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# Hybrid Intelligent Controller for Interior Permanent Magnet Synchronous Motor Drives

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***Abstract:*** ***A hybrid neuro-fuzzy scheme for online tuning of a genetic-based proportional–integral (PI) controller for an interior permanent-magnet synchronous motor (IPMSM) drive is presented in this paper. Under various disturbance conditions this proposed controller measures accurate speed control for IPMSM. Based on motor dynamics considering uncertainties initially different operating conditions are obtained in this work. The PI controller parameters in a closed-loop vector control scheme are optimized using genetic algorithm in each operating conditions. The minimum speed deviation, minimum settling time and zero steady-state error is obtained using a performance index in the optimization procedure. The PI controller parameters to ensure optimum drive performance under different disturbances are online tunned using a fuzzy basis function network (FBFN). A natural framework for combining numerical and linguistic information in a uniform fashion are gain by using a proposed FBFN-based PI controller. A digital signal processor board DS 1102 for a laboratory 1-hp IPMSM is used for real time implementation of a proposed controller. Effectiveness of the proposed controller is verified by simulation as well as experimental results at different dynamic operating conditions. A proposed controller is used for an IPMSM drive applications.***
***Keywords: Neuro-fuzzy control, permanent-magnet synchronous motor, proportional–integral (PI) controller, speed control, vector control, Digital signal processor (DSP), genetic algorithm (GA).***

## I. INTRODUCTION

In the last two decades, technology has improved nature of the manufacturing process. Automation is the need of the industries to increase productivity and quality. Electric drives in the industry play important roles to automate the process. Fast and accurate control of machines is simple. User friendly control programs will make the automation effectively. Most of the industrial processes are multivariable in nature, which increase the complexity of the system and which results in demand of advanced control strategies. Now a day, Artificial Intelligent (AI) algorithms are to play significant roles in science and engineering as a family of nature-inspired, population-based algorithms. Artificial Intelligent (AI) techniques are used to provide optimal solutions to several complex benchmark problems. Literature reviews indicate that the IPMSM has now a fashionable design option in all fields such as transportation, industrial processing, power plants, and domestic appliances and so on. Control of IPMSM is complex due to its highly nonlinear nature. PI controller, Fuzzy, ANN, ANFIS and GA controllers are investigated and still there is a scope to increase the performance of the motor.

## II. LITERATURE SURVEY

Harshada V. Deo [2] The aim of this paper is to present the study of various control techniques used for speed control of permanent magnet synchronous motor (PMSM). As PMSM is increasingly used in high-performance applications in industry, such applications require speed controllers with high accuracy, high performance and flexibility and efficiency in the design process and implementation. The study reviews that various approaches are available regarding both the controller type (ranging from fuzzy logic, neural networks to classical PID control algorithms) and the implementation (ranging from pure hardware implementations to combined hardware-software or pure software solutions). However, the majority of the reviewed papers lack a holistic modeling of the control system. There is a gap between the design and simulation of the controller and on other side, the design of the hardware implementation. Due to this accuracy, performance and efficiency of the control system of PMSM gets affected. Thus the future scope is to try to fill in the gap in the existing literature by developing a novel system which will overcome drawbacks of the existing methods.

A. Shakilabanu [3] The essential characteristics of traction motor are accurate speed and stability during load change. In this paper three types of controllers PI, Fuzzy PI and BLEBIC are used as speed controllers in the IPMSM control and simulated in MATLAB / Simulink. The performance of the system is analyzed with all three controllers and compared. From the simulation results it is

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clear that system performance is improved by Fuzzy PI and BLEBIC controller. The Fuzzy PI controller improves speed response compared to conventional PI controller in terms of overshoot, steady state error, drooping speed during load change and settling time after load change. BLEBIC controller is better than PI and Fuzzy PI controller in terms of stability. It quickly settles in speed after load change compared to other two controllers. Meantime BLEBIC controller produces the same response for rated speed, above rated speed and below rated speed of the machine. Simulation results show the robust performance of BELBIC against the disturbance. The BLEBIC controller based IPMSM drive is suitable for traction to operate in a wide speed range and frequent load changing condition.

Mohamed Zaky [4] An adaptive and robust sliding mode position control of an IPMSM drive has been proposed. The switching surface of SMC has been designed using a LQR technique. The quadratic optimal control method has been used to select the state feedback control gain. Feedback and switching gains are selected to satisfy both stability and fast convergence of the IPMSM. Simulation and experimental results have been presented to validate the performance of the position control method. A SMC-based IPMSM drive system with adaptive feedback gain design has confirmed a superior behavior than a traditional SMC. As proved, the conventional SMC is sensitive to parameters uncertainty in the reaching mode. However, the proposed SMC position controller has no overshoot with a less sensitivity to parameters uncertainty. Also, the rotor position is robust to a load disturbance and backs rapidly without chattering. P. Jeevananthan [5] a fuzzy rule-base design of fuzzy logic speed control has been studied for speed control of vector controlled PMSM Drive. The set of fuzzy decision rules are formulated based on the literature review of the controller's design. In this paper, comparative results for traditional PI controller and Fuzzy logic controller for speed response during start-up under no load, load disturbance and changes in command settings. The Simulation study is realized in MATLAB environment. The investigation of fuzzy controllers is carried out based on several selected speed response. The work can be upgraded to sensor less speed controller by using speed and position estimators. Z. Hashemia [6] An AW controller for an interior permanent magnet synchronous motor drive is presented in this paper. The AW controller parameters have been optimized off-line by using a GA technique with a performance index to reflect the minimum settling time, minimum overshoot/undershoot, and zero steady-state error. Based on the various operating conditions and optimized control parameters, the RBFN has been trained for on-line tuning of the AW controller parameters. The simulation results show the ability of the proposed technique under different operating conditions, such as sudden load change, and step change of speed (over a wide speed range). Negar Etemadi [7] in this paper investigated an intelligent control of permanent magnet synchronous motors. It was learning process using active control. In fact, by solving the active control answer, the correct answer is given learning process. Intelligent controller in simulation results were evaluated with different initial conditions, good results were obtained. In the second simulation, was considered a set point. The simulation results show that the essence of chaos is learning well. The architecture proposed in Table 1 is expressed almost the best mode available. Membership functions of input-output type, number of repetitions, the most important factors. Intelligent controller must see PMSM workspace. For this reason in Fig. 6 after stability (suppression chaos) it is considered to be a desired value. It can be intelligent controller helps to understand the nature of chaotic PMSM. The simulation results show a good performance intelligent control. Atif Iqbal [8] the paper deals with vector control of a three-phase surface mount PMSM, utilizing an indirect rotor flux-oriented controller and model reference adaptive fuzzy logic speed controller. Operation in the speed mode is studied, utilizing the current control in the synchronous reference frame. The attainable performance is examined by simulation as well as experimentation. Very fast dynamic behavior is achieved by utilizing a model reference fuzzy logic controller in the speed loop. A number of transients including acceleration, deceleration, and reversing and load rejection are examined. It is shown that by using an FLMRC very quick and precise control can be achieved.

## III. PROPOSED SYSTEM

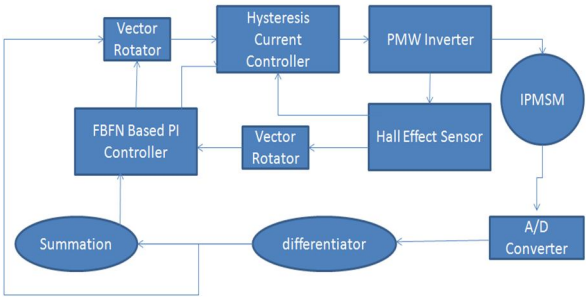


Fig 1 Block diagram of the proposed FBFN-based controller for IPMSM drive

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The block diagram of the closed-loop vector control scheme of the IPMSM incorporating the proposed FBFN controller is shown in Figure 1. The drive is experimentally implemented using a digital signal processor (DSP) board DS1102 through both hardware and software.

The hardware schematic for real-time implementation of the proposed IPMSM drive is shown in Figure 2. The DS1102 board is based on a Texas Instruments (TI) TMS320C31, a 32-bit floating-point DSP. The DSP has been supplemented by a set of on-board peripherals used in digital control systems, such as A/D, D/A converters and incremental encoder interfaces.

The DS 1102 is also equipped with a TI TMS320P14, a 16-bit microcontroller DSP that acts as a slave processor and is used for some special purposes. In this work, the slave processor is used for digital I/O configuration. The actual motor currents are measured by the Hall-effect sensors, which have good frequency response and are fed to the DSP board through an A/D converter. As the motor neutral is isolated, only two phase currents are fed back and the other phase current is calculated from them. The rotor position is measured by an optical incremental encoder which is mounted at the rotor shaft end. Then, it fed to the DSP board through encoder interface.

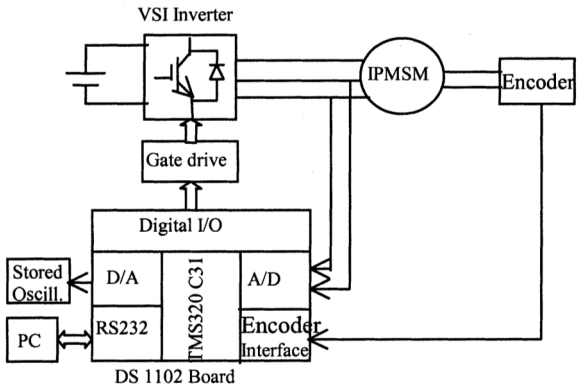


Fig 2 Hardware schematic for real-time implementation

The encoder generates 4096 pulses per revolution. By using a fourfold pulse multiplication the number of pulses is increased to 4 4096 in order to get better resolution. A 24-bit position counter is used to count the encoder pulses and is read by a calling function in the software.

The motor speed is calculated from the rotor position by backward difference interpolation. A digital moving average filter is used to remove the noise from the speed signal. The calculated actual motor speed compared with command speed and the speed error is used to calculate the torque component of the current using the FBFN-based PI control algorithm. The command phase currents are generated from and using inverse Park's transformation. In order to implement the vector control algorithm, the hysteresis controller is used as the current controller. It is to be noted that other types of current controllers have also been used earlier.

However, it is beyond the scope of this paper. The hysteresis current controller compares the command currents with the corresponding actual motor currents and generates the logic signals, which act as firing pulses for the inverter switches. Thus, these six PWM logic signals are the output of the DSP board and are fed to the base drive circuit of the inverter power module. The D/A channels are used to capture the necessary output signals in a digital storage oscilloscope. The complete IPMSM drive is implemented through software by developing a program in high-level ANSI "C" programming language.

The program is compiled by the TI "C" compiler and then the program is downloaded to the DSP controller board. The sampling frequency for experimental implementation of the proposed IPMSM drive system is 6.67 kHz.

## IV. CONCLUSION

A novel speed control technique based on a hybrid intelligent controller for an IPMSM drive has been presented in this paper. In the proposed hybrid intelligent approach a new neuro-fuzzy technique is used for online tuning of the parameters of a PI controller whose initial values are optimized by a GA. The closed-loop vector control of the IPMSM drive incorporating the proposed FBFN controller has been successfully implemented in real time for a laboratory 1-hp IPMSM drive. The PI controller parameters have been optimized offline using a GA with a performance index to reflect the minimum settling time, minimum overshoot/undershoot, and zero steady-state error. Based on the optimized operating conditions and control parameters the FBFN structure has been developed and trained for online tuning of the PI controller parameters. The validity of the proposed control technique has been established both in simulation and experiment at different operating conditions such as sudden load change, step change of speed,

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parameter variations, etc. There is close agreement between simulation and experimental results. The drive has been found robust in terms of quick response and disturbance rejection.

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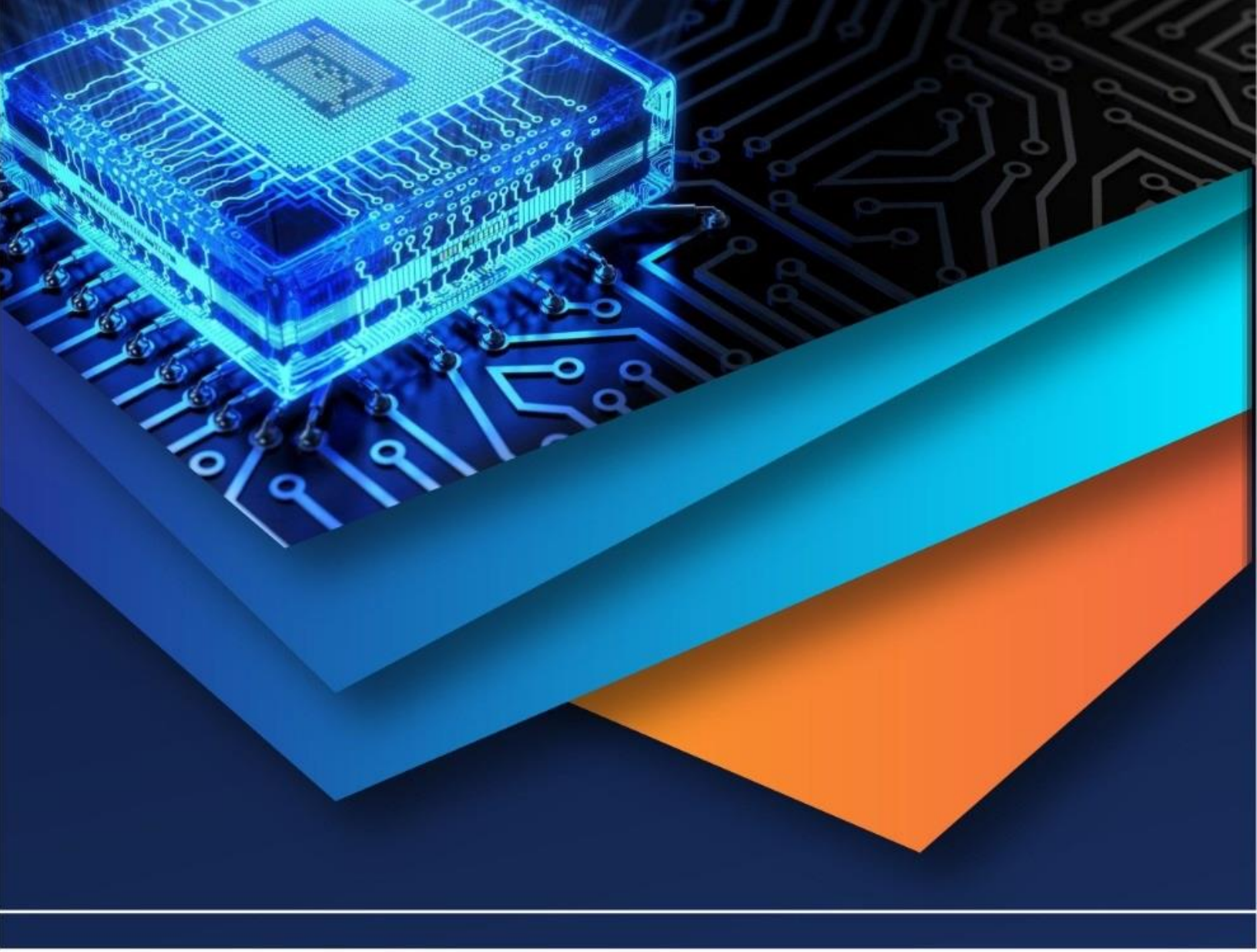

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