Implementation of AI in Solar-powered Brushless DC Motor

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Abstract - *This project seeks to design a brushless DC motor, incorporating artificial intelligence in order to ensure a smooth and reliable operation of the motor. The project also runs on solar energy, making it a sustainable solution too. The principles of artificial neural networks (ANN) and fuzzy logic are included as AI algorithms in the project. Maximum power point tracking (MPPT), designed with ANN, is employed to ensure that the solar energy extracted by the solar panel is maximum at all times. The speed control of the motor is done using fuzzy logic, because of its accuracy in enforcing proper control by checking for the error margin to compensate for it.*

Key Words: Artificial Neural Network (ANN), fuzzy logic, Maximum Power Point Tracking (MPPT), brushless DC motor.

1. INTRODUCTION

The ongoing rapid depletion of energy resources has forced humankind to look into harnessing alternate, more perennial energy sources. Naturally, a lot of research is on efficient extraction and usage of different renewable energy sources. Solar energy is possibly the more accessible of the different renewable energy sources [1]. Due to a very easy installation procedure, solar energy is easily the most utilized renewable energy source. It can be installed on rooftops, and is hence mostly exposed to sunlight. Solar energy is even more advantageous to use in the tropics, where there is an almost continuous exposure to the sun every day. Hence, the solar photovoltaic (PV) technology is capable of serving bigger systems due to this versatility and provides a much greener alternative to analogous non-renewable energy sources [1]. A brushless DC (BLDC) motor is one of the most important electrical machines by means of requirements and applications at present [11].

Repeated attempts and technologies are being innovated to mimic the cognitive powers of humans. While humans being in control is always followed by fears of low reliability among others, the presence of a computer in that place seems to quell such trepidation. Of course, the computer has to be trained

using specialized software and training tools, for it to be able to monitor a system as well as a person with on-field experience of twenty years. The term "artificial intelligence" refers to a machine capable of mimicking the thinking process of a human brain, to some extent. AI is implemented using many techniques, and this project deals with two of them.

Fuzzy logic is a computational logic that works on the concepts of half-truths. Generally, the binary values of '0' and '1' are all that a machine can comprehend. Fuzzy logic introduces the concept that those values can also be somewhere between the two; in other words, that it can possess infinitely many intermediate values. The other AI technology incorporated into the project is artificial neural network (ANN) [5]. To enable the machine to think artificially, the machine is trained. A known quantity or set of values are provided as the input. The machine processes this input initially, and suppose a further value is provided as the question, the machine does manage to return as answer. However, the accuracy of this data is quite circumspect. It may or may not be the correct answer. Then the machine has to be trained in order to hone its accuracy and ensure that the output obtained is optimal.

The advantages offered by such a means of control are quite significant. For starters, speed control will be quite accurate thanks to fuzzy, which varies the error signals to get to zero and match the user requirement. The usage of ANN along with the theory of maximizing power extracted from the solar panel will help to control the input PWM levels to within controlled levels [5]. To add to this, this system can be transplanted onto many other applications and be made use of in a more specialized and efficient manner. For instance, water pumps can make use of AI along with converters and inverters, with different motors in order

We face an increasing need to automate many trivial processes, so as to focus manpower on more pressing problems, like in research and development of more advanced problems. The only stipulation here is that the motor's speed has to be fixed by human intervention only. But thereon, no intervention from the user is needed.

The system will be able to adjust to the stipulated speed automatically, even if, for example, a load is added. The load may momentarily affect the speed, but then an error signal will be picked up and the system will work to automatically get it back to the required speed. This way, there doesn't need to be continuous surveillance of the system during

normal working.

The solar panel is a key part of the project. Seeing as renewable energy is becoming all the vogue, not just because of the numerous benefits but also due to the diminishing stock of conventional energy sources, the panel provides the pump energy that is clean and non-polluting while at the same time promising very low maintenance costs. While solar panels are notoriously inefficient, the technology is getting cheaper and better with time, not to mention the fact that the sun is present for enough time to store energy and use any time of the day [13, 14]. A disadvantage right now, besides cost, is that only a select population may be able to reap all benefits of the technology at present, as solar energy, due to an innate inefficiency, can be used justifiably only in places with enough sunlight most days of the year. This way, some part of the world may be ruled out as a place to install solar panels since the returns are too low to cover the high investment. Yet, there is room for all this to get really better as the technology is improving rapidly.

2. TOPOLOGY OF PROPOSED SYSTEM

The design includes the solar panel, which will work using the ANN-based MPPT algorithm to extract maximum power from the sun. The feedback to the motor is embedded with fuzzy logic. This will enable speed control. The inverter is given PWM input. The PWM waveform is automatically optimized by the ANN algorithm. The PV cell receives sunlight and transduces it into electrical energy, making use of MPPT Algorithm. The MPPT Algorithm ensures that maximum sunlight can be absorbed by the panel. The DC/DC Boost Converter boosts the voltage of the incoming electric by using fuzzy logic [2, 9, 12]. Inverter uses PWM Input and converts the incoming DC signals to 3-phase AC, as the BLDC motor only accepts a 3-phase AC supply [3, 8]. By using the fuzzy logic and ANN methodologies the accurate tracking of the sunlight using MPPT is achieved. The brushless DC motor will work without manual intervention, due to which power consumption can be reduced, and makes use of renewable energy in the process. Most existing systems have chosen to make use of only one AI technology. While it may not be considered to be disadvantageous, it is possible to enhance performance by implementing more forms of AI. Fuzzy logic allows for accurate speed control by constantly tracking error signals from the specified speed. This allows the motor to gradually change to the new speed specified by the user and allows for a smooth speed change.

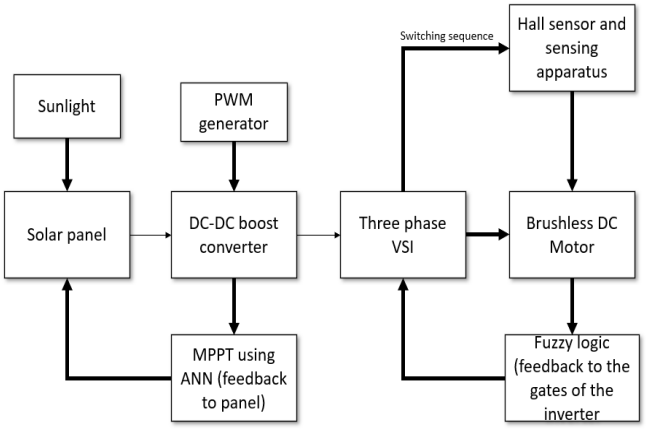

Fig.1 Block diagram of proposed system

3. MAXIMUM POWER POINT TRACKING

Several techniques which uses ANN based PV MPPT, which is non-electrical and the input- based MPPT and it uses irradiance (G) and temperature (T) as input and give V_{mpp} as an output and is taken as reference V_{pv} [4, 5, 6]. The PWM generated will generate required duty cycle, the PI controller's output is provided to the PWM [10]. Optimal tuning provides better performance. MPPT is used to extract maximum solar energy from the incident sunlight. It ensures that the panel is able to stay at its maximum power point at all times.

A. The Perturb & Observe (P&O) Algorithm

This method depends on a technique called 'perturbation'. [6, 7] This is the most widely used algorithm. This method comprises of changing the module's voltage and noting the corresponding change in output (power) supplied by the module to the converter setup. The PV controller varies the module's output in incremental steps. These steps are fixed and can also be varied. Both output voltage and current values are the control parameters, hence the name 'perturbation' is accorded.

B. Clustering

Clustering is another technique of solving problems, in a variety of platforms, including in ANN and Python for example. Also referred to as cluster analysis, this method of implementing ANN involves grouping different sets of objects into 'clusters', such that each object in a cluster is similar to other objects in that cluster compared to objects in the other clusters. Initially, the system is provided with values as input data. From there, the system is trained iteratively, till the values obtained reaches a satisfactory result. In this project, the MPPT algorithm implemented is meant to extract maximum power from sunlight.

The algorithm ensures that the input to the inverter, after the voltage is boosted, is at a constant level.

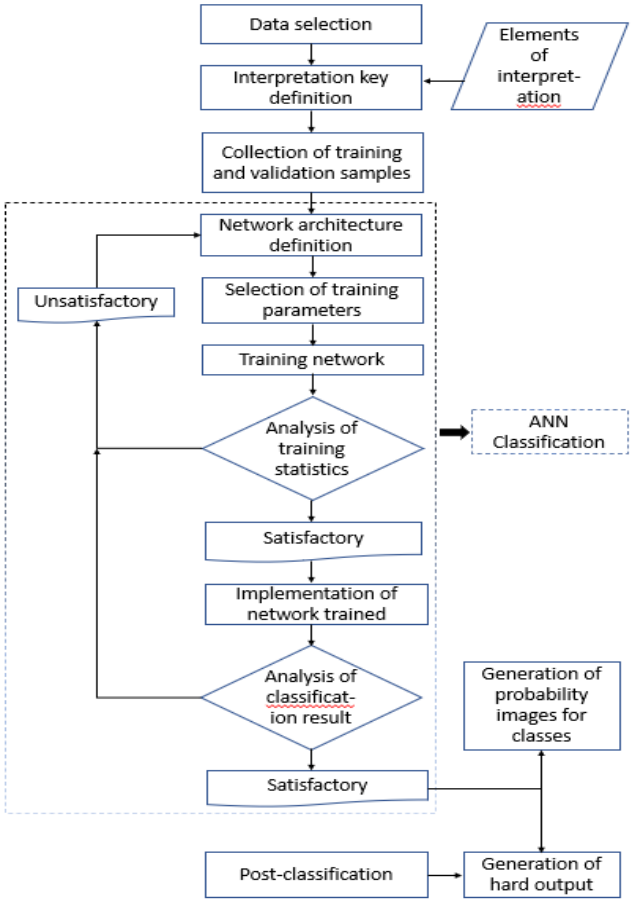

Fig. 2 General flowchart of clustering

4. TRAINING OF NEURAL NETWORK

The neural networks are calculated at various parameters which involves the temperature changes and also the irradiance. These are performed using voltage obtained using MPPT which has a maximum value [1, 6]. The obtained data is being trained according to various needs using data points and neurons that help in building the network. With the amount of neuron and data points the higher level of integrity in the result can be obtained. This will improve the accuracy of the system and accurate results are obtained.

5. POSITION SENSOR

This sensor is mainly used to detect the position of the rotor and will send signals depending on it. With appropriate logic circuits the suitable output from the position sensors is obtained. The motor involves a process that includes six steps of switching processes where each step has an angle of 60 degrees. These degrees are detected using position sensors and this will in turn be detected by the Hall sensors which detect three Hall signals where the switching is being suitably decoded and detected [15]. The sensors are placed in such a way that the give accuracy signals on detection of the rotor magnetic fields. As the brushless DC motor is a contact-less motor and does not feature commutation similar to conventional motors, it is dependent on Hall sensors to decide the movement and direction of the rotor blades.

6. SIMULATION AND DISCUSSION

The simulation to be studied further was performed using MATLAB Simulink. The diagrams below are the different performance curves of the system. The simulation diagram depicts a detailed structure of the circuit, which comprises of a boost converter, a three-phase inverter and the brushless DC motor as its chief components. The circuit is powered by a PV module and is monitored and controlled by the AI algorithms embedded onto the panel and the motor feedback.

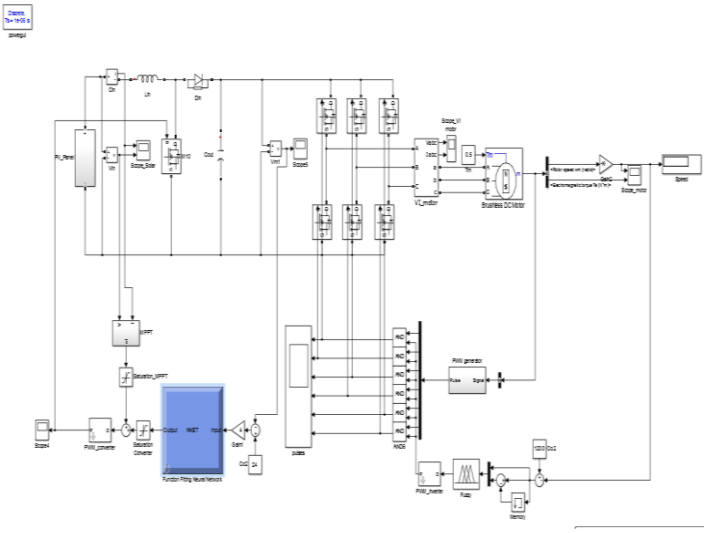

Fig. 3 Simulation diagram

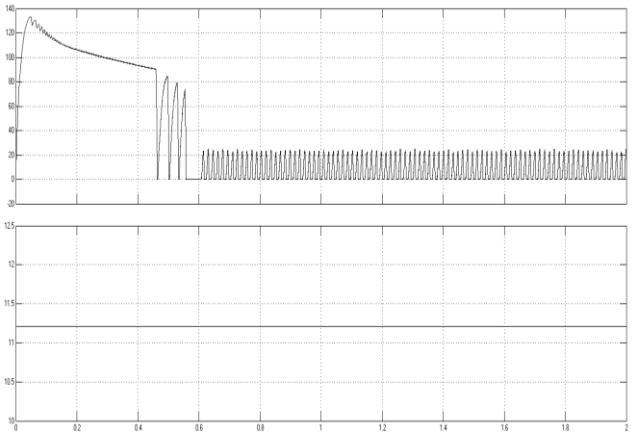

Fig. 4 Input voltage and current curves

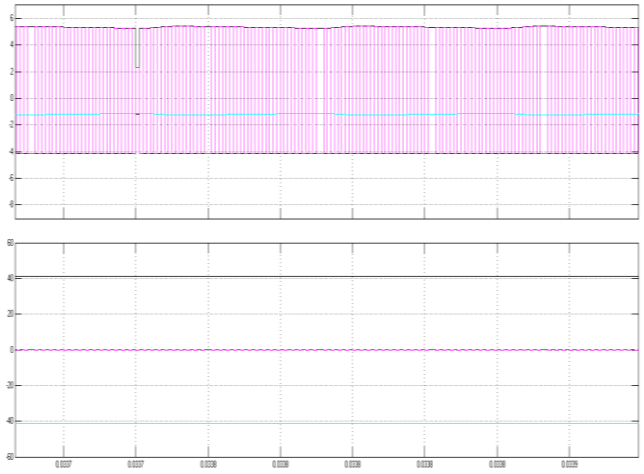

Fig. 5 Output voltage of inverter

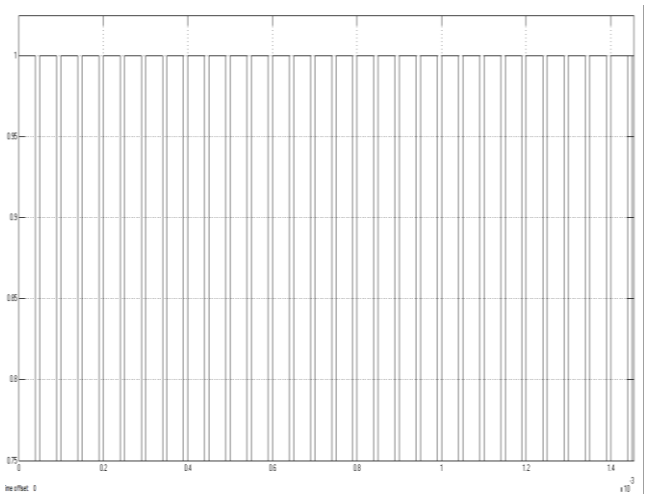

Fig. 6 Pulses to the boost converter switch

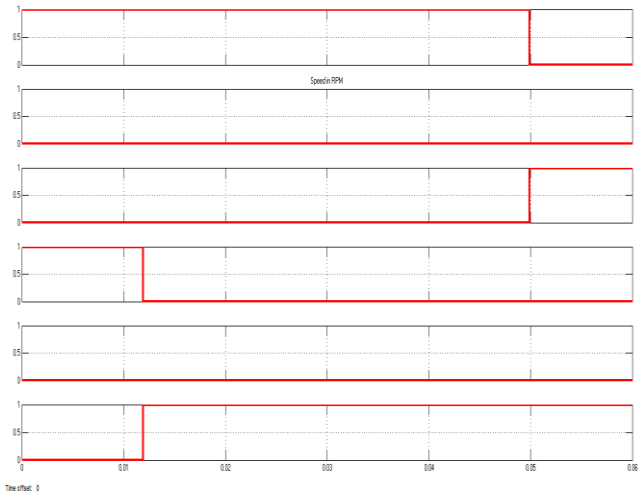

Fig. 7 Inverter switch pulses

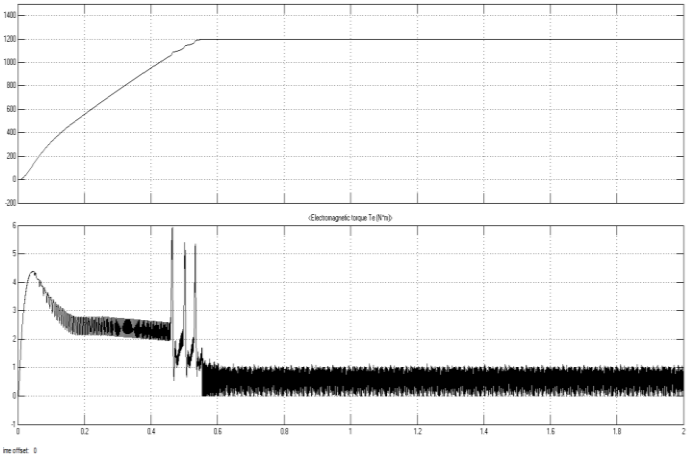

Fig. 8 Speed curve of the rotor

Fig. 3 is the simulation diagram designed in Simulink. The PV module powers the system. The input voltage is boosted by the converter and is fed to the three-phase voltage source inverter. The inverter determines the switching sequence and switching frequency of the BLDC motor, essentially controlling both speed and direction of the motor. The feedback from the motor is governed by fuzzy logic, which performs speed control. The PV panel is optimized by the MPPT algorithm in order to extract the maximum possible energy from sunlight. Fig. 4 is the curve depicting the input voltage and current curves. In all motors the starting current is very high, nearly 5 times the rated current. Hence a sharp spike is observed, that gradually reduces to within the rated current value. The pulsating waveform in Fig.5 represents the supply to the BLDC motor. This waveform regulates the switching sequence and frequency of the motor, as this supply to the motor determines both of those attributes that are instrumental in deciding the speed of the motor. In Fig. 6, the pulses to the boost converter are given by the ANN system as feedback, in order to keep the voltage values within limits. The three-phase inverter has six switches, two representing each phase. The switches alternate conduction, as pairs in each phase. The switches are activated by a gate pulse that is given to switches that are part of that phase. The other switches are inactive then. Only when a gate signal is given to the switches will an output be produced. The waveform of the pulses given to the inverter switches are represented by Fig. 7. The speed of the rotor follows a trend as shown in Fig. 8. Initially when the motor is started and an initial starting speed is specified, the fuzzy algorithm calculates an 'error' and a 'change in error' signal. Hence, the motor gradually begins increasing speed from rest. As the motor speed increases both the error signals reduce in magnitude. Once the motor reaches the speed fixed by the user, the error signals become zero and the curve is stabilized.

7. CONCLUSION

This paper explores the idea of a brushless DC motor capable of running on solar power. The main feature of this paper is the implementation of AI in two forms : one, in the

form of fuzzy logic to control the speed of the brushless DC motor, and two, as the MPPT algorithm which ensures that the solar panel is at its maximum power point all the time, and hence puts out the maximum power. The setup is simple and usable in many forms. BLDC motors form a very huge part of electric-powered vehicles by powering the wheels in a form known as the 'hub'. This hub, powered by solar energy and controlled very accurately with fuzzy logic, can operate very efficiently and provide linear acceleration, which is a crucial feature sought for in vehicles. It can be implemented in a water pump by attaching a centrifugal pump to the system, which will then be powered by the motor [16]. To use this system in a more specific manner, addition of Internet of Things (IoT) can be considered.

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