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Research paper

A Novel Approach of Renewable Energy Powered Hybrid Electrical Vehicle Using BLDC Motor

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Abstract

Renewable energy based hybrid electrical vehicle (HEV) has been useful to make clean and green environment. Solar energy is available during day time which feed energy to run HEV and opposite wind energy also one of the input and it also useful to feed energy input to the vehicle. In the existing system of hybrid powered vehicles are not utilizing this energy properly due to some drawbacks related to blade stiffness, vehicle friction torque and efficiency. This proposed system overcome those difficulties and supply the power very conveniently. The noveltyof this paper is wind extraction; this system of approach is very helpful to convert the available opposite wind to the vehicle into useful energy. Wind outlet provisions are also available to reduce vehicle friction torque. The power sources such as solar, wind and fuel cell and the appliances of the car made sophisticated, which are controlled by a universal controller. The BLDC motor controlled by fuzzy PID concept of making the system is so reliable and control all the system operations effectively.

Keywords: *Novel wind extractor, BLDC, Solar and PID controller.*

1. Introduction

Future fuel consumption growth of vehicle in the world is kept on increasing 2 % per year [9]. In the upcoming years of next four decades, the electrical powered vehicle requirement is essential to compensate fuel demand and also this is very helpful for living things. Present electrical demand in the world is 15 TW; it is growing upto 30 TW approximately [1]. Electrical energy requirement has been fulfilling from natural resources of fossil fuels and other minerals by non-renewable type of power extraction. This form of power generation is very harmful for living things; the pollution outlet of non-renewable thermal plant is 37% of So_2 and 20% of other gases, which are making dangerous things [10]. Coal conversion efficiency also only 10% and it produce ashes & other dust particles and its final efficiency are 40% [2].

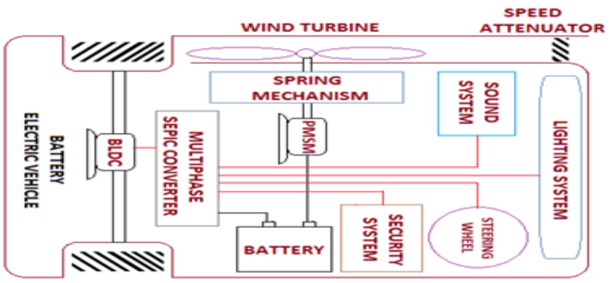


Fig. 1. Proposed renewable energy powered vehicle

This form of power generation does not helpful for living things itscreates environmental pollution and increases the global warming, which leads to create acid rain [3]. Main drawback of conventional form of power generations are less efficiency, air pollution, global warming and the power generation also in remote areas or non-people living areas, which required huge materials to transmit power to the load centre [7].

The conventional form of electric vehicle powered from some charging stations, the problem of this method is charging time, the vehicle should wait until the charge will complete to 100% [4] [5] and [6]. To overcome this drawback some solar powered electric vehicle was introduced by some researchers, the drawback related to the research is non-reliable, during night time and cloudy day's source is not possible. Here the proposed research work introduced 100% renewable powered electric vehicle, which is highly reliable from three different sources, the sources are solar, wind and spring mechanism. Device which converts solar into electrical energy is known as photo-voltaic device which working under photo-voltaic principle is too fixed in the roof of the vehicle, likewise wind energy extractor placed in side of the vehicle. This novel method of extraction is the main work which produces more electrical and helps to drive the vehicle effectively.

2. Closed loop control of BLDC based vehicle drive

Closed loop control of BLDC based vehicle drive is as shown in Figure 2. It minimizes the complexities related to the existing control vehicle drive system. Proposed vehicle drive consists of two control loops, the outer loop is position control and the inner loop is for current control. This type of control system design is simple and this proposed drive consists of Fuzzy PID (FPID) controller, which improves the drive performance. The proposed vehicle drive has DC-link current in the place of three phase currents to reduce the implementation cost.

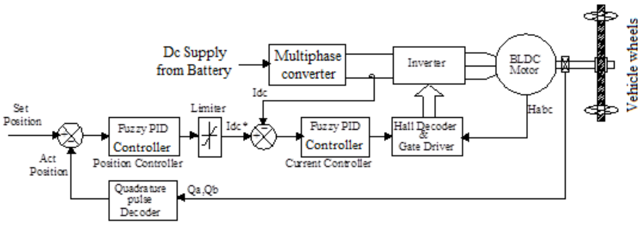


Fig. 2: Closed loop control for renewable energy powered vehicle

FPID controller is suitablefor this proposed vehicle drive is as shown in Figure 3. FPID is the combination ofFPI and FPD controllers, Measurement changes (CE) and Error (E)
E = set value – actual value&CE = (present sample– previous sample) measurement.

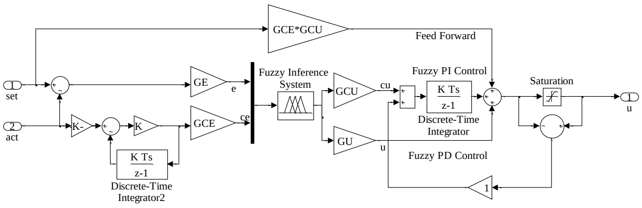
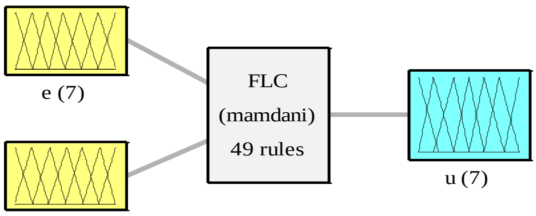


Fig. 3: FPID controller

FPID controller is designed and analysedby usingFuzzy Logic Toolbox in MATLAB/SIMULINK software. In this software have separate FIS (Fuzzy Inference System) and Graphical User Interface (GUI) to design the Fuzzy Logic Controllers (FLC). One of the FIS is Mamdani and defuzzification method is centre of gravity, which consist of two inputs and one output is constructed as shown in Figure 4.



System FLC: 2 inputs, 1 outputs, 49 rules
Fig.4: Mamdani FIS

Input and output variables were mapped by a Membership Function (MF) to work with FIS. Generally using triangular MF with a cross neighbour set of MF value of 0.5 is as shown in Figure 5 for a input variable error ‘E’.

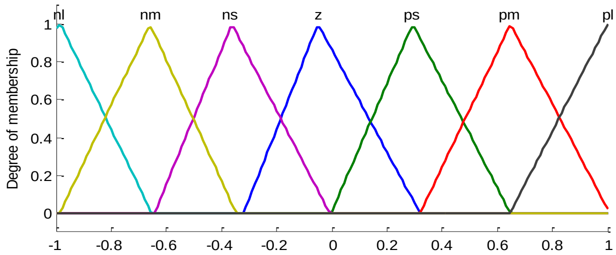


Fig. 5: Membership function of input variable ‘e’

The linguistic variables are divided into seven groups; the range of MF is used as standard form of unity ±1. Other variable MF of CE as shown in Figure 6 and output control signal ‘u’ as shown in Figure 8 are same in structures of universal standards.

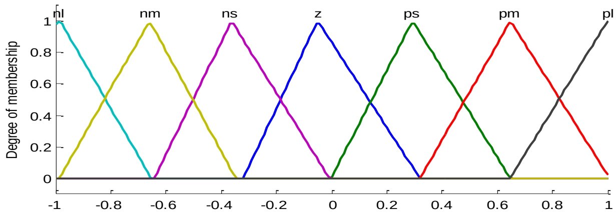


Fig. 6: Membership function of input variable ‘ce’

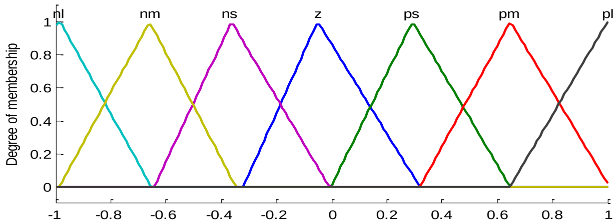


Fig.7: Membership function of output variable ‘u’

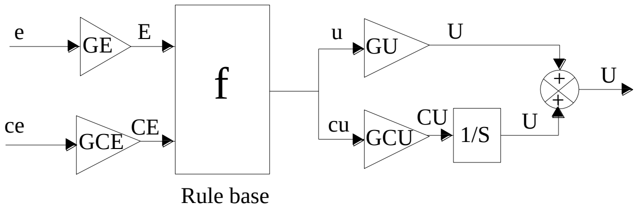


Fig.8: Fuzzy PID controller

$$U_n(FPID) = U_n(FPI) + U_n(FPD)$$

$$U_n(FPID) = \left(GCU*GCE*E_n + GCU*GE*\sum_{i=1}^{n} E_i T_s\right)$$

$$+\left(GU*GE*E_n + GU*GCE*\frac{E_n - E_{n-1}}{T_s}\right)$$

$$U_n(FPID) = (GCU*GCE + GU*GE)*E_n$$

$$+(GCU*GE)*\sum_{i=1}^{n} E_i T_s + (GU*GCE)*\frac{E_n - E_{n-1}}{T_s} \tag{1}$$

$$K_p = GCU*GCE + GU*GE \tag{2}$$

$$K_i = GCU*GE \tag{3}$$

$$K_d = GU*GCE \tag{4}$$

Output of fuzzy PID controller is as per equation 1. The Fuzzy PID controller and membership function of output variables are shown in figures 7 and 8. Equations 2, 3 & 4 are computed for PID controllers gain. From the Equations 5 to 8, the fuzzy scaling factors are determined from the known conventional PID controller gain values as listed in Table 1.

$$GE = \frac{1}{\max .error} \tag{5}$$

$$GCE = GE*\left(K_p - \sqrt{K_p^2 - 4K_i K_d}\right)\frac{K_i}{2} \tag{6}$$

$$GCU = \frac{K_i}{GE} \tag{7}$$

$$GU = \frac{K_d}{GCE} \tag{8}$$

Table 1: Designed fuzzy scaling factors

Position controller	Current controller
GE = 0.002	GE = 00.17
GCE = 0.057	GCE = 00.35
GCU = 8.703	GCU = 04.10
GU = 29.034	GU = 16.00

3. Results and discussion

A closed loop Speed control of BLDC Motor by Fuzzy PID is simulated with BLDC motor model in state space modelling, transfer equation and transfer equations. The proposed BLDC motor is simulated as per data sheets tables as shown in table. II. A 24V Faulshaber 3564024B series and their specified data sheet information's are used for simulation with corresponding system variables. Battery with inverter and BLDC motor module is taken form Simulink library block sets and their settings has been changed as per our requirements. The design of BLDC motor is verified using parameters listed in TableII and modelled in MATLAB SIMULINK environment to verify design analysis of Brushless DC motor. A Faulhaber BLDC motor (Series-2444024B)[10] and Motor driver rated current 6A peak have been taken for simulation with BLDC motor is set value of 10000rpm speed and simulated performance of motor at no load and loaded condition is presented.

Table2: BLDC motor parameters

Motor parameter	Symbol	Values	Units
Nominal Voltage	Vn	24	Volt
Output power	P_{2max}	101	Watts
Speed constant	Kn	475	Rpm/V
Current constant	Ki	0.050	A/mNm
Back EMF constant	KE	2.107	mV/rpm
Stall torque	MH	371	mNM
Friction torque, Static	Co	1.10	mNm
Friction torque, dynamic	Cv	2.4*e-4	mNm/rpm
Torque constant	`Km	20.12	mNM/A

Faulhaber BLDC Motor with model 3564B series is designed in MATLAB based on transfer function, state space modelling and transfer equations in open-loop condition and results is presented in fig.9. The Motor characteristic of each modelling method is tabulated below in Table III.

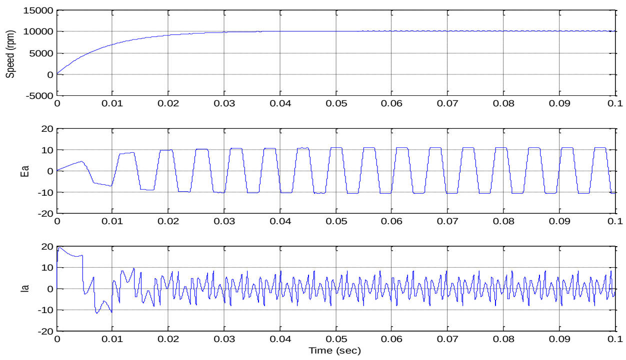


Fig.9: Output waveform of BLDC motor model in transfer functions

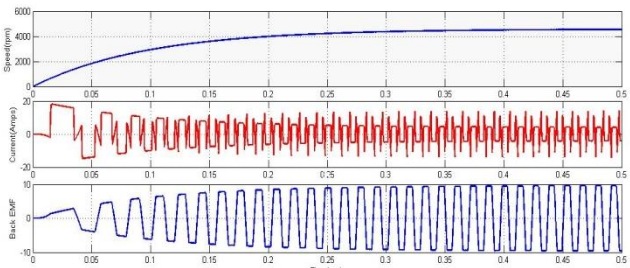


Fig.10: Output waveform of BLDC motor model in transfer equations

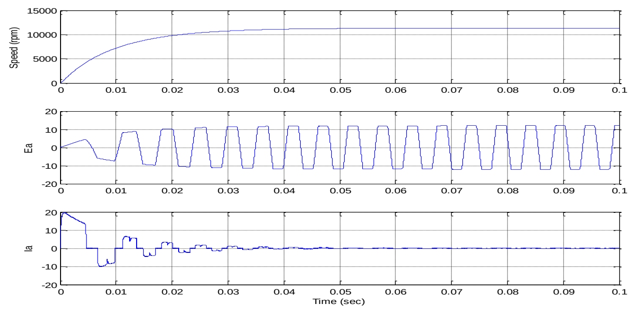


Fig.11: output waveforms of BLDC motor model in state space model

Six PWM gate pulses are generated as per decoding logic in both directions. For 120° conduction mode of inverter operation, observed results clearly show the phase delay between $Q_1$and Q_2 is 60° electrical for rest. If motor rotates clockwise, then gate pulse Q_3 lags Q_1 120° electrically. If motor rotates counter clockwise, then gate pulse Q_3 leads Q_1 120° electrically. Likewise all the gate pulses are verified.

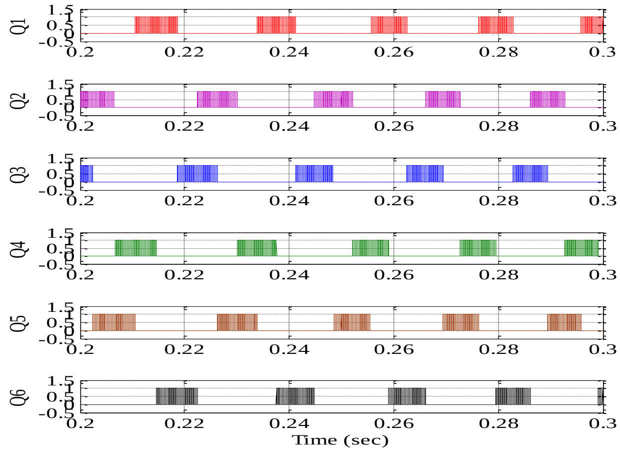


Fig.12: Gate pulse for inverter

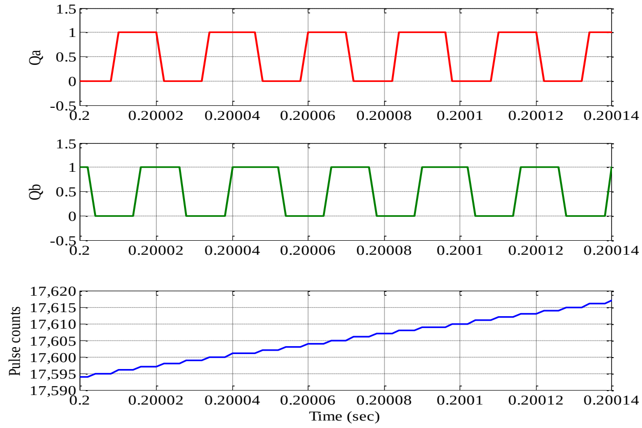


Fig.13: QEP Signal

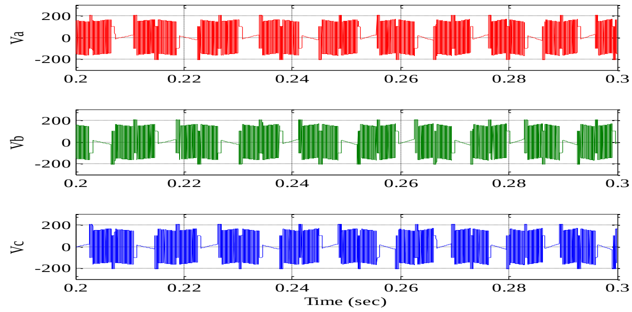


Fig.14: Phase voltage

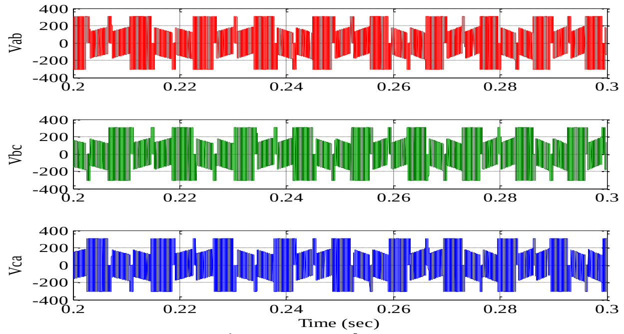


Fig.15: Line Voltage

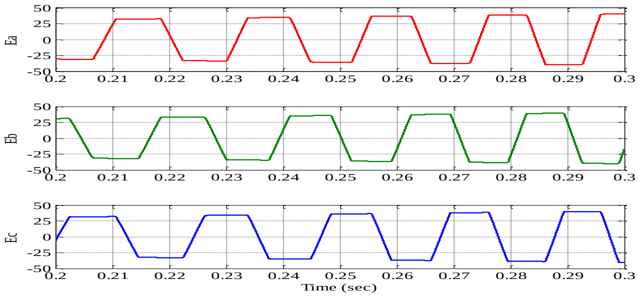


Fig.16: Back EMF

Table III BLDC Motor modelling comparison

Parameters	**Transfer Function**	**Transfer equations**	**State Space Modeling**
Speed (11300rpm)	4000 range	Achieved	Achieved
Dynamic Characteristics (settling time to reach rated speed)	Slow	Moderate	Fast
Back EMF (Pure Trapezoidal)	Achieved	Achieved	Achieved
Current (quasi Square)	N.A	N.A	Achieved
PWM Current control (IaIbIc)	N.A	Achieved	Achieved
Hysterias Current control (IaIbIc)	Achieved	Achieved	Achieved
PWM Current control (Idc)	N.A	N.A	Achieved
Hysterias current Controller(Idc)	N.A	N.A	Achieved

As in case of transfer function from fig.10 speed is achieved moderately with better dynamic characteristics compare to transfer equations and existence of poor current distortion. From fig.11 the state space modelling holds fast dynamic performance and speed achieved with rated value and generates pure quasi-square waveform to drive BLDC motor effectively. Gate pulse of the inverter, QEP signal, Back EMF, Phase voltage and line voltage are shown in the figures 12 to figure 16. Powergui block in MATLAB has automatically converted the MATLAB-model into average model in SIMULINK which is not possible in transfer function and State-space modelling of BLDC motor.

5. Conclusion

The performance of the evaluation results show that, such a modelling is very useful in studying the drive system before taking up the dedicated controller design, accounting the relevant dynamic parameters of the motor. The paper presents an implementation of BLDC motor dynamic model, by using the transfer functions, transfer equations and state space modelling using MATLAB-SIMULINK in which all methods performed well and every method has its drawbacks. An inverter mathematical model is also simulated in MATLAB-SIMULINK with corresponding encoder, current controller.

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