Hybrid Renewable Energy Based CFSI for and Motor Application using ANFIS Based MPPT and IFOC Controller

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Abstract. In many industrial applications, the varying speed of the motor drives has become essential for the fast dynamic load conditions. Therefore, the detailed analysis of Field Oriented Control (FOC) with the sensor-less technique of BLDC is proposed where the reference speed is obtained from the MPPT based ANFIS controllers for control the speed. The FOC not only control the magnitude but also provides the phasor control. With Back-EMF estimation process, the motor is applied to obtain the torque ripple minimization and correct speed control using simpler IFOC. It is used to estimate speed in a sensorless and to map the continuous velocity variation. This approximate velocity is used to activate and to predict hall switching output less BLDC motor signals with low tension MATLAB / Simulink tool is using for results verification.

Keywords: ANFIS Controller, BLDC Motor, Back EMF Method, Indirect Field Oriented Controller (FOC)

1. Introduction

In recent days, electric power utilization is exploiting by motor load applications. The huge transformation of human styles and the development of the use of electric motors have increased the interest in electrical vitality. The CFSI converter is designed to extract the power from PV source and increase the voltage gain. CFSI's implementation guides PV to load and WECS. In order to control speed, and is proposed using IFOC method EMF estimate back. The proposed CFSI feeds both the BLDC motor and the RL load, using the new IFOC to control the speed of the BLDC motor. The demand for electrical energy is based on renewable sources. Solar, wind and fuel cells are the most commonly used renewable resources. Solar and wind energy is the most important source of energy for power generation [1]. Hybrid renewable energy uses continuous energy flow and meets sufficient energy demand. Efficient energy consumption is a serious issue in the use of a sustainable source. The best possible use of MPPT techniques is based on the efficiency of the power flow. Various control strategies exist and the algorithm-based MPPT is proposed by researchers [2-4]. In [4-6] the MPPT based on ANFIS makes use of the Properties and advantages of Artificial Neural Network (ANN) and Fuzzy Logic Control (FLC). The FLC properties open the way to follow the rules produces a non-linearity property. There are different types of algorithms used in MPPT techniques. The INC algorithm is very accurate than the P&O calculation. Incremental conduct can be realized at a high cost because it includes
progressively complex methods; it is worth it when more energy needs to be exchanged from the source. Hybrid renewable energy sources have been effectively exchanged through MPPT [7-9]. The principle pact is to plan the inverter design on the basis of a consistent quality, productive and cost-effective system. The dispute is to configure a high gain. In this way, the CFSI is proposed and a high output gain ratio can be created inverter. In the earlier period, implementation of the system is increasingly difficult and exorbitant. However, it does have the disadvantage of leakage of current flows. Power quality is reduced as a result of the infusion of leakage currents afterwards, downsides of less output gain inverter [10]. Efficient energy from a hybrid renewable source is obtained from the CFSI control technology used by the BLDC engine. The efficient energy from the hybrid renewable source is obtained by the control techniques of CFSI which is given to the BLDC motor [11-12]. The BLDC motors are ordinarily utilized in numerous applications, for example, car, PC, mechanical, aviation and so on. In BLDC there is no appearance of brushes henceforth maintenance of BLDC is less. This has the Due to low inertia: BLDC motor has the benefit of fast response to model reference waveform of trapezoidal voltage, and a quasi-rectangular waveform of voltage. The BLDC engine has many favorable circumstances over other motor drives and is suitable for higher output responsibilities. Various control methods are proposed in that back EMF and IFOC controller behaves well under dynamic load conditions. [13] Operate on electromagnetic, and mechanical commutation is not required. The electronic commutation requires. Using Hall Impact location sensors is achieved for the continuous monitoring of rotor location [14-15]. The BLDC motors are mostly favored for high-speed applications and work is undertaking the production of BLDC power. This is operated by CFSI system is implemented to improve the output of motors. IFOC approach is used and BLDC motor speed is measured instead of being collected from a sensor, the back EMF measurement method is used [16-17].

2. Proposed system
In this proposed system consists of hybrid renewable resources struggling to produce efficient electricity, and the ANFIS-based MPPT control system for CFSI and IFOC motor control controllers appears to be completed. The successful converter power is transferred via the CFSI to the BLDC motor. The new IFOC gives the inverter switches the pulses of the gate for engine speed control. The proposed BLDC engine load scheme is shown in figure 1.

3. Modelling
3.1 PV Energy Generation
There's just a harmful quantity of fossil fuels and minerals for electricity generation recently. As a result, the use of sustainable energy source assets is rapidly expanding step by step. Owing to sun-powered energy is most widely used as renewable sources. The Photovoltaic (PV) system utilizes solar energy. The photovoltaic device converts directly into electricity at daylight. PV cells, which form a key for PV generation. A PV cell is a semiconductor diode which includes diode. The photoelectric effect is the
theory used in system. The theory includes the cycle of electrons forced out each time the solar radiation is absorbed by the PV cell. PV device has two types of layout. They are 1) single diode model 2) two-diode model. The proposed single diode model has less complexity and more rapid results the proposed have faster outputs. Figure 2. Shows the single PV model. Simulation of a single model can be achieved by using the equations shown in the following: A single diode configuration is equated by

\[
I_0 = I_{pc} - I_{rs} \left( e^{\frac{V_{pv} + I_{pv}R_{series}}{a} - 1} - \frac{V_{pv} + IR_{series}}{R_{shunt}} \right)
\]

(1)

The following equation shows that PV model’s current (I) and voltage (V) (I-V) characteristics:

Where

- \(I_0\) - output current,
- \(I_{pc}\) - photocurrent,
- \(R_{series}\) - series resistance, and
- \(R_{shunt}\) - shunt resistance
- \(I_{rs}\) - saturation current which is reversed,
- \(V_{pv}\) - voltage of the PV cell,
- \(I_{pv}\) - current of the PV cell,

Figure 2. Mathematical Modeling of the Proposed PV Model

3.2 Incremental & Conductance (Inc) Maximum Power Point Tracking (MPPT) Method

The MPPT is a tracking device that tracks the maximum power because renewable sources cannot achieve the use of efficient power, especially in PV panels. The MPPT is then run in a PV panel to improve performance. The P&O approach has the advantages of simplicity but can't precisely control the full power point it faces the issue of wandering around the maximum power point without correctly pointing it and, however, it will almost certainly not respond to minor and regular changes in irradiance

Figure 3. Flowchart of the INC MPPT Algorithm
3.3 Wind Energy Generation

The Wind energy is a vitality commodity for eco-companions even as it needs the less space for installations. The use of wind turbines makes use of wind power. Different designs for wind turbines are suggested for the successful task of generating wind power. The power network has a combination of the transfer of power DC and AC. In comparison to variable speed wind turbines, the fixed turbine is less efficient, just as it has the maximum speed run. The WECS wind energy transmission shown at figure 4. Design of the construction, four fundamental parameters is considered. They are engines, windscreens, gearboxes and power tools. The method of extracting wind energy involves the wind turbine that absorbs wind energy, and the wind energy that has been captured using a generator, is converted to wind power. Turbine modeling is performed by partnership, and is provided by,

$$ P_m = \frac{1}{2} \rho S_{sa} C_{\text{power}} (\lambda, \beta) \omega^3 $$

Where $P_m$ is the mechanical power, where $S_{sa}$ is the air density, where $s_{sa}$ is the rotor tip, where Power is the strength coefficient, where wind speed is $\omega$. The rotor blade TSR, $\beta$ the rotor blade pitch angle.

Configuration of PMSG turbine used for producing wind. The synchronous permanent magnet generator has advantages such as no requirement for excitation winding, no electrical indulgence, increasingly stable & safe, no slip ring supply, simple construction, reduced maintenance, most resistant limit and highly efficient

![Wind Energy Conversion System (WECS)](image)

3.4 Proposed CFSI

The CFSI shown in figure 5. The power grid has a mix of power transmission DC and AC, primary diodes D1 and D2, four switch inverters S1-S4 and C3 and C4 split condensers. The current source inverter is worked in four modes. The primary Sa switch is switched ON in mode 1. The L1 input inducer charges the power supply. Hence the current in L1 is slowly rising. . The primary switch is switched to ON in mode 3. Input inducer L2 charges the energy of the signal. Then the current in L2 slowly rises. In mode 4 both the main Qa and Qb switches are switched ON. Input inductors L1 and L2 charge during this mode. Even the current in the inductors is rising. The equation gives the raise up ratio service cycle.

$$ \text{Duty cycle} = 1 - \frac{V_{in}}{V_{out}} $$

$$ V_{in} = V_{C1} + V_{C2} $$

$$ V_{L1} = V_{C1} - V_{Qa} $$

During ON time of Qa and Qb, the $V_Qa$ and $V_Qb$ are given by,

$$ V_{Qa} = 0, (0 < t < \text{sampling time}) $$

$$ V_{Qb} = 0, (0 < t < \text{sampling time}) $$
During OFF time of Qa and Qb, the \( V_{Qa} \) and \( V_{Qb} \) are given by

\[
V_{Qa} = \frac{V_{in}}{2}, \quad (0 < t < \text{sampling time})
\]  

\[
V_{Qb} = \frac{V_{in}}{2}, \quad (0 < t < \text{sampling time})
\]  

**Figure 5.** Circuit diagram of CFSI for BLDC motor

3.5 **Adaptive neural fuzzy inference program and its algorithm**

There are numerous control systems that analysts suggest. The PID controller has the primary impediment of inadequate monitoring of the reference value when the complex conditions are substantially extended. The neural network and the fuzzy inference method are drawn in because it has the advantage of following the reference value when large aggravations and changes in input occur, but they face complexity disadvantage. And they can't have user-friendly experience. ANFIS has introduced a hybrid technology that combines the advantages of both fuzzy and neural networking techniques. ANFIS integrates the process of obtaining input values and processing them as per fuzzy process rules, and the simulated output from the fuzzy rules is again sophisticated by specifying rules for the accuracy of the system via the neural network. Layer 1 shall include the input date for processing purposes. Inputs are defined by membership functions. Layer 2 performs AND operates on the basis of fuzzy rules with input data. The layer 3 performs the same AND operation based on the rules for accuracy enhancement described by the neural network. The output parameter is modified through layer 4. Layer 5 provides the desired performance by processing the input data with the rules provided. Figure 6. displays the general block diagram for the current ANFIS scheme and the ANFIS model.

The assignment of the learning algorithm for the ANFIS architecture is to adjust all the parameters that can be modified. It uses the hybrid algorithm which combines the method of least squares with the method of gradient descent. This combination addresses the slowness problems in training the values. The system of the least squares acts as forward pass, and the system of gradient descent acts as backward pass. The parameters modifiable in the first layer are considered parameters of the principle. In the fourth layer, the parameters which can be modified are called consequent parameters. The forward pass is used to combine the resulting parameters with the fixed parameters of the premise. The reverse transfer invokes the process of optimizing the parameters of the premises according to the fuzzy set of values input. Through ANFIS architecture, the back propagation algorithm is often used to address the error in the output side by optimizing only the parameters for the assumption. The hybrid algorithm has greater efficacy than the other algorithm. Table.1. Represents regulation laws for the ANFIS.
Figure 6. Architecture of ANFIS and MPPT based ANFIS

Table 1. ANFSI rules

| ∆e  | NB | NM | NS | ZE | PS | PM | PB |
|-----|----|----|----|----|----|----|----|
| NB  | NZ | NZ | NS | NM | PS | PM | PB |
| NM  | NZ | NZ | NZ | NS | PM | PM | PB |
| NS  | NZ | NZ | NZ | NZ | PM | PM | PB |
| ZE  | NB | NS | NZ | NS | PS | NZ | NZ |
| PS  | NB | NM | NS | NZ | NZ | NZ | NZ |
| PM  | NB | NM | NS | PS | NZ | NZ | NZ |
| PB  | NM | NM | NS | PM | NZ | NZ | NZ |

3.6 Back EMF and IFOC controller

It is important to calculate three phase voltage and current flowing from the inverter to the current flowing from the inverter to the BLDC motor which is used for measuring the BLDC motor back EMF. Calculation of line voltages and line currents from determined values. Three phase EMF equation can be estimated from mathematical modeling of the BLDC motor back and the absolute value of the back EMF is obtained by equation (3), which helps to determine the motor’s rotor speed.

\[
\begin{bmatrix}
V_a \\
V_b \\
V_c
\end{bmatrix} = \begin{bmatrix}
R & 0 & 0 \\
0 & R & 0 \\
0 & 0 & R
\end{bmatrix} \begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix} + \begin{bmatrix}
L - M & 0 & 0 \\
0 & L - M & 0 \\
0 & 0 & L - M
\end{bmatrix} \frac{d}{dt} \begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix} + \begin{bmatrix}
e_a \\
e_b \\
e_c
\end{bmatrix}
\]

\[
\omega_r = \frac{E_m}{2 \ast P \ast \phi}
\]
\[ I_{ref} = \frac{T_{ref}}{2 \pi P \phi} \]

Where, \( V_a, V_b, V_c \) phase voltage, \( I_a, I_b, I_c \) Phase currents, \( e_a, e_b, e_c \) back EMF of BLDC motor

The early research into program is to measure the speed of the motor engine and to be re-calculated using the EMF equation process. After assessing the approximate controller, the reference current is determined on the basis of the it is related to the equation (5). Estimates are created using an essential rotor angled by the operator. To produce the gate pulses must be measured, which is combined with the reference current. The Inc& Con calculation is used to extract of the obligation duration is determined from the current reference value's MPPT algorithm balances. Hysteresis Controller. The present controller function properly only when we are correctly characterizing the two category viz. Higher band hysteresis and lower relay band hysteresis. Present error is fed as the controller input and when the error is below or when the pulse exceeds the band limit, low gate pulse is produced to shut down switches. Unless the band limit is selected, it will be low.

Figure 7. Proposed Hysteresis Controller

4. Simulink Results

Figure 8. Shows the PV and WECS powered CFSI powered BLDC engine drive simulink implementation. Hybrid renewable energy source is built which contains solar parameters like speed and torque PV and wind-generated energy is fed to CFSI. Figure 9 represents the waveform of DC connection voltage, and the BLDC motor stator current. Speed is measured using rear EMF calculation, sensing phase voltage and phase currents. EMF is calculated with mathematical simulation machine back. Rotor speed is determined on the basis of the relationship between back EMF and predicted engine speed.

Figure 8. Overall Matlab/Simulink diagram for BLDC Motor
The IFOC has removed harmonics of current and THD value to the lowest compared to the control techniques used previously. For a reference speed of 600 rpm, the response of system is shown in Figure 11 at Figure 13. Plot of actual speed, electro-magnetic torque and approximate speed of the BLDC motor is shown.

The findings show that projected velocity is equal to the real velocity at all Times also at different load commands and different reference speeds.
5. Conclusion
In this paper, improvement of the efficiency of a sensor with a lower BLDC engine fed from hybrid renewable energy sources such as PV and a current charged inverter using IFOC control technology paper. Using FFT stator current study, improved sensor performance less BLDC motor with IFOC control technique is tested to reduce THD of the drive. The DC contact voltage, stator current harmonics are speed and torque are achieved using the IFOC control method MATLAB / simulink verifies the outputs of PV and wind driven CFSI.

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