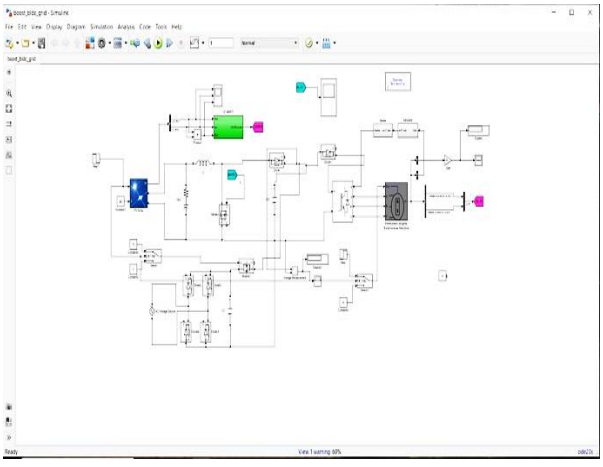

Fig.3 Simulation of a proposed Hardware System

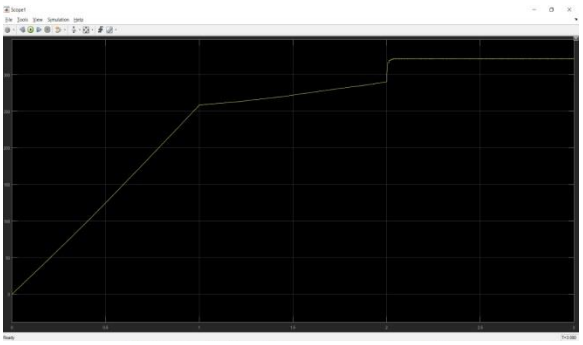

Fig.4 Voltage across output of the Converter circuit

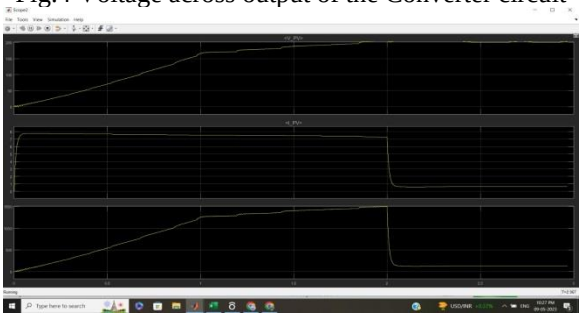

Fig 5 Output Waveform of MPPT (Vpv, Ipv, Ppv)

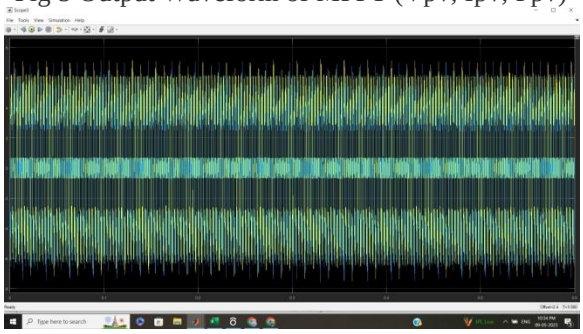

Fig. 6 Stator current waveforms of stator current

IX. CONCLUSION AND FUTURE SCOPE

In conclusion of this proposed system, grid-connected solar-based water pumping systems using BLDC motors offer a reliable, efficient, and cost-effective solution for water pumping needs in both rural and urban areas. These systems provide a sustainable source of energy, reducing dependence on grid electricity and minimizing carbon emissions. By using BLDC motors, the systems achieve high efficiency and reliability, while reducing maintenance requirements and operational costs. Despite the initial cost of installation, the long-term benefits of these systems make them a worthwhile investment for many applications. With proper planning, installation, and maintenance, grid-connected solar-based water pumping systems using BLDC motors can provide a reliable and sustainable source of water for agriculture, drinking water, livestock watering, aquaculture, water features, and industrial applications.

The future scope for grid-connected solar-based water pumping systems using BLDC motors is very promising. One of the key areas of development for these systems is the integration of energy storage technologies, such as batteries or other energy storage devices, to allow for greater flexibility in system operation and the ability to store energy for use during periods of low sunlight or high water demand. There is also potential for the development of hybrid systems that combine solar energy with other renewable energy sources, such as wind or hydropower, to provide a more reliable and consistent source of energy for water pumping systems. Another future scope is a bidirectional grid-interactive system. The excess energy from solar can be supplied to the grid by an interactive system, which helps to reduce the electricity bill

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