International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XI **Month of publication:** November 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Constant Switching Frequency Predictive Current Control Technique with Fuzzy Logic Controller for Field Oriented Permanent Magnet Synchronous Motor Drive

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Abstract: This paper builds up a predictive current controller (PCC)with fuzzy logic controller(FLC) as speed controller for quick torque observing and elite operation of a permanent magnet synchronous motor (PMSM) drive including consistent switching frequency. Its reaction is contrasted with that of a run of the proportional– integral (PI) current controller in field oriented control (FOC) methodology. And also based on the analysis of PMSM transient responses a fuzzy logic controller (FLC) is developed. The proposed control technique PCC with FLC realizes a good dynamic behavior of the motor, a good rejection of impact loads disturbance. The aftereffects of applying the fuzzy logic controller as speed controller with PCC to a PMSM gives best performance and high efficient operation of current and torque control than those acquired by the utilization of a regular controller (PI).

I. INTRODUCTION

During the current years, the established field-oriented control (FOC) procedure has been considered as the best and dependable control technique for control hardware drive systems including substituting current machines. Essentially, the current is controlled in a two-pivot d– q synchronous turning reference outline [1], empowering free machine torque and attractive field checking. New rising control plans (prescient, versatile, neural systems, fuzzy, neuro-fuzzy andso on.) are being examined with a specific end goal to enhance the transient execution and proficiency of electric drives. In spite of the fact that, they frequently require a high testing frequency and expend expansive calculation energy of digital signal processors (DSP), because of mechanical improvement of microcontrollers, huge numbers of them can be actualized in present day DSPs with a sensibly low cost for control gadgets and electrical drive applications.

Among them, predictive control (PC) has sound and invaluable qualities, for example, enhanced rotational speed reaction contrasted with the traditional PI control plans [2]. The created electromagnetic torque is specifically subject to the stator current [1]; thusly, a powerful, quick, and exact stator current control can conceivably enhance the dynamic execution.

The primary standard of PC is to utilize the drive system model to foresee the future conduct of the state factors (e.g., d– q current parts) [2]. The fundamental four sorts of PC systems connected to motor control are hysteresis-based, direction based, and deadbeat and finite set model predictive control (FS-MPC), otherwise called direct prescient control (DPC) [3]. DPC have been the most broadly researched predictive control, concentrating on execution and parameters affectability assessments, offering a natural premise, and showing straightforwardness and adaptability.

DPC can be actualized as persistent or limited control set. Moreover, rather than the PCC, it needn't bother with a different pulse modulation process [5] (i.e., sinusoidal PWM (SPWM), space vector modulation (SVM) [1]). It considers a limited arrangement of incitation that relates to the eight conceivable switching states (voltage vectors) of the inverter [6]. Every one of the blends of the conceivable states, considering the forecast skyline, are assessed. DPC can deal with system imperatives, for example, the greatest output voltage limits from the inverter and the most extreme motor current.

The cost work, that should be limited, is the most essential and complex piece of DPC. It can be intended to completely unique objectives, such as limiting power losses, switching frequency or basic mode voltage, by altering the weighting factors presented in each term, using only a solitary control law [7]. In any case, it ought to be considered that a more unpredictable cost work likewise implies that even colossal calculation control is required [5]. The procedure decided for the DPC configuration relies upon the application. In high power appraisals, the switching frequency diminishment is of incredible significance, empowering lessening of the relating switching misfortunes [8], to enhance effectiveness, while the control mistake is normally the fundamental focus to limit, with a specific end goal to guarantee the system solidness during drifters.

Acritical disadvantage of the DPC is that the switching frequency may differ, as the condition of switches relies upon the arrangement of sources of info, regularly requiring appropriate inactive electromagnetic impedance (EMI)filter outline [3].

In deadbeat, a permanent magnet synchronous motor (PMSM) demonstrate is utilized as a part of request to anticipate the stator voltages after one modulation period, permitting focalizing on the coveted currents in a period skyline [5]. A pulse width-modulation(PWM) process fundamentally drives the converter, guaranteeing a settled switching frequency. This controller additionally gives a quick unique reaction yet its execution is frequently touchy to show parameter jumbling mistakes, system delay, and the inverter's nonlinearity [4]. Bum control does not request a cost work minimization calculation; along these lines, it is less computationally complex than DPC.

Various productions on PC variations in the writing are dedicated to electric drive systems. An execution of direct current controller (DCC) to a PMSM has been proposed. Contingent upon the coveted execution, two variations are viewed as, outputting either bring down switching frequency or lower current swell. A finite control set model based prescient control (FCS-MPC) connected to control converters is proposed, permitting control of various converters and different sorts of factors lightening the need of PWM strategies and inside course control circles. The utilization of a PC procedure for an excellent current control in a PMSM driven by a voltage source inverter, without utilizing direct controllers is portrayed. a DPC procedure of chip based brushless PMSM drives is portrayed, in light of the numerical assessment of the armature twisting current, in correspondence to each option inverter state. a high-precision PWM VSI dead-time remuneration technique is proposed in view of a sustain forward approach that produces repaying signals got from the current and inverter output. In another "sans model" PC approach for a PMSM is produced, by assessing the discovery of current contrasts. A completely enhanced DPC procedure in view of the systematization of the cost work development for IM and PMSM controllers, with no fell structure.

The point of the present examination is the advancement of a novel prescient current controller (PCC) plot for PMSM drive systems, consolidating the fundamental qualities of DPC and miscreant PC strategies. It is similarly in light of the improvement of a goal work; nonetheless, the output of the controller is a reference voltage in the d– q synchronous turning reference outline and not an arrangement of pulses as in the established DPC case. The proposed control design drives the voltage reference to a pulse modulator for the inverter as in the miscreant PC. Also, the voltage reference is not processed by the evening out of the following phase anticipated currents $i_d;i_s$ to its reference esteems [6].

The cost work is picked properly, constraining the control procedure to meet the coveted criteria. It generally contains terms identified with current control square support. Besides, extra terms could be incorporated into the controller, empowering accomplishment of a bargain among a few extra criteria [7] (i.e., control misfortunes minimization, torque swell lessening, and so on.

II. MACHINE MODEL DESCRIPTION

The main equations used to model the PMSM under transient operation are developed by using two-axis d–q current components. Such equations can be written in matrix form as follows:

$$\frac{d}{dt}\begin{bmatrix} i_d(t) \\ i_q(t) \end{bmatrix} = \begin{bmatrix} -\frac{R}{L_d} & \frac{\omega_e(t)L_q}{L_d} \\ -\frac{\omega_e(t)L_d}{L_q} & -\frac{R}{L_q} \end{bmatrix}\begin{bmatrix} i_d(t) \\ i_q(t) \end{bmatrix} + \begin{bmatrix} \frac{1}{L_d} & 0 \\ 0 & \frac{1}{L_q} \end{bmatrix}\begin{bmatrix} v_d(t) \\ v_q(t) \end{bmatrix} - \begin{bmatrix} 0 \\ \frac{\omega_e(t)\wedge_d}{L_q} \end{bmatrix} \qquad (1)$$

Including standard images organized in Table I. These conditions utilize the d– q tomahawks current segments i_d (t), i_q(t) as state factors in a dynamic model of the PMSM. The d– q tomahawks voltage parts v_d (t), v_q(t) are considered as the data sources (activations) of the system. The previously mentioned state space show is dealt with as a moment arranges straight parameter variety (LPV) display. The state lattice is variable as a component of the currents electrical frequency (t), which is in relentless state straightforwardly corresponding to the rotational speed ω (t). The third term of the condition is considered as a no controllable info, which is relative to the result of the electrical frequency and the permanent rotor magnetic flux Λd. The motor electromagnetic torque created is given by

$$T_e(t) = \frac{3}{2}\cdot\frac{P}{2}\left[\wedge_d\, i_q(t) - \wedge_q\, i_d(t)\right] \quad (2)$$

From (2), it comes about that, if the current of the d-axis is set equivalent to zero, at that point the torque per current proportion is expanded. Along these lines, the excitation of the machine is accomplished exclusively by the attractive material of the rotor. In addition, the mechanical sub model of the machine is portrayed by the rotational increasing speed condition, which connects the mechanical rotational speed ω with the electromagnetic torque Te and the mechanical load torque Tm

$$J \cdot \frac{d\omega}{d_t} = T_e(t) - T_m - F\omega(t) \qquad (3)$$

III. CONTROL SCHEMES FOR PMSM CONSIDERED

An average control conspires for an motor drive system contains two levels of shut control circles [4]. The rotational speed is controlled by an outside control circle, utilizing a PI controller that wipes out the support between the reference speed and the real speed, which is measured by a speed sensor or assessed by deduction of the signal delivered by an edge position encoder.

The output of the speed controller is the reference purpose of the q-axis current, in light of the fact that, as indicated by (3), obviously the torque is relative to the $i_q$current segment. For whatever is left of this paper, the reference point for i_d current segment is set to zero, considering that the motor does not work in a field-debilitating operation mode. So the second term in (2) is precluded for the motivations behind the PC configuration, guaranteeing greatest torque per ampere. As the present segments i_d, i_q on a reference outline pivoting with the electrical frequencyω_e, are considered as the state factors of the system, the reference voltages of the inverter are the system inputs. The three-phase inverter could be similarly determined specifically by d_q voltage references as sources of info, utilizing the SVM strategy [1].

A. PI-FOC Control of PMSMs

A FOC is a traditional way to deal with control air conditioning machines. FOC is actualized in this task with a specific end goal to approve the execution of the proposed PC through a reasonable correlation. The PI current controller is composed utilizing straight control outline procedures. Likewise, it is based on a DSP for trial testing. The primary rule of FOC is that it utilizes an organize system that lines up with the rotor flux vector. The control system ought to be produced on a sufficient reference outline. The change from the symmetric three-phaseno rotating reference outline (abc) to d– q reference outline, which turns with the electrical frequency ω_e, is known as Park change. In that casing, a free control of the electrical torque and the extent of the d-axis transition can be drawn closer, by independently controlling the turning current segments i_d and i_q, individually. The rotor attractive field is kept up consistent by setting reference equivalent to zero. The motor stator currents $i_d^*$and i_q, processed by the estimation of two of the three-phase abccurrents and flows, are subtracted from the reference signals i_d^*, i_q^*delivering a mistake motion, as info

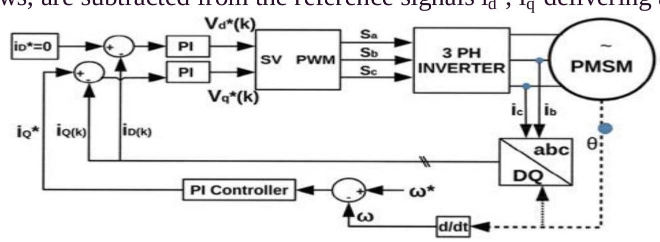

Fig.1 Main scheme of the typical FOC strategy, using PI controllers for both speed and current control loops.

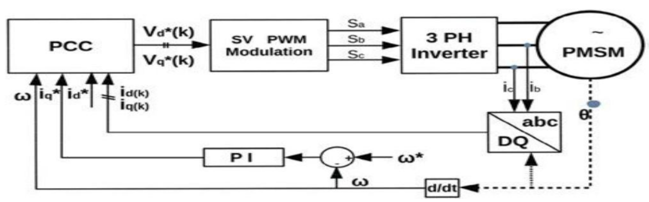

Fig.2 Main scheme of PCC, using PI controller for the speed controlloop.

For the PI controllers, as illustrated in Fig. 1. The PI controller generates an output voltage reference in the rotating reference frame d–q.

B. Predictive Current Control of PMSM

The PCC replaces the PI direct controllers utilized for the PMSM current control in the established FOC plot, by a PC system, keeping in mind the end goal to upgrade the execution of the present control. As in the PI-FOC case, a space vector modulation

block (SV-PWM) changes over the controller output voltage reference $v^*{}_{dqk}$ into obligation cycles forced on the inverter [1]. These are demonstrated as s_a,s_b ands_c individually, and are getting the Boolean esteems 0 or 1, portraying the condition of each upward switch of the converter, open or shut, separately. This regulation strategy guarantees a settled switchingfrequency, which is of extraordinary significance in the event of execution of a detached channel in the output of the converter [2]. Like other prescient controllers, deadbeat calculation depends on the motor display keeping in mind the end goal to acquire the voltage reference that ought to be connected with a specific end goal to get the coveted current toward the finish of the switching time frame$i^*{}_{dqk+1}$. The coveted current is shown by the reference$i^*{}_{dqk}$. Rotational speed ω and d– q current estimations dqk are gotten from the rotor point obtained by the encoder and the phase current estimations, individually, at each examining period. Because of the calculation time and sensors and activation spread time, some postponement could happen in the system reaction. That is the reason proper defer remuneration is normally incorporated into miscreant plans [6]. The control plot proposed is displayed in Fig. 2. For the execution of the proposed PC strategy on each time step, the differential condition display (1) ought to be changed to a discrete time demonstrate. At that point, a cost work must be characterized. The control factors at each progression ought to be controlled, keeping in mind the end goal to limit
the cost work fulfilling on a similar time all the disparity impediments set.

1)Discretization of the Machine: For the usage of a prescient controller, in view of the dynamic model of the machine, it is important to change over the nonstop time PMSM show into a discrete time display. Along these lines, the subsequent phase time condition of the d– q currents could be anticipated, by the present estimation of the d– q ebbs and flows, the deliberate electrical speed and the information d– q voltages. In the event that the examining time frame Ts is sufficiently short to consider that the precise pivot during Ts is immaterial, the PMSM can be demonstrated in discrete time by methods for Taylor arrangement development [6].Thus, the state space show (1) is changed to the discrete state space given by

$$\begin{bmatrix} i_{d_{k+1}} \\ i_{q_{k-1}} \end{bmatrix} = \begin{bmatrix} 1-\frac{RT_s}{L_{dq}} & \omega_{ek}T_s \\ -\omega_{ek}T_s & 1-\frac{RT_s}{L_{dq}} \end{bmatrix} \begin{bmatrix} i_{d_k} \\ i_{q_k} \end{bmatrix} + \begin{bmatrix} \frac{T_s}{L_{dq}} & 0 \\ 0 & \frac{T}{L_q} \end{bmatrix} \begin{bmatrix} v_{d_k} \\ v_{q_k} \end{bmatrix} - \begin{bmatrix} 0 \\ \frac{\omega_{ek}T_s\wedge_d}{L_{dq}} \end{bmatrix} \tag{4}$$

WhereL_{dq}= L_v= $L_q$is the stator inductance, which takes a similar incentive along the two tomahawks, as the machine is symmetrical. The portrayed discretization technique, expect that the rotational speed is steady during an inspecting period, in light of the way that the mechanical time consistent is significantly more noteworthy than the electrical one.

2) Predictive Optimization Method: On the subsequent phase, the issue of the controller configuration includes the calculation of the reference voltage that ought to be actualized right now step, guaranteeing that the present will take after the reference at the following phase. This objective can be communicated as the minimization of the anticipated currents $i_{(dqk+1)}$ dissimilarity from the reference value $i^*{}_{dqk}$. A cost work that consolidates this goal is detailed as takes after

$$\hat{g}(V^*_{dqk}) = e^T_{i_{k+1}} e_{i_{k+1}}$$

$e_{ik} = i^*_{dqk} - i_{dqk}$ (5)

According to (3), the desired value of the d-axis current is usually equal to zero. Consequently, the cost function that has to be minimized can be simplified as follows:

$\hat{g}(V^*_{dk}, V^*_{qk}) = i^2_{dk+1} + (i_{qk+1} - i^*_{qk})^2$(6)

The cost function (6) contains the voltages $v^*{}_{dk}$, $v^*{}_{qk}$as variables that have to be determined at each time step ensuring that the function takes its minimum value. The prediction currentsi_{dqk+1} , i_{qk+1} can be expressed as function of the reference voltages and the measured current and speed values i_{dk}, $i_{qk}$and ω_k, respectively, through (4).

Finally, the cost function can take the following form:

$\hat{g}(\underline{u}k) = \underline{u}^T_k \lambda^2 \underline{u}_k + \mu_k \underline{u}_k$ (7)

The parametrs of this cost function are determined as follows:

$$\underline{u}_k = \begin{bmatrix} v_{d_k} \\ v_{q_k} \end{bmatrix}$$

$$\lambda = \frac{T_s}{L_{dq}}$$

$$\mu_k = \begin{bmatrix} \mu_{1k} & \mu_{2k} \end{bmatrix}$$

$\mu_{1k} = 2\lambda(a_1 i_{dk} + a_{2k} i_{qk})$
$\mu_{2k} = 2\lambda(-a_2 i_{dk} + a_{1k} i_{qk} - i^*_{qk} - \omega_{ek}\lambda \wedge_d)$
$a_1 = 1 - \frac{RT_S}{L_{dq}}$
$a_{2k} = \omega_{ek} T_S$

The constant diagonal matrix μ_k of $\bar{g}$is time variable, because they depend on the feedback current and speed signals i_{dk},$i_{qk}$and ω_k. Moreover, μ_{2k}relies upon the reference current signal $i^*{}_{qk}$which is likewise time variable as it is the output of the outside speed control circle.

Accordingly, the enhancement procedure happens at each time step, creating a period variable voltage reference signal.

A limitation forced on the issue is that the present amplitude never surpasses a characterized maximum esteem, for motor wellbeing and dependability reasons. The greatest current is chosen by the specialized determinations of the motor as the most extreme transient reasonable current.

All the more particularly, the "greatest current" limitation is communicated through the accompanying imbalance articulation:

$$\begin{Bmatrix} i_{d\,k+1} < \mu_{max} \\ i_{d\,k+1} < \mu_{max} \end{Bmatrix} \qquad (8)$$

By substituting (4) into (8) outputs that the “optimum” input voltages should handle the following constraints:

$$\begin{Bmatrix} v^*_{dk} < \frac{1}{\lambda}(i_{max} - a_1 i_{dk} - a_{2k} i_{qk}) \\ v^*_{qk} < \frac{1}{\lambda}(i_{max} - a_2 i_{dk} - a_{1k} i_{qk}) + \omega_{ek} \wedge_d \end{Bmatrix} \qquad (9)$$

The control law is now expressed in (7) as a quadratic optimization problem under the linear constraints (9) that is solved in each time step online, by using a Newton iterative method, based on Hessian matrix inversion.

The proposed optimization algorithm is simply implemented for the present application, and its execution does not demand extreme computational capacity, taking advantage of two main characteristics. First, the Hessian matrix is diagonal and consequently immediately invertible. Moreover, the iteration algorithm operates considering the solution of the most recent completed optimization process, as initial point. So the process is usually converging in a very few steps.

According to the Newton iterative optimization algorithm, the r + 1 iteration result is derived as a function of the rth iteration result by the following formula:

$$\underline{u}_{k_{r+1}} = \underline{u}_{k_r} - \gamma\left(\underline{u}_{k_r} + \frac{1}{2\lambda^2}\mu_k{}^T\right) \qquad (10)$$

WhereH_g is Hessian Matrix of function$\bar{g}$, giving

$$H_{g_{ij}}(\underline{u}_{k_r}) = \frac{\partial \hat{g}}{\partial u_t \partial u_j} \Big| \underline{u} = \underline{u}_{k_r}$$

$\gamma \in (0,1]$

$\underline{u}_{k_0} = \underline{u}_{k-1}$

For the specified cost function, by substituting the partial derivatives, (10) could be simplified as follows:

$$\underline{u}_{k_{r+1}} = \underline{u}_{k_r} - \gamma(\underline{u}_{k_r} + \frac{1}{2\lambda^2}\mu_k{}^T) \qquad (11)$$

The N-R algorithm is modified by the introduction of the γ coefficient$0 < \gamma < 1$, enabling reduction of the step size in order to prevent divergence, potential numerical instabilities, overshooting, and frequent constraint violations. It may be noted that this modification could increase the number of iterations under steady-state conditions. The convergence condition of the algorithm is formulated so as that the Euclidian norm of the difference between the results two sequential iterations does not exceed an acceptable error ε. Thus, it is formed as follows:

$$\left\|\underline{u}_{k_{r+1}} - \underline{u}_{k_r}\right\| \leq \varepsilon \qquad (12)$$

3) Computational Delay Compensation: One of the main issues of MPC is the computational effort on the DSP and on the pulse modulation technique that causes time delay. This problem can be solved by applying a simple modification of the proposed control process, in order to achieve compensation of the computational delays. The idea is that the input $v^*{}_{qk}$implemented to the pulse modulator at time t_k should be computed by the optimization process at time t_{k-1} . However, the measurement current values i_{dk} , i_{qk} could not be available prior tot_k. The proposed solutionto this problem is that the next time period currents i_{dqk-1} can be

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

estimated at the time t_{k-1} by the prediction model (4), by using the previous feedback current signals i_{dk-1} , i_{qk-1} for below equation (13).

The optimization process is still a quadratic problem as described in the previous paragraph, based on the minimization of $\bar{g}$. The electrical frequency ω_e does not change noticeably between a few time steps related to the current change.

$$\begin{bmatrix} i^p_{dk} \\ i^p_{dk} \end{bmatrix} \begin{bmatrix} 1-\frac{RT_s}{L_{dq}} & \omega_{ek}T_s \\ -\omega_{ek}T_s & 1-\frac{RT_s}{L_{dq}} \end{bmatrix} \begin{bmatrix} i_{d\,k-1} \\ i_{q_{k-1}} \end{bmatrix} + \begin{bmatrix} \frac{T_s}{L_{dq}} & 0 \\ 0 & \frac{T}{L_q} \end{bmatrix} \begin{bmatrix} v^*_{dk-1} \\ v^*_{qk-1} \end{bmatrix} - \begin{bmatrix} 0 \\ \frac{\omega_{ek}T_s\wedge_d}{L_{dq}} \end{bmatrix} \quad (13)$$

It could also be assumed that the reference current $i^*{}_q$ can be considered constant between a few time periods $i^*{}_{qk} \approx i^*{}_{qk-1}$, as it is a result of the mechanical speed control process. The measured currents i_{dk}, i_{qk} should be replaced in $\bar{g}$ with their predicted values. So the coefficients of $\bar{g}$ can be changed as follows:

$$\mu_{1_k} = 2\lambda(a_1 i^p_{d_k} + a_{2_k} i^p_{qk}) \quad (14)$$

$$\mu_{2_k} = 2\lambda(a_1 i^p_{d_k} + a_{2_{k-1}} i^p_{qk} - i^*_{q_{k-1}} - \omega_{e_{k-1}}\lambda \wedge_d) \quad (15)$$

The maximum current limitations can now be formulated as follows:

$$\begin{cases} v^*_{dk} < \frac{1}{\lambda}(i_{max} - a_1 i^p_{q_k} - a_{2k} i^p_{q_k}) \\ v^*_{qk} < \frac{1}{\lambda}(i_{max} + a_{2_{k-1}} i^p_{q_k} - a_1 i^p_{q_k}) + \omega_{ek-1} \wedge_d \end{cases}$$

(16)

This methodology could be extended to an even larger time horizon, and several time steps, depending on the computational delay that each control strategy performs and on the hard ware where the certain application is built.

IV. FUZZY LOGIC CONTROLLER (FLC)

L. A. Zadeh submits the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy logic properties of reality, which are very inconvenient and sometime even impossible to be described using conventional methods. Fuzzy set theory has been commonly used in the control area with some application to power system. A simple fuzzy logic control theory is built up by a group of systematic rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is constructed to study the dynamic behavior of converter. Furthermore, design of fuzzy logic controller can provide advantageous both small signal and large signal dynamic performance at same time, which is not feasible with linear control technique. Thus, fuzzy controller has been potential ability to improve the robustness of compensator. The basic scheme of a fuzzy logic controller is shown in Fig 3 and consists of four principal components such as: a fuzzification connection or interface, which converts input data into suitable linguistic values; a knowledge base, which composed of a data base with the required linguistic definitions and the control rule set; a decision taking logic which, simulating a human decision procedure, infer the fuzzy control action from the knowledge of the control logic rules and linguistic changeable definitions; a de-fuzzification interface which yields non fuzzy logic control action

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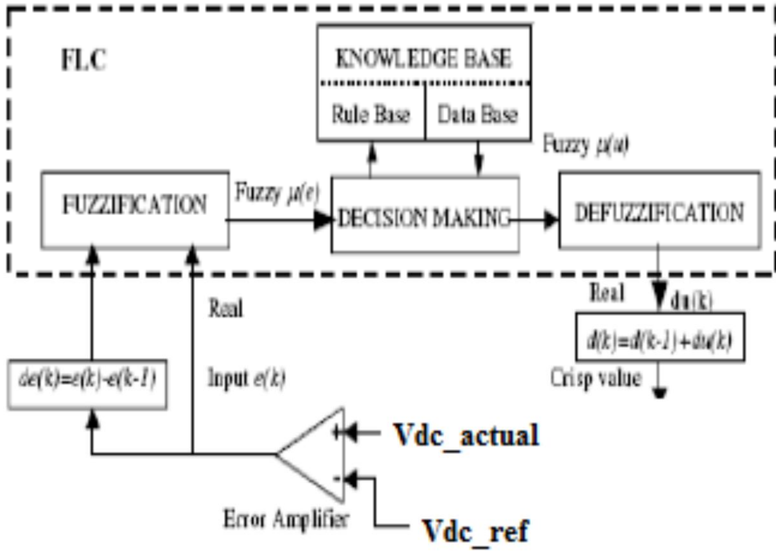
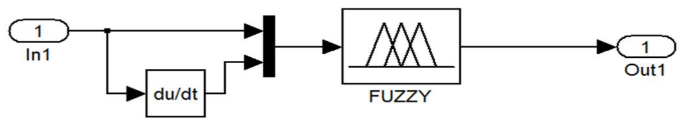


(a)



(b)

Fig.3(a) Block diagram of the Fuzzy Logic Controller (FLC) (b) Fuzzy system.

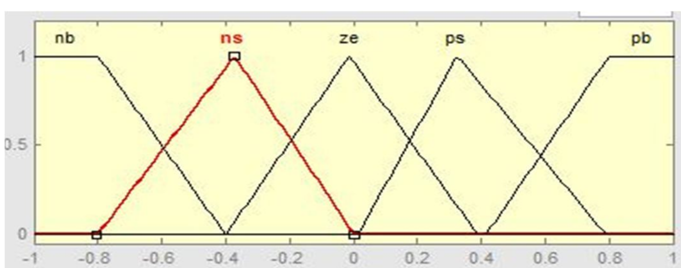


Fig.4 Membership functions for input1, input2, and output

Rule Base: the elements of this rule base table are finding based on the theory that in the transient state, large errors require coarse control, which need coarse in-put/output variables; in the steady state, small errors need fine control, which needs a fine input/output variable

TABLE.1 RULES OF FUZZY CONTROLLER

I/p1 / I/p2	NB	NS	ZE	PS	PB
NB	PB	PB	ZE	NS	NB
NS	PB	PB	ZE	NS	NB
ZE	PB	PS	ZE	NS	NB
PS	PB	PS	PS	NS	NB
PB	PB	PB	PB	PB	PB

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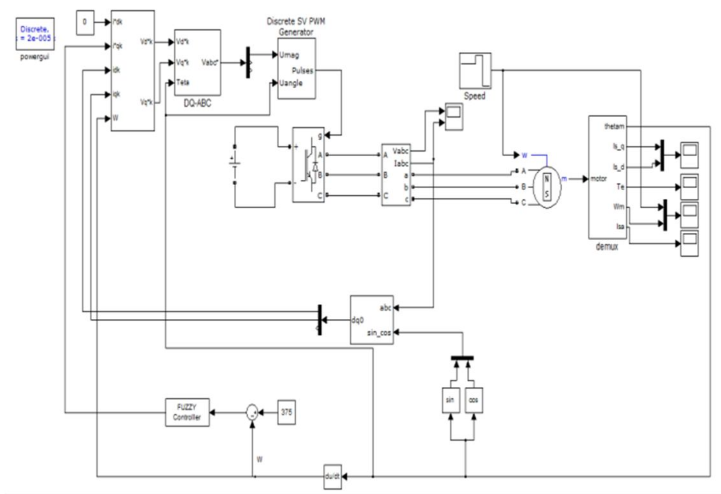


Fig.5. Simulation diagram of Main scheme of PCC, using FLC controller for the speed control loop.

V. SIMULATION RESULTS

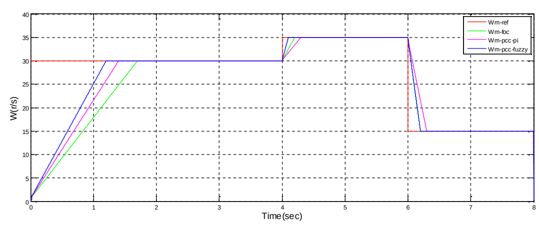
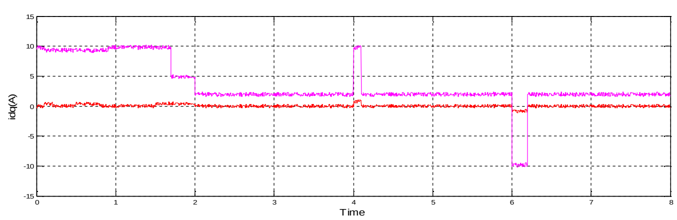
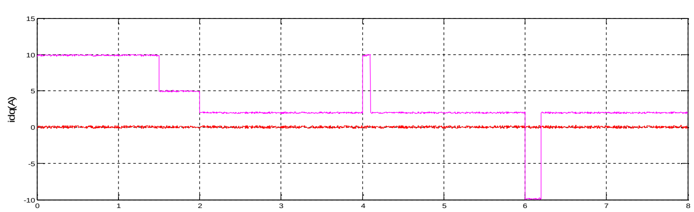


Fig.5.Rotational speed response –PI-FOC, PI-PCC and FLC-PCC.



(a)



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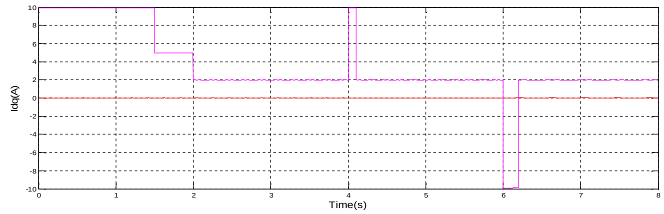
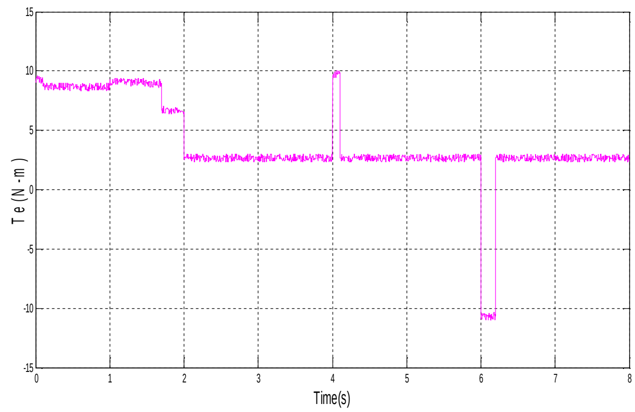
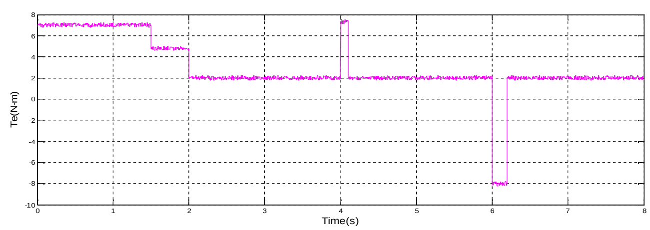


(C)

Fig.6.D-Q Current response (a) PI-FOC, (b)PI-PCC and (c) FLC-PCC



(a)



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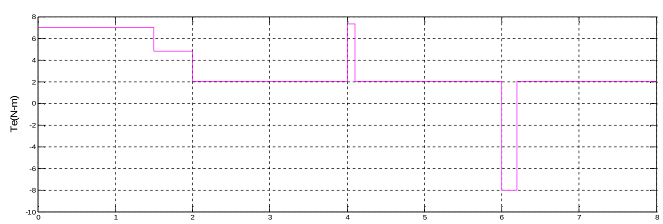
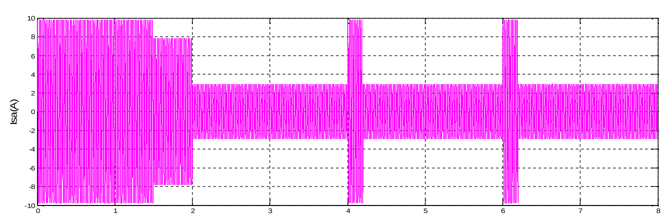


(c)

Fig.7.Electromagnetic Torque response (a) PI-FOC, (b) PI-PCC and (c) FLC-PCC



(a)

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
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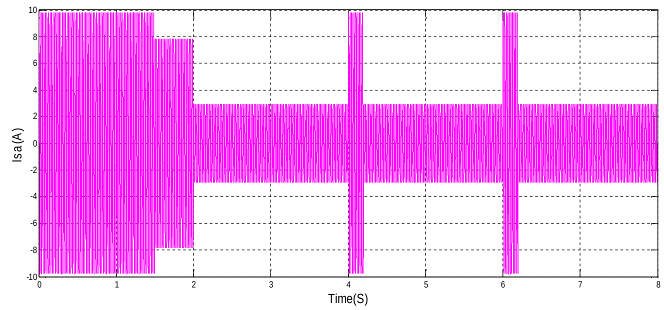
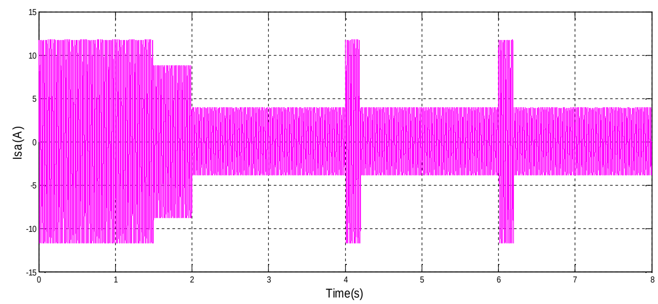
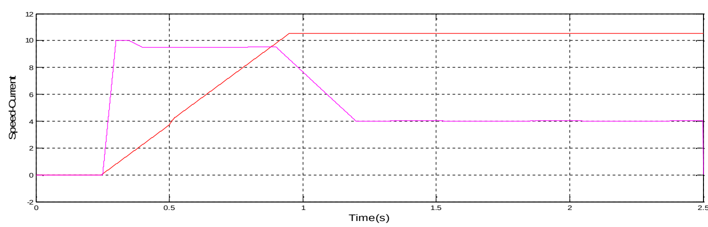


(b)

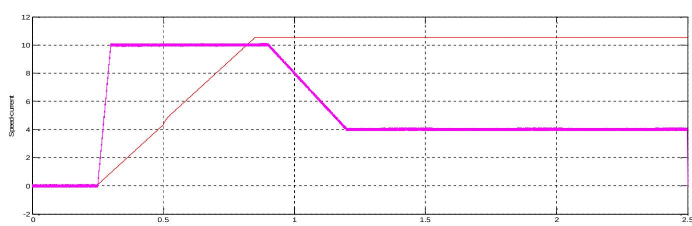


(c)

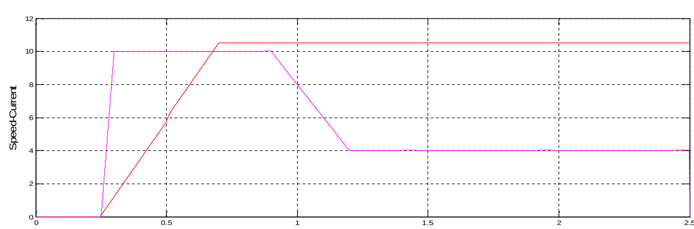
Fig.8. Motor Current Ia response – (a) PI-FOC, (b) PI-PCC and (c) FLC-PCC



(a)



(b)



(c)

Fig.9 speed-current response (a) PI-FOC, (b) PI-PCC and (c) FLC-PCC

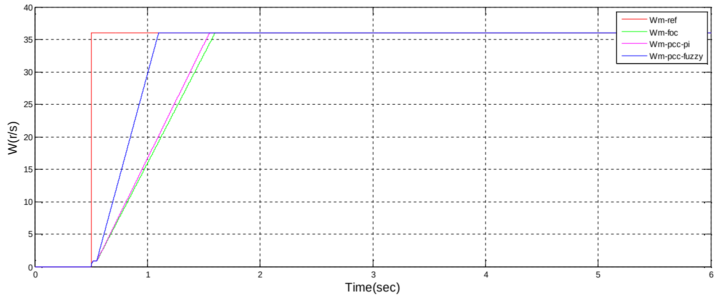


Fig.10. Simulated results of motor starting under full load - speed ω versus reference speed -PI-FOC, PCC and FLC-PCC

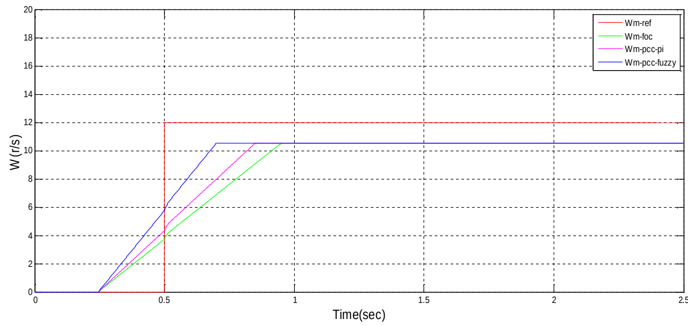


Fig.11. Simulated results of speed versus reference speed response PI-FOC, PI-PCC and FLC-PCC

Table.2comparision Of Pi-Foc, Pi-Pcc And Flc-Pcc Simulations

	PI-FOC	PI-PCC	FLC-PCC
Speed rising time	1.55sec	1.25sec	1.08sec
Max. speed overshoot	6.6%	2%	1.01%
Max. steady state error	2.8%	0%	0%
THD	9.86%	6.57%	4.9%

VI. CONCLUSION

In this paper, a consistent switching frequency PCC using Fuzzy logic controller for speed control has been produced for a PMSM drive system, intended for electric vehicle applications. The proposed Fuzzy logic controller reaction has been contrasted with an ordinary PI-FOC method. The recreated aftereffects of the two controllers have been approved by estimations on a test setup. The proposed system fuzzy logic controller showed imperative preferences: it gave speedier reaction to speed changes and additionally littler current and torque swell. It is additionally discernible that it for all intents and purposes dispensed with the speed varieties during a torque venture, because of a quicker current development. In addition, such a FLC procedure empowers combination of extra criteria in the controller cost work and to give dynamic performance in the speed in system.

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