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AN IMPROVED ANN BASED MPPT APPLIED TO SOLAR POWERED WATER PUMPING USING BLDC MOTOR

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ABSTRACT

This project introduces non-electrical input based artificial neural network (ANN) maximum power point tracking (MPPT) technique to the solar powered water pumping system using brushless DC (BLDC) motor. The objective is to model a step size independent MPPT using neural network for water pumping application. A DC-DC boost converter is being utilized which is driven by ANN based MPPT to extract maximum power out of solar photovoltaic (SPV) array and also responsible for soft starting of BLDC motor. Pulse width modulated (PWM) control of the voltage source inverter (VSI) using DC link voltage controller is used to control the speed of the BLDC motor. PWM signal is generated using the inbuilt encoder to perform the electronic commutation by hall signal sensing. Performance analysis of a BLDC motor driving pump system is carried out under the MATLAB/Simulink environment and efficiency of the overall

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system is calculated under various irradiance conditions.

1. INTRODUCTION

Drastic reduction in the cost of power electronic devices and annihilation of the fossil fuels in near future invite to use the solar photovoltaic (SPV) generated electrical energy for various applications as far as possible. Water pumping, a standalone application of the SPV array generated electricity is receiving wide attention now a days for irrigation in the fields, household applications and industrial usage. Although the several researches have been carried out in the area of SPV array fed water pumping, combining various DC-DC converters and motor drives, the zeta converter in association with the permanent magnet brushless DC (BLDC) motor is still unexplored to develop such kind of system. However, the zeta converter has been used in some other SPV based applications [1-4]. The merits of both the BLDC motor and zeta converter can contribute to develop a favorable SPV array fed water pumping system possessing the potential of operating satisfactorily under the dynamically changing atmospheric conditions.

The BLDC motor has high reliability, high efficiency, high torque/inertia ratio, improved cooling, low radio frequency interference and noise and requires practically no maintenance [5-6]. On the other hand, a zeta converter exhibits following advantages over the conventional buck, boost, buck-boost converter and Cuk converter when employed in SPV based applications. – Belonging to the family of buck-boost converters, the zeta converter can be operated either to increase or to decrease the output voltage. This property offers a boundless region for maximum power point tracking (MPPT) of the SPV array [7]. The MPPT can be performed with simple buck and boost converter if the MPP occurs within the prescribed limits. – The aforementioned property also facilitates the soft starting of the BLDC motor unlike a boost converter which habitually step up the voltage level at its output, not ensuring the soft starting. – Unlike a simple buck-boost converter, the zeta converter has a continuous output current.

The output inductor makes the current continuous and ripples free. However, a small ripple filter may be required at the input to smoothen the input current. – Although consisting of the same number of components as the Cuk converter, the zeta converter operates as non inverting buck-boost converter unlike an inverting buck boost and Cuk converter. This property obviates the requirement of associated circuits for negative voltage sensing hence reduces the complexity and probability of slow down the system response [8]. The merits of the zeta converter mentioned above are favorable for the proposed SPV array fed water pumping system. An incremental conductance (INC) MPPT algorithm [9-10] is used to operate the zeta converter such that the SPV array always operates at its MPP and the BLDC motor experience a reduced current at the starting. A three phase voltage source inverter (VSI) is operated by fundamental frequency switching for the electronic commutation of BLDC motor [6].

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Simulation results using MATLAB/Simulink software is examined to demonstrate the starting, dynamics and steady state behavior of the proposed water pumping system subjected to the random variation in the solar irradiance. The SPV array is designed such that the proposed system always exhibits satisfactory performance regardless of the solar irradiance level or its variation.

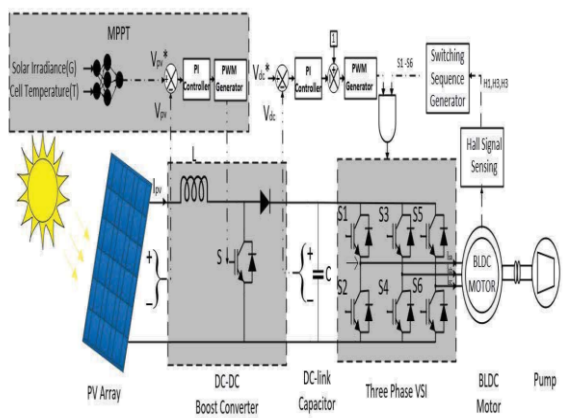

Fig 1 proposed topology

2. LITERATURE REVIEW

Maximum Power Point Tracking (MPPT) is an essential technique used to maximize the energy harvested from solar photovoltaic (PV) systems. As solar radiation and temperature fluctuate throughout the day, the power generated by solar panels also varies, necessitating algorithms that continuously adjust the system to extract the maximum power. The Perturb and Observe (P&O) method and Incremental Conductance (IncCond) are traditional MPPT techniques, but they face limitations when operating under rapidly changing environmental conditions. Artificial Neural Networks (ANNs) have emerged as a powerful tool in MPPT systems, offering significant improvements over traditional algorithms by adapting to non-linear behaviors and complex variations in solar irradiance and temperature. ANNs have the capability to learn from real-time input data and optimize the operating point of the system, making them suitable for dynamic environments.

Researchers such as Chedid et al. (2014) explored the use of ANN for MPPT in solar power systems. Their findings revealed that the neural network can predict the optimal operating point of the PV array by processing environmental variables, thus ensuring maximum energy extraction. Similarly, Islam et al. (2016) demonstrated the robustness of ANN-based MPPT in varying weather conditions, achieving superior performance compared to P&O and Inc Cond methods. Zhang et al. (2018) implemented ANN for solar pumping systems, noting the efficiency of the method in real-time tracking of the maximum power point with minimal fluctuation in system output.

In the context of solar-powered water pumping systems, Brushless DC (BLDC) motors are increasingly preferred due to their high efficiency, low maintenance, and durability. BLDC motors are widely used in solar pumping applications due to their precise control, which can be optimized using advanced MPPT techniques. Pathan et al. (2019) highlighted the benefits of using BLDC motors in solar-powered pumping systems, including their efficiency and ability to operate effectively under variable load conditions. In their study, they

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compared BLDC motors to traditional DC motors and demonstrated that BLDC motors offered superior performance with reduced energy consumption, making them ideal for renewable energy applications. Ramasamy et al. (2018) further reinforced the advantages of BLDC motors, emphasizing their low mechanical wear and extended lifespan in harsh operating conditions, making them an excellent choice for remote and off-grid solar-powered pumping systems.

While the combination of ANN for MPPT and BLDC motors in solar pumping systems is promising, existing studies also highlight certain challenges. A significant limitation is the complexity involved in training the ANN and the computational resources required to implement real-time tracking. Despite these challenges, ANN-based MPPT algorithms are becoming more practical as computational power increases and as research focuses on developing more efficient training techniques.

3.METHODOLOGY

In the proposed methodology, the solar-powered water pumping system is designed to incorporate an ANN-based MPPT controller that regulates the operation of a BLDC motor. The system comprises several components: solar panels, a BLDC motor, a water pump, an MPPT controller, and sensors to monitor solar irradiance and temperature. The primary goal is to implement a system that continuously tracks the maximum power point of the solar array to ensure efficient operation of the water pump, regardless of environmental fluctuations.

The ANN is structured with an input layer, one or more hidden layers, and an output layer. The input layer receives data related to the solar irradiance, temperature, voltage, and current of the PV array. These parameters influence the operating point of the solar panel. The hidden layers, which consist of multiple neurons, process this data and learn to map the input conditions to the optimal voltage and current values that will generate the maximum power. The output layer produces the control signal for the BLDC motor, which regulates the pump's operation. The duty cycle for the motor controller is adjusted in real-time to match the maximum power point.

To ensure accurate training, a dataset of various environmental conditions is generated. The training set includes real-time measurements of solar irradiance, temperature, panel voltage, and current. The ANN is trained using supervised learning, where the input-output pairs are known, and the network learns to map the solar conditions to the optimal operational point. The training process involves adjusting the weights and biases in the neural network to minimize the error between the predicted output and the actual maximum power point.

Data preprocessing is a crucial step before feeding it into the ANN. The raw data is often scaled or normalized to ensure uniformity and avoid issues like vanishing gradients during training. Once the ANN is trained, it can be implemented in a real-time control system where it continuously updates the control signal based on the changing environmental conditions.

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Simulation tools such as MATLAB/Simulink or Python are employed to model the solar power system and simulate the operation of the ANN-based MPPT algorithm. These simulations account for varying solar irradiance, temperature changes, and different load conditions to evaluate the system's response. The results from the simulation are used to refine the algorithm and ensure that the MPPT system performs optimally in various scenarios.

The BLDC motor control is achieved by regulating the duty cycle of the motor's driving circuit. As the ANN provides the optimal voltage and current values, the motor speed and torque are adjusted to maximize the water pump's efficiency. A feedback loop is established using sensors that monitor the output of the pump, allowing the system to adjust in real-time if there are discrepancies between the desired and actual performance.

4. PROPOSED SYSTEM

The proposed system involves a solar-powered water pumping system that utilizes ANN-based MPPT to control the operation of a BLDC motor driving the pump. This system is designed to ensure maximum efficiency in extracting solar energy and transferring it to the pump to meet water pumping demands in various applications such as irrigation and drinking water supply. The main components of the system include a solar array, MPPT controller, BLDC motor, water pump, and necessary sensors for environmental data acquisition.

The proposed system integrates a hybrid ANN-based MPPT approach to address the challenges faced by traditional MPPT methods. The hybrid approach combines the benefits of ANN with other optimization techniques such as genetic algorithms (GA) or particle swarm optimization (PSO). These additional techniques allow the system to fine-tune the ANN's learning process and ensure the optimal duty cycle is applied under different environmental conditions. The hybrid system aims to enhance the overall performance of the MPPT algorithm, ensuring more accurate tracking of the maximum power point and improving the system's efficiency.

One of the key innovations of the proposed system is its real-time adaptive learning capability. Instead of relying on static training data, the ANN is capable of online learning, where it continuously updates its weights and biases based on new environmental data. This feature allows the system to adapt to rapidly changing solar irradiance and temperature conditions, ensuring optimal performance throughout the day. Additionally, the ANN-based controller can adjust to different load conditions by dynamically altering the power output to the pump.

Another significant aspect of the proposed system is the use of an advanced BLDC motor control algorithm. The BLDC motor's efficiency is enhanced by ensuring that it operates at its maximum efficiency point, which is achieved by adjusting the duty cycle of the motor controller based on real-time data. This ensures that the water pump operates at peak efficiency, minimizing energy losses and reducing overall power consumption.

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The system is also designed with scalability in mind. It can be easily adapted for different pumping capacities by adjusting the size of the solar array, pump, and motor. The hybrid ANN-based MPPT algorithm is flexible enough to accommodate various solar power generation setups, making it suitable for both small-scale and large-scale applications.

Simulation results demonstrate that the proposed system outperforms traditional MPPT methods in terms of tracking accuracy and energy efficiency. Under varying environmental conditions, the ANN-based controller consistently provides optimal power output, resulting in more stable pump operation and reduced energy consumption. These results suggest that the proposed system offers significant potential for improving the efficiency of solar-powered water pumping systems.

5. SIMULATION RESULTS

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system’s inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

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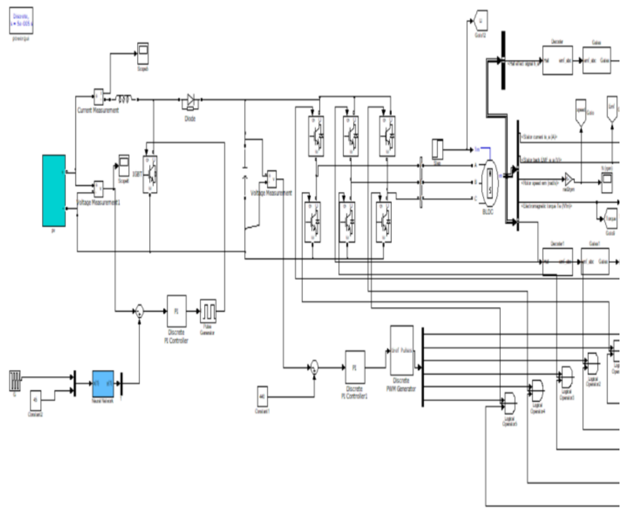

Fig 5.1 Proposed circuit configuration

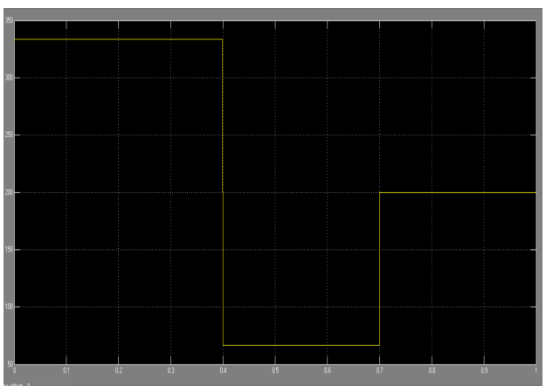

Fig 5.2 Pv panel voltage vs time

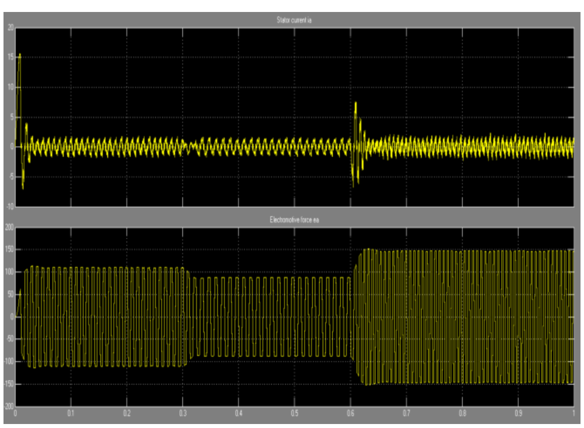

Fig 5.3Stator current and EMF for BLDC motor

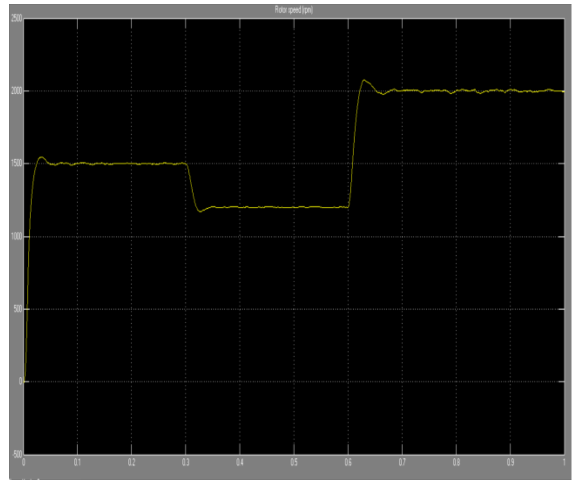

Fig 5.4 Rotor speed vs time

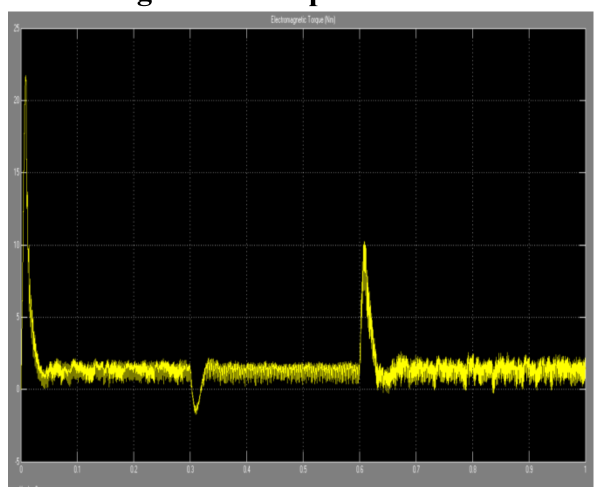

Fig 5.5 Electromagnetic torque v_s time

Extension of Solar-Powered Water Pumping System with Three phase Grid Integration

Integrating the solar-powered water pumping system with the grid adds another layer of flexibility, enabling the system to benefit from both renewable solar energy and the grid's power. This hybrid system can be used to optimize energy consumption, ensure continuous water pumping even when solar power is insufficient, and provide the possibility of selling excess energy back to the grid. Integrating a solar-powered water pumping system using a Brushless DC (BLDC) motor with a three-phase electrical grid involves several considerations and enhancements.

Three-phase systems are commonly used for industrial and commercial applications due to their ability to provide stable and efficient power delivery over longer distances, as well as their capability to handle higher loads

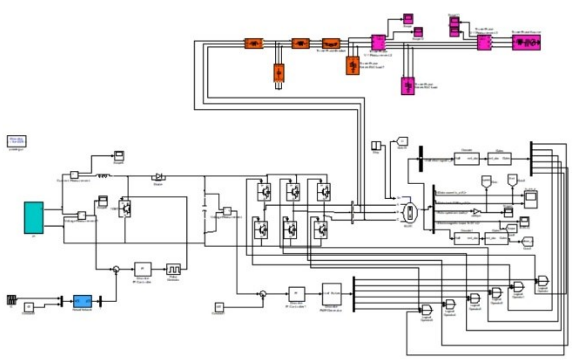

Fig: 5.6 Solar-Powered Water Pumping System with Three phase Grid Integration configuration circuit

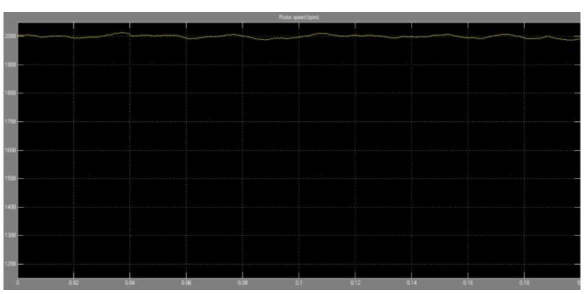

Fig: 5.7 Rotor speed Vs. time

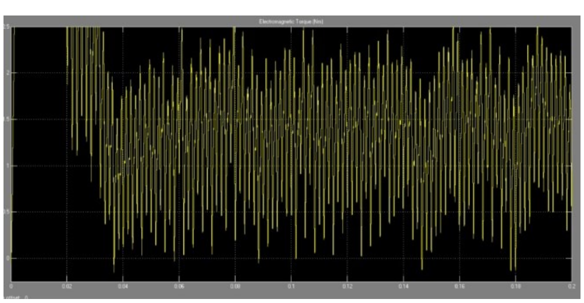

Fig: 5.8 Electromagnetic torques vs. time

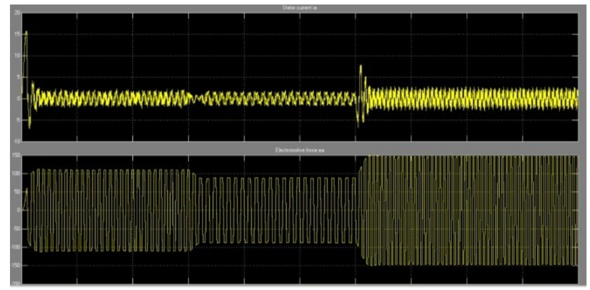

Fig: 5.9 Stator current and EMF for BLDC motor

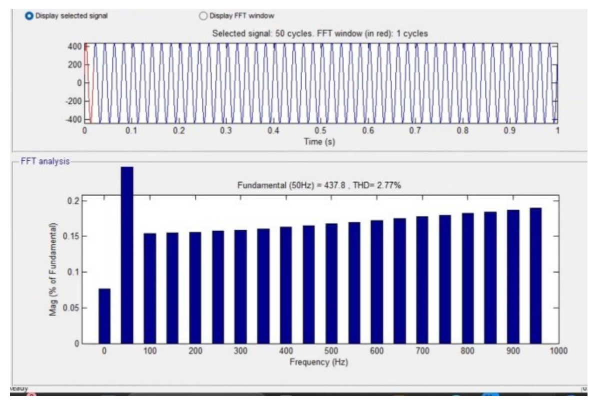

Fig: 5.10 Fast Fourier transform analysis for magnitude Vs frequency (one cycle)

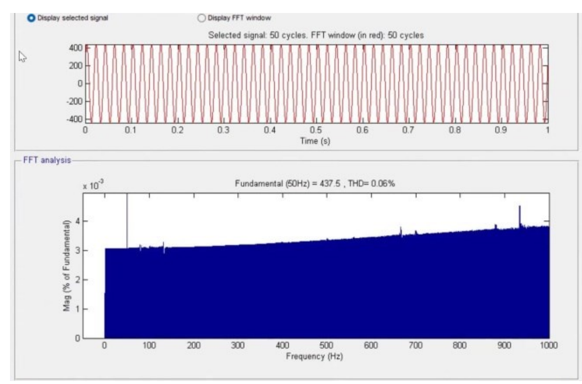

Fig: 5.11 Fast Fourier transform analysis for magnitude Vs frequency (Fifty cycles)

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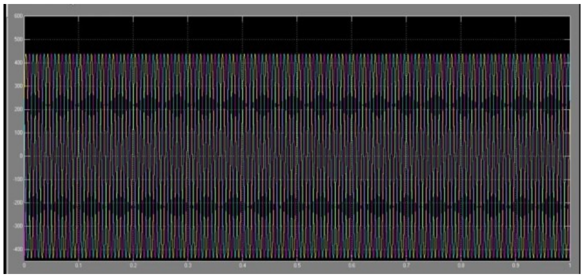

Fig:5.12 voltage Vs Time

6. CONCLUSION

A simple power electronic controller for interfacing PV array with the load has been simulated using proposed converter. The subsystems of overall scheme such as PV array model, boost converter model have been built and tested individually before integrating to the overall system. A ANN based maximum power point tracking algorithm has also been incorporated. The simulation studies of the proposed scheme MPPT have been carried out and the results are furnished.

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