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# Implementation of neuro and fuzzy logic in sensing the position of BLDCM Intelligent control of BLDCM: A Literature Review

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***Abstract: The main objective of this paper is to study how can we sense the position of a brushless D.C Motor using artificial neural network/ fuzzy logic/neuro-fuzzy combination?The simulation will be MATLAB/SIMULINK based. We are change the mode of sensing from hall sensors to other form.***

**Keywords: BLDCM, fuzzy controller, MATLAB/SIMULINK, ,sensor less.**

**[I]Introduction :** The main objective of this paper is to study all the work which has been done till now on brushless D.C Motor using artificial neural network, fuzzy logic and neuro-fuzzy combination. The objective is to sense the position of the motor with the help of one of the simulation. There is a lot of work has been done in the field of control of a brushless dc motor using fuzzy logic & artificial neural network as a tool. Before getting into the depth I have gone through all the previous work done on brushless DC motor. Let's have a rough idea about BLDC Motor its mode of operation and the technique which I am going to apply and those are the primarily three concepts prevailing over the intelligent control:

- Fuzzy Logic Control
- Neural Network based Control
- Neuro-Fuzzy Control i.e., hybrid control

**[II] BLDC MOTOR**

A Brushless DC Motor (also known as a BLDC Motor), is a synchronous electric motor powered by a direct current. As the name implies, the Brushless DC Motor does not operate using brushes; rather it operates with a controller via electronic commutation.

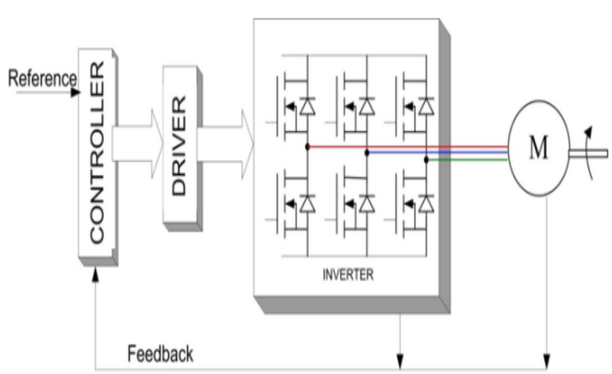


Fig. No.1

An electronic Brushless DC Controller (also known as a Driver, or Electronic Speed Controller), replaces the mechanical commutation system utilized by a Brush DC Motor, and is required by most Brushless DC Motors to operate. In a Brushless DC Motor controller, either a Hall Effect Sensor or Back EMF (Electromotive Force) is used to identify the position of the rotor. Understanding the orientation of the rotor is crucial to operating the Brushless DC Motor.

The Hall Effect uses three hall sensors within the Brushless DC Motor to help detect the position of the rotor. This method is primarily used in speed detection, positioning, current sensing, and proximity switching. The magnetic field changes in response to the transducer that varies its output voltage. Feedback is created by directly returning a voltage, because the sensor operates as an analogue transducer. The distance between the Hall plate and a known magnetic field can be determined with a group of sensors, and the relative position of the magnet can be deduced. A Hall sensor can act as an on/off switch in a digital mode when combined with circuitry.

Back EMF, also known as the Counter-Electromotive Force, is caused by a changing electromagnetic field. In a Brushless DC Motor, back EMF is a voltage that occurs where there is motion between the external magnetic field and the armature of the motor. In other words, the voltage is developed in an inductor by an alternating or pulsating current. The polarity of the voltage is constantly the reverse of the input voltage. This method is commonly used to measure the position and speed of the Brushless DC Motor indirectly, and due to the lack of Hall Sensors within the controller, these are often referred to as sensor less controller.

Optical Encoders can also be added to the Brushless DC Motor, allowing both direction and speed to be determined. More precise applications may use Optical Encoders with a third index signal, to determine pulse per revolution.

**[a]Four Quadrant Operation:**

There are four possiblemodes or quadrants of operation usinga Brushless DC Motor which is depicted in
Fig. 3.When BLDC motor (Fig. 4) is operating in the first andthird quadrant, the supplied voltage is greater than the backemf which is forward motoring and reverse motoring modesrespectively, but the direction of current flow differs. Whenthe motor operates in the second and fourth quadrant the valueof the back emf generated by the motor should be greaterthan the supplied voltage which are the forward braking

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andreverse braking modes of operation respectively, here again the direction of current flow is reversed.The BLDC motor is initially made to rotate in clockwise direction,but when the speed reversal command is obtained, thecontrol goes into the clockwise regenerationmode,which bringsthe rotor to the standstill position. Instead of waiting for the absolute standstill position, continuous energization of the mainphase is attempted. This rapidly slows down the rotor to a standstillposition. Therefore, there is the necessity for determiningthe instant when the rotor of the machine is ideally positionedfor reversal.Hall effect sensors are used to ascertain the rotor position and
from the Hall sensor outputs, it is determined whether the machine has reversed its direction. This is the ideal moment for energizing the stator phase so that the machine can start motoringin the counter clockwise direction

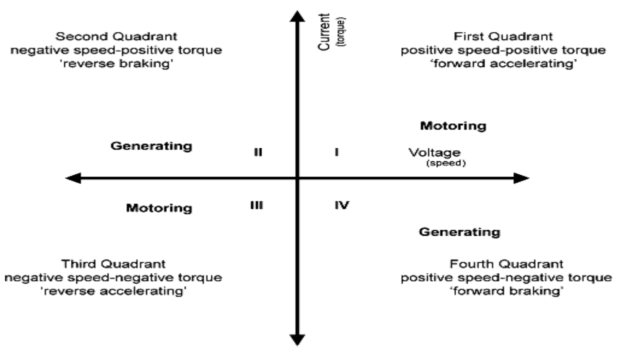


**Fig. 2 Four Quadrants of operation.**

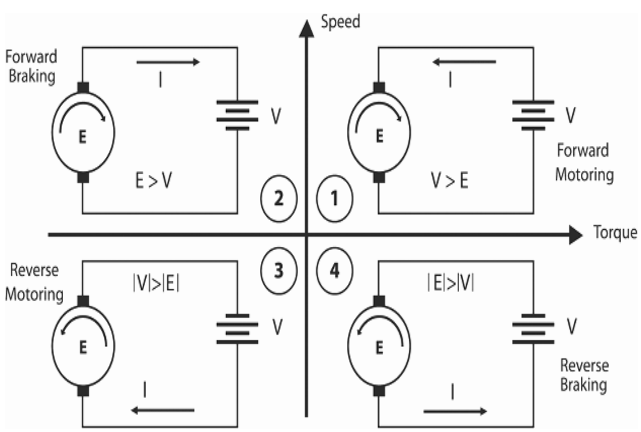


**Fig. 3. Operating Modes**

**(A)Fuzzy Logic Control**
In the first concept, the controller is represented as a set of rules, which accepts/gives the inputs/outputs in the form of linguistic variables. The main advantages of such a controller are:

- Approximate knowledge of plant is required
- Knowledge representation and inference is simple.
- Implementation is fairly easy.

**MO-yuen Chow Paul V. Goode et.ol 1993 [1]**started working on early detection of faults in rotating machines with the emerging technology of *artificial neural networks* and fuzzy *logic* which provided enhanced safety, reliability, and economic issues of power systems without the use of expensive equipment or accurate mathematical models that were required in conventional fault detection techniques. Since most machine dynamics are non-linear and stochastic, many assumptions must be made regarding the system in order to arrive at a simple and reasonable mathematical model of the machine. Although the *ANN* can provide the correct input-output fault detection relation, it is essentially a "black box" device; i.e., it does not provide heuristic reasoning about the fault detection process. Fuzzy *logic* could be a solution to this problem. Fuzzy logic can easily and systematically transfer heuristic, linguistic, and qualitative knowledge, (preferred by humans) to numbers and quantitative knowledge, and vice-versa. Unfortunately, the major drawback of fuzzy logic is the difficulty in giving an exact solution to the problems, while an exact solution is essential for motor fault detection. *Learning theory,* based on the *Principle* of *Maximum Entropy,* is presented in the paper to estimate the average number of training examples.

**(B)Neural Network based Control**
In the second concept, the controller is represented as a nonlinear map between the inputs and outputs. Depending on a specific plant, the map (in the form of a network) can be trained to implement any kind of control strategy. A neuro-controller (neural networks based control system) performs a specific form of the adaptive control with the controller taking the form of a multi-layer network and the adaptable parameters being defined as the adjustable weights. The main its advantages are:

- Parallel architecture
- Any kind of nonlinear mapping is possible
- Training is possible for various operating conditions, so it can be adapted to any desired situation.

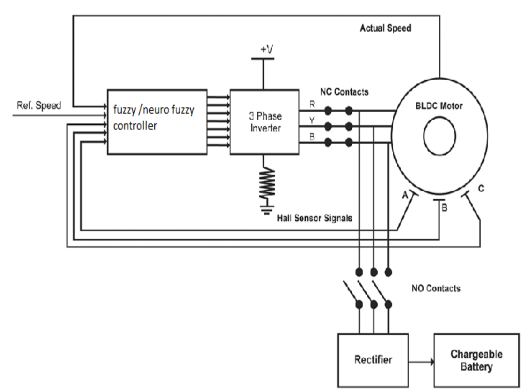


**Fig. 4BLDC Motor with Fuzzy/neuro controller**

**Fengtai Huang &DapengTienet.ol 1996 [2]** worked to identify the rotating angles of the rotor instead of using position sensors they used neural networks. The simulation result shows that stator voltages and currents can be used to estimate the rotor position. This approach was based on flux linkage estimation, which may pave the way to intelligently controlling a brushless dc motor in real time.. One more problem was handled by **AmedRubaai, Raj Kotaru, M. David Kankam, et.ol 1997 [3]**

in there paper they proposed an on-line control architecture for non-linear brushless dc motors operating in a high performance drives environment. The developed control architecture possesses the capabilities of simultaneous on-line identification and control. The control action was implemented in such a way that system speed trajectory followed a pre-determined signal. The ability of the neuro-controller to maintain reasonable tracking accuracy in the presence of external noise was demonstrated. The neural network considered there was a feed forward network with sigmoid functions. The ability of the neuro-controller to learn (in real-time) a periodic jump/drop in the external load was also simulated, and very promising results were observed. It is difficult to acquire higher performance using conventional PID controller, because BDCM servo system is a nonlinear system with uncertainties of parameters and environment variations during operation.**Wang Liinei, Wang Yan &GuoQingding, LuoRuifLiet.ol 1998[4]** worked on DSP based neural network controller of high performance brushless DC motor servo system. This paper presents a position servo controller of BDCM based on multi-layer feed forward neural network. In order to satisfy the real time requirement of the system a DSP (TMS320C30) was used as an executing processor.

In this paper, three layer structures were adopted. In theory, the more the hidden nodes, the better the mapping ability of NN. But the computing time is correspondingly increased. During a trial-and-error procedure, seven nodes are certified in hidden layer. Results showed that NN controller have good tracking performance and can adapt the uncertainties of system parameters. Simulation and experiment result indicate the feasibility of proposed control scheme. Compare with conventional controller, NN controller can remain high accuracy even in the condition of uncertainties existing in plant parameters and control process.**Ahmed Rubaai and Raj Kotaru again in 1999 [5**] worked on a nonlinear neuro-controller but this time it was for controlling the speed of brushless dc motors operating in a high performance drives environment. They used three-hidden-layer dynamic neural networks to control inputs and the identification parameters of the system simultaneously in real time while the system in operation. The problem of persistently spanning excitation faced with the use of an on-line neuro-controller was addressed. They verified the ability of the neuro-controller to remember previously-trained reference tracks when confronted with an input excitation that was markedly different from what it was trained and also investigated was the sensitivity of real-time neuro-controllers to system parametric changes. Simulations showed that the network needs to be trained for longer periods but eventually succeeds in capturing the dynamics of the rapid load changes in the process of fulfilling its main objective of emulating the brushless dc motor system dynamics.Techniques. **Rajesh Kumar SanthoshVijayaPadmanabanet.ol 2006[7]** presented a sensorless scheme for rotor position estimation of permanent magnet brushless dc motor using Artificial Neural Networks with the formulation and comprehensive analysis of vector control PMBLDC drive. They found that the developed neural network based position estimation scheme worked efficiently for both on loading and at no-load. The sensorless scheme not only eliminates the position sensor, thereby cutting the cost but also transforms the drive in to a highly efficient drive by eliminating the losses caused by the position sensor. The estimation error was found to be very minimal of the order of fraction of a percent thereby proving that the developed system was a very efficient and reliable.**Yingfa Wang, Changliang Xia, Maohua Zhang, Dan Liu et.ol 2007 [8]** presented an adaptive speed control approach based on genetic algorithm tuning Radial Basis Function (RBF) neural network controller for brushless DC motor, the RBF neural network whose structure and parameters of hidden-unit have been trained by genetic algorithm off-line constitutes a speed loop controller. **S. J. Imen and M. Shakeriet.ol 2007 [9]** reported an effective control method for linear motor by using feedback and learning adaptive feed forward controller. The feedback is preformed based on a PID method by linear Second order model of a linear motor. The learning adaptive feed forward controller was based on neural network with one hidden layer second-order B-spline basis functions and was used for prediction the un-modelled forces and unknown relations. **S. M.M.Mirtalaei, J.S.Moghani, K.Malekian, B.Abdiet.ol 2008 [10]** worked on sensorless operation over wide speed range. They presented a novel sensorless control method for brushless DC motors using two similar fuzzy logiy based neural network observers. To determine the commutation instants, a new technique based on the sign of the back-EMF space vector components was proposed. They replaced fuzzy logic observer by two neural network ones with the same performance which are easier to implement. **Vinatha U, SwethaPola.,TCS, Dr K.P.Vittalet.ol [11]** presented the modeling of Brushless DC motor drive system along with control system for speed and current by using MATLAB / SIMULINK. The performance evaluation results show that, such a modeling is very useful in studying the drive system before taking up the dedicated controller design, accounting the relevant dynamic parameters of the motor. **Zheng LI et.ol 2009 [12]** presented a control scheme combined with CMAC neural network and PID controller for the brushless DC motor. The mathematical model of square-wave PM BLDC motor is adopted and used to build the simulation block models.

The simple fuzzy controller represents a good nonlinear controller; however, it cannot adapt its structure whenever the situation demands. Sometimes the fuzzy controllers with fix structures fail to stabilize the plant under wide variations in the operating conditions. These types of controllers also lack the parallelism of neural controllers. On the other hand the neural networks are very much adaptive to situations by adjusting their weights accordingly. The parallel architecture enables faster implementation of the control algorithm. However in the presence of noise and other uncertainties the performance may deteriorate. Some times in certain neural controller structures the model of the plant is required. But in case of plants whose model becomes uncertain it is difficult to use neural networks with fixed structures.. **A. HalvaeiNiasar, A. Vahedi, H. Moghbelli**

**after 1999 [6]** introduced principle of a new adaptive Neuro-Fuzzy Controller (NFC) for speed control of Brushless DC (BLDC) motor drives. They observed that NF controller had better performance rather than PI controller. In order to overcome the disadvantages introduced by position sensors, there arouse a need for sensorless scheme of the drive.**K. Naga Sujatha, Dr.K.Vaisakh, Anand.Get.ol 2010 [13]** presented a control scheme combined with neural network, fuzzy controller and PI- controller for the brushless DC motor. Traditional sensorless BLDC control techniques suffer from low efficiency at low speed due to degraded signal to noise ratio on feedback signals and low dynamic response so, **Carlo ConcariFabrizioTroniet.ol 2010[14]** presented a novel sensorless control algorithm based on a differential measurement, which allows higher dynamic performance and lower minimum operating speed with respect to traditional techniques without requiring dedicated hardware solutions or complex calculations. BLDC's speed servo system is multivariable, nonlinear and strong coupling. Its performance is easily influenced by the parameter variation, the cogging torque and the load disturbance.To solve the deficiency **Zhi Liu, Hong Guo, Dayu Wang, Zhiyong Wu, JinquanXuet.ol2010[15],** represented the algorithm of active-disturbance rejection control (ADRC) based on back-propagation (BP) neural network. The ADRC is independent of accurate system and its extended-state observer can estimate the disturbance of the system accurately. However, the parameters of Nonlinear Feedback (NF) in ADRC are difficult to obtain. **SheebaJoice, C. ,Dr. S.R. Paranjothi, Dr.JawaharSenthil Kumar et.ol 2011[16]** used dsPIC30F4011 controller with the BLDC four quadrant operation. They simulated the results using MATLAB / Simulink and analysed, the proposed control scheme. It made the motor to change the direction from CW to CCW without going to standstill position. The time taken to achieve this braking is comparatively less. **P.Devendra, Rajetesh.g, K Alice Mary, and Ch. Saibabuet.ol 2011[17]** also investigated sensorless control of BLDC Motor. The performance of this method is like both Artificial Neural Networks (ANN) and Fuzzy Logic (FL). In both ANN and FL case, the input pass through the input layer (by input membership function) and the output could be seen in output layer .Therefore, ANFIS uses a combination of least squares estimation and back propagation for membership function parameter estimation. The validity of the proposed approach is shown through simulation. It is demonstrated in this paper that ANFIS is a very powerful approach for building a complex and nonlinear relationship between a set of input and output. Nevertheless, most of these converter topologies employ the hard-switching technique which causes high switching losses and severe electromagnetic interference **Sreekala. P Victor Jose et.ol 2011[18]** proposed neural network based speed control of brushless DC motor using soft-switching inverter. A sincere effort is made to develop a fuzzy logic and neural network controller in a speed control of BLDC motor drive using resonant pole inverter with MATLAB Simulink. The waveforms for stator current and back emf were studied in comparison with the neural network Control of BLDC motor drive. R. Kandiban and R.Arulmozhiyalet.ol 2012 worked on the speed control of a BLDC motor using adaptive fuzzy controller. They also studied the various controllers and found that it is difficult to tune the parameters and get satisfied control characteristics by using normal conventional PID controller.and comparatively Adaptive fuzzy controller is much easier or computing.the modelling, control and simulation of the bldc motor have been done using package MATLAB/SIMULINK

These three concepts prevailing over the intelligent control are used by many of the scholars and researchers in their work. Let's through a light on the work they have done and the problem they faced while working on their area of inquiry. In the entire papers one thing was common in their area of inquiry and that is BLDCM. I have noticed the key concepts, factors, variables. And the current theories they have used or found. I have highlighted the inconsistencies and other shortcoming in the previous methods. And also studied why further testing was required like lack of evidence, inconclusiveness, contradictory/limited results and what designs were faulty.

## (IV)BLDCM AND INTELLIGENT CONTROL USING MATLAB/SIMULINK

Safety, reliability, and economy were the main issues faced during that era where expensive equipment or accurate mathematical models were required in conventional fault detection...**G.RanjithKumar& K.N.V Prasad ET.OL 2012 [19]** has simulated two different types of inverters for current control of a BLDCM. They showed that current controller with cascaded H-Bridge MLI is better based on the FFT analysis observed from the simulation results.the ripple content in the voltage and current waveorms are observed with current controller using VSI and current controller using cascade H-Bridge MLI**. H.E.A. Ibrahim , F.N. Hassan , Anas O. Shomeret.ol 2013 [20]** this paper presents a Particle Swarm Optimization (PSO) technique and bacterial foraging (BF) technique for determining the optimal parameters of (PID) controller for speed control of a brushless DC motor (BLDC) where the (BLDC) motor is modelled in Simulink in Matlab. The proposed technique was more efficient in improving the step response characteristics as well as reducing the steady-state error, rise time, settling time and maximum overshoot.By comparing between PSO method and BF technique, it shows that PSO method can improve the dynamic performance of the system in a better way.**MadhurimaChattopadhyaya, PriyankaRoyb , SharmiDuttaaet.ol 2012** in this paper to study the behavioural characteristic of Brushless DC motor and also analyses the harmonics present in the stator current, rotor speed and acceleration of the BLDC drive circuit a simulation model has been developed. Hence in order to improve the accuracy of the motor drive control system, we have introduced a de-noising module in the feedback path. This de-noised signal is compared with the original one and the deviation (error) between these two signals is further rectified by the PI controller present in the forward path. All these analyses are achieved by using discrete wavelet transform (DWT). For simulation purpose, we have used MATLAB/SIMULINK based platform and developed the models of those motors in SIMULINK from mathematical expressions derived from working principles of motor. The purpose of the PI controller is to achieve good tracking to torque (i.e. angular acceleration). The acceleration is decomposed and de-noised further by choosing Coif let as mother wavelet. The study of the de-noised signal is discussed in detail.**AgusPurwadi, Jimmy Dozeno, Nana Heryanaet.ol 2013 [22]** The growing development of Electric vehicle industry due to more greener transportation needs, encouraging ITB as a research based educational institution to give their effort and participation in developing electric city car prototype, especially for Indonesia used. Two fundamental components in the electric car are the electric motor and its energy storage system. The motor used in this ITB-1electric car is brushless dc (BLDC) motor type. A controller will be used to convert the dc source into ac for BLDC motor power source. How far an electric car can reach their destination depends on how much energy that is stored in the batteries. This electrical energy storage will affect performance of the electric car. Therefore we have to protect the battery from anything that can make the battery's life shorter. Voltage is one of the parameters that must be controlled by the battery management system, so that the battery can be protected effectively. In this paper, a10 kW BLDC motor and its energy storage i.e. LiFePO4 battery types, will be evaluated based on their performance result from the tests.**DebjyotiChowdhury, MadhurimaChattopadhyay, Priyanka Roy et.ol 2013 [23]**This paper deals with a new commutation approach to achieve the sensor less drive of permanent magnet BLDC motor over the conventional six switch commutation circuitry. In the simulation model, we have introduced four switch three phase Brushless DC (BLDC) motor drive in which the rotor position is estimated using back EMF detection technique. In sensor less concept, the electronic commutation circuit plays an important role to drive motors because of their not self-commutating nature. In this work, power electronics based inverter along with logical circuitry has been employed in order to perk up the sensor less technique of BLDC motor. This driving procedure is always advantageous over sensored drives of BLDC motors, which come with bulky module using Hall-effect position sensors to detect the rotor position. Thus, this sensor less performance not only reducing the hardware complexity but also minimizes the consumption of power by associated circuitry. The effectiveness of the design is demonstrated through simulation results. The performance of this design is first evaluated by MATLAB based SIMULINK platform which gives a satisfactory result. Finally, this study helps us to develop a real time implementation of cost effective drive without hall sensors for BLDC motor.

**(V)CONCLUSION**

If you will notice that none of them has worked upon implementation of Four Quadrant Operation of Three Phase Brushless DC Motor with load variation using artificial neural network/fuzzy logic to sense the position of the motor. And there is a lot of scope because majority of the scholars have worked on the speed control of a BLDC motor. We can also work on an artificial neural network as a controller modelled on MATLAB and compare it with the conventional controllers.

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