Design and implementation of variable and constant load for induction motor

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Article Info

ABSTRACT

To design and implementation of variable and constant with no load for induction motor (IM) that is the goal in this work. This paper was including three parts, first the simulation model with no load for IM, Second the simulation model with constant load for IM, Third the simulation model with variable load for IM. In addition, this work includes comparative between two different controllers (PI and fuzzy logic control (FLC). The simulation results clearly the implementation of variable and constant with no load for IM. The simulation response of the system achieves better results when choosing to use type fuzzy-PI controller technique comparison with conventional PI controller and improve the performance of the system at different operation conditions.

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1. INTRODUCTION

The 3-phase IM is important of electrical machines that widely used in different industrial applications [1]. They perform their characteristic for decades and adapt themselves at different operate conditions [2], such as oil refineries, electric power stations, and factories because their simple in design, high efficiency, good self-starting, good power factor, low manufacturing costs relatively, and small value of inertia [3]. The disadvantages of IM have represented in non-linear multivariable in addition to complex of mathematical model, so IM inherently unable to operate at different range of speed, therefore to solve these problems is used multi types of controllers such as PI controllers. Very comprehensive remarks era that gives a very efficient method to several manipulate problems inside the real world. These controllers are simplicity, reliability. Robust of the systems and tuned properly therefore they becomes important in industrial applications.

However, PI controller can't offer the good control overall performance in running condition [4]. The authors of [5-7] are present hybrid control system by using FLC and conventional controllers by using mathematical of IM and these studies deals with the structure of model to obtain high-performance tracking of IM. In [8] proposes speed control of IM by using conventional techniques (PI and PID) controllers with vector control technique at full load condition and discuss simulation results with these controllers and without any controller. The study [9] proposes system to control on speed of IM by using feedback close loop system with fuzzy-PID controller. This system has other advantages that combination between 3-phase step-up transformer and 3-phase drive to able control any 3-phase machine on a 1-phase supply, also study [10] refers speed control of IM by using MATLAB Toolbox and Simulink model to developed this model by using FLC which available constant speed at varies loads conditions. Many studies had proposed different approach to resolve the downside of (PI controller). The usage of artificial intelligence techniques (AIT) so one of these techniques are very important for controlling non-linear system without independent on behaviors of internal system such as (FLC) that

permits designers to address efficaciously difficult closed loop system in order to reduce time as well as costs, supports non-linear system which can be using in motor control fields [11]. PI controller can be tuned the gain by (AIT), (FLC) and online tuned with changing conditions of system [12], the controller gains are the best advantage of these controllers because which allow using the human experience for the generation of the tuning law [13]. This study provides fuzzy-PI controller that FLC adjust parameters of PI and comparative with conventional PI controller at different operation conditions include (no load, constant and variable loads) of IM in order to improve operation of this motor and obtain high performance at real time.

2. MATHEMATICAL MODEL OF IM:-

The equivalent circuit of IM for (q and d winding circuit) which can be used to analysis the model of IM shows in Figure 1, while power circuit of the 3-phase IM shows in Figure 2 [14,15].

(a)   (b)
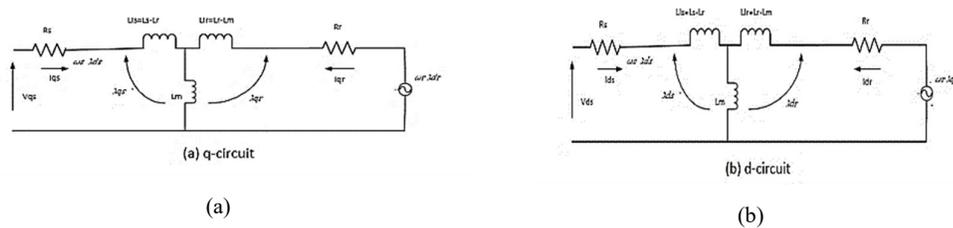
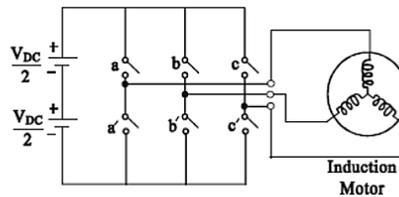Figure 1. Equivalent circuit of IM

Figure 2. Power circuit of 3-phase IM

Dynamic model of IM can represent by writing deferential equation for electrical and mechanical quantities (voltage and torque) and can shown in mathematical model of IM include the equations below [3].

A-Electrical system equations

$$v_{s=} R_s\, i_s + \frac{1}{w_0}\frac{d\lambda_s}{dt} + w_k M_{\frac{n}{2}}\lambda_s \tag{1}$$

$$v_{s=} R_r\, i_r + \frac{1}{w_0}\frac{d\lambda_r}{dt} + (w_k - w_m)M_{\frac{n}{2}}\lambda_r \tag{2}$$

Here $\lambda = \begin{bmatrix}\lambda_d\\\lambda_q\end{bmatrix}, i = \begin{bmatrix}i_d\\i_q\end{bmatrix}, M_{\frac{n}{2}} = \begin{bmatrix}0 & -1\\1 & 0\end{bmatrix}$

B- Flux linkage-current relations

For d-axis:

$$\lambda_{sd} = L_s i_{sd} + L_m i_{rd} \tag{3}$$
$$\lambda_{rd} = L_m i_{sd} + L_r i_{rd} \tag{4}$$

For q axis:

$$\lambda_{sq} = L_s i_{sq} + L_m i_{rq} \tag{5}$$
$$\lambda_{rq} = L_m i_{sq} + L_r i_{rq} \tag{6}$$

Where $L_s = L_m + L_{sl}, L_r = L_m + L_{rl}$

C- Mechanical system equations:-

$$T_e = 2H \frac{dw_{msec}}{dt} + B_m w_{se} + T_e \qquad (7)$$

Where $T_e, \lambda_s * i_s = M\frac{n}{2}\lambda_s * i_s \qquad (8)$

$$w_{se} = \frac{2}{p}w_m \qquad (9)$$

3.   Induction motor and controller

This paper proposes operation of IM at different conditions such as (no load, constant and variable loads) without controller and by using each of PI and fuzzy-PI controller to develop performance of IM at different operation conditions, the following steps in this paper present in the flow chart which shows in Figure 3.
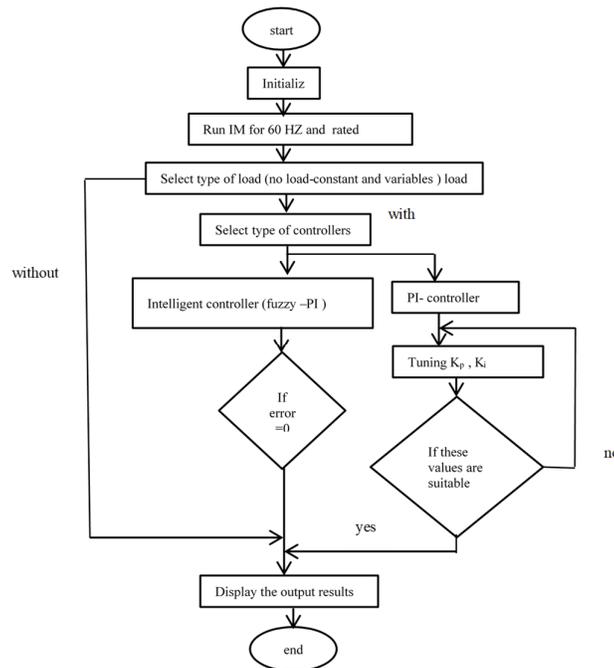

Figure 3. Flow chart for performance of model

3.1. Simulation of induction motor

The 3-phase voltages and frequency are inputs of a squirrel cage IM, while the 3- phase currents, torque and rotor speed are outputs of IM model [14]. Simulink model of IM shows in Figure 4.
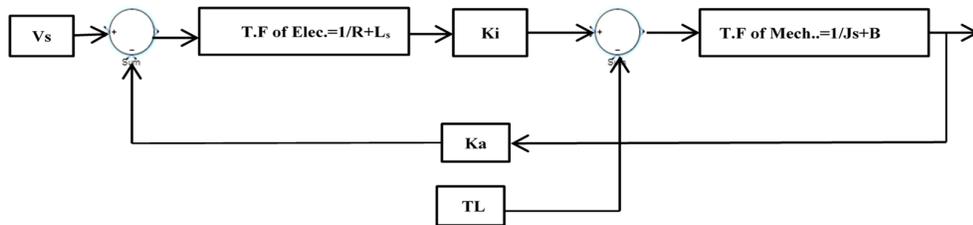

Figure 4. Simulink model of IM

The parameters of the IM propose in this paper as shown in Table 1.

Table 1. parameters of IM

parameters	values
P (AV)	3*746
V (line-line)	220 (r.m.s)
f (Hz)	60
R_s (Ω)	0.435
L_s (H)	2*2e-3
R_r (Ω)	0.816
L_r(H)	2e-3
L_m (H)	69.31e-3
J (kg.m^2)	0.089
F_c	0
Pole pair	2

Where:
P= power, V = Voltage, f = frequency, R_s = stator resistance, L_s = stator inductance, R_r = rotor resistance, L_r = rotor inductance, L_m = mutual inductance, J= inertia, F_c = friction factor.

3.2. PI controller

PI controller can propose high performance only when the controller system operates at operating point, so the PI controller does not frequently properly tune at operating condition changes and variations of parameters, in order to develop automatic tuning of PI controller parameters [13]. PI controller drives plant to control weighted summation of error and integration of values. The conventional or linear PI controller has described in 10.

$$Y(t) = e(t)K_P + K_i \int_0^t e(t)dt \tag{10}$$

Where Kp is the proportional gain and Ki is integral gain of controller while error signal e(t) is the difference between the reference r(t) and the process output c(t) [8].

$$e(t) = r(t) - c(t) \tag{11}$$

Table 2. indicates effect of parameters for PI on controller system, whereas Figure 5 refers to block diagram of this controller.

Table 2. effect of parameters of PI

parameters	t_{rise}	$t_{over\ shoot}$	t_{tuning}	e_{rror}
k_p	Dec.	Incr.	Small change	Dec.
k_i	Dec.	Incr.	Incr.	eliminate

Where:
Dec.= decrese , Incr= increase,
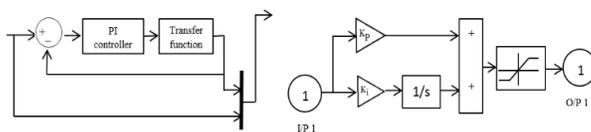Figure 6 shows PI -controller structure (kp, ki) are input of PI -controller and (u) is output [16, 17].

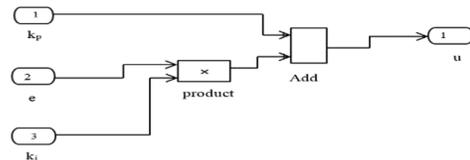Figure 5. Simulink and block diagram of PI controller   Figure 6. The structure of PI controller

3.3. Fuzzy-PI controller

The (FLC) is one of best applications where the fuzzy theory can apply successfully, so it can solve problems in nonlinear control system but the system model is complex to build therefore knowledge of the process is important to obtain the fuzzy rules. (FLC) consists of 3 steps: 1) fuzzification 2) evaluation of control rules 3) defuzzification [18]. (FLC) have the advantages more than the classical control. They are

including wide range of operating cases. Cheaper to improve and easier in neural language expressions. Mamdani is type of (FLC) can use in two systems. The first is multiple inputs multiple outputs while the other is multiple input and signal output system. The interest of (FLC) is adopted operators experiment or knowledge of the system in a heuristic way and in design process, the thresholds of fuzzy lingual variables are often selection randomly so an incorrect controller values reach to unstable mode, an opposite consequence, breakdown and separation [19, 20]. Figure 7 refers to block diagram of (FLC) [21].
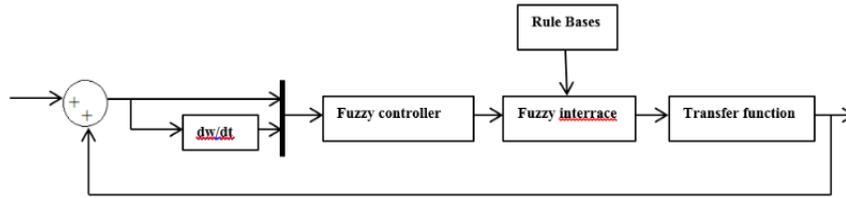

Figure 7. Block diagram of (FLC)

The main goales of (fuzzy-PI) controller are to decrease control planner complication and develop dynamic and static performances of the system. Essentially for systems designing are complex. The parameters are difficult to obtain in this state. The (PI) controller is designed to set parameters Kp and Ki orderly to meet suitable required characteristics include rise time, maximum value of overshoot, steady state error and settling time. Therefore, (FLC) control signal according to the integral and proportional actions of the PI-controller [13]. (FLC) has (2) inputs are represented error e(k) and change of error Δe(k).

e(k) = r(k)−y(k), Δe(k) =e(k) − e(k − 1)

where (r) indicated to applied set point input and (y) denote to plant output, (k) indicate present state whereas (k−1) is previous case of this system, while output of (FLC) is gradual change in value of Δe(k) [22], Figure 8 inducates to block diagram of (fuzzy-PI) controller [23].
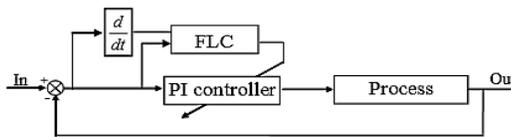

Figure 8. Block diagram of (fuzzy –PI) controller

4. SIMULINK MODEL AND SIMULATION RESULTS
4.1.Simulink model

Figure 9 Shows simulation model of IM without controller at variable conditions of load (no load, constant and variable load) as follows.
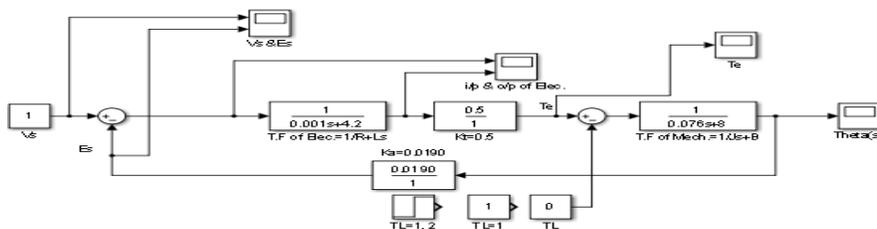

Figure 9. Simulink Model of I.M without Controller

Simulation Model of I.M with PI Controller at variable loads (no load, constant and variable loads) as shown in Figure 10. In addition, Simulink Model of I.M with PI Controller at variable loads (no load, constant and variable load) as shown in Figure 11.
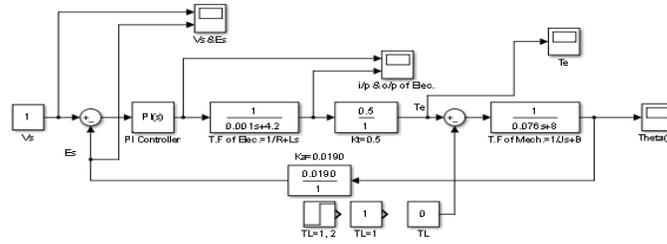
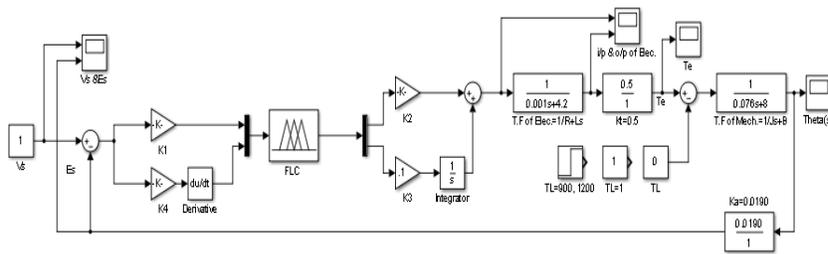Figure 10. Simulink model of I.M with PI- Controller

Figure 11. Simulink model of I.M with (fuzzy-PI) Controller

4.2. Simulation results

The simulation results include, at no load, at constant load with PI controller and with fuzzy-PI (FLPI) controller.

4.2.1. The simulation results at no load include:

The simulation results discuss three different states, the first includes operation of motor without any controller while two other states discuss the performance with two techniques had represented in PI and fuzzy-PI controller.

First, simulation results without control at no load and the simulation response of the system at no load without any controllers can be show in the Figure 12.

Second part includes simulation results with PI controller at no load; Figure 1) shows the simulation response of the system.

Third part discuss the response of the system by using fuzzy-PI (FLPI) controller at no load condition, the simulation results of this part can be shown in Figure 14.
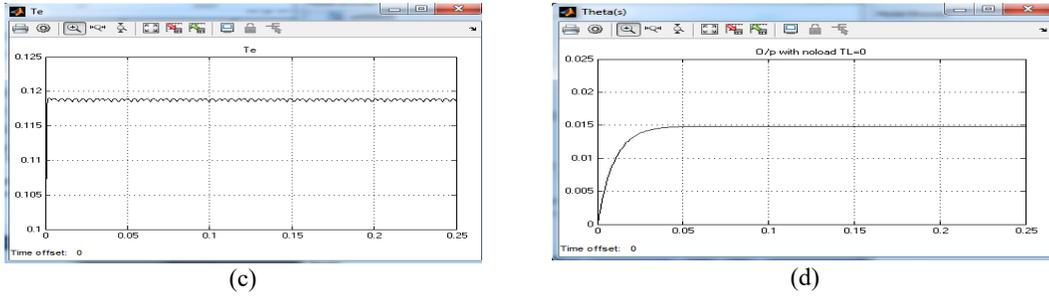
(a)   (b)

(c)

(d)
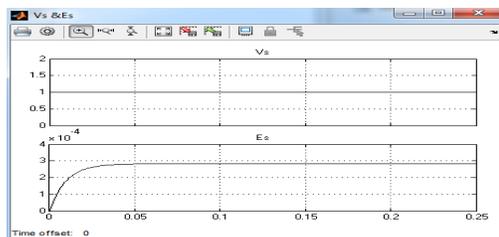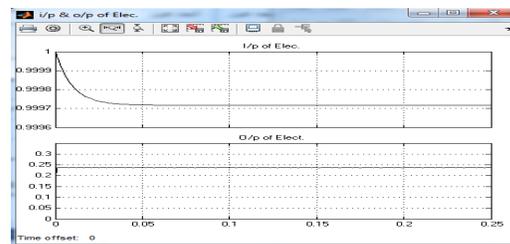
Figure 12. Simulation response of the system at no load without controller, (a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te, (d) Simulation response of o/p

(a)

(b)

(c)

(d)

Figure 13. Simulation response of the system at no load with PI controller, (a) Simulation response of the Vs & Es, (b) Simulation response ofi/p & o/p, (c) Simulation response of Te, (d) Simulation response of o/p

(a)

(b)

(c)

(d)

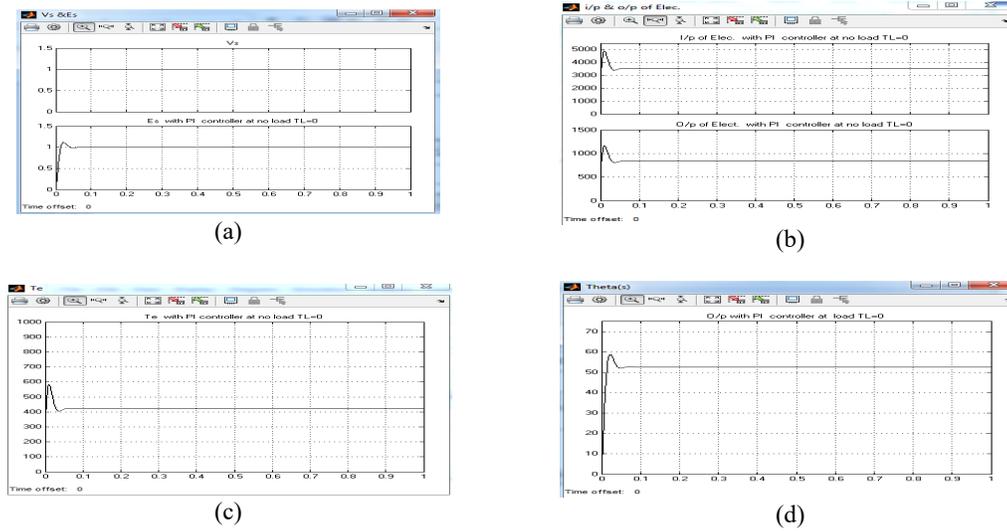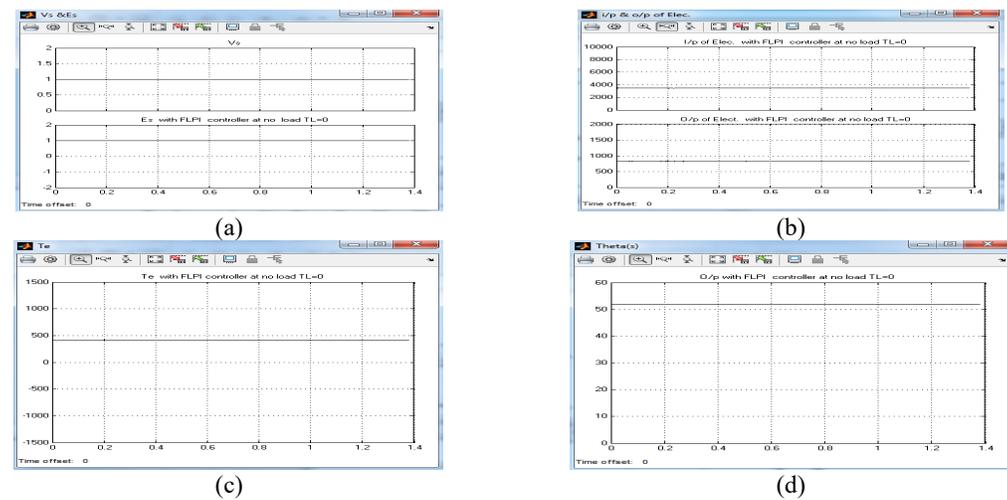Figure 14. Simulation response of the system at no load with FLPI controller, (a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te, (d) Simulation response of o/p

4.2.2. The Simulation results at constant load include:

First, simulation results without control at constant load and the simulation response of the system at no load without any controllers can be show in the Figure 15. Second part includes simulation results with PI controller at constant load; Figure 16 shows the simulation response of the system. Third part discuss the response of the system by using fuzzy-PI (FLPI) controller at constant load condition, the simulation results of this part can be shown in Figure 17.
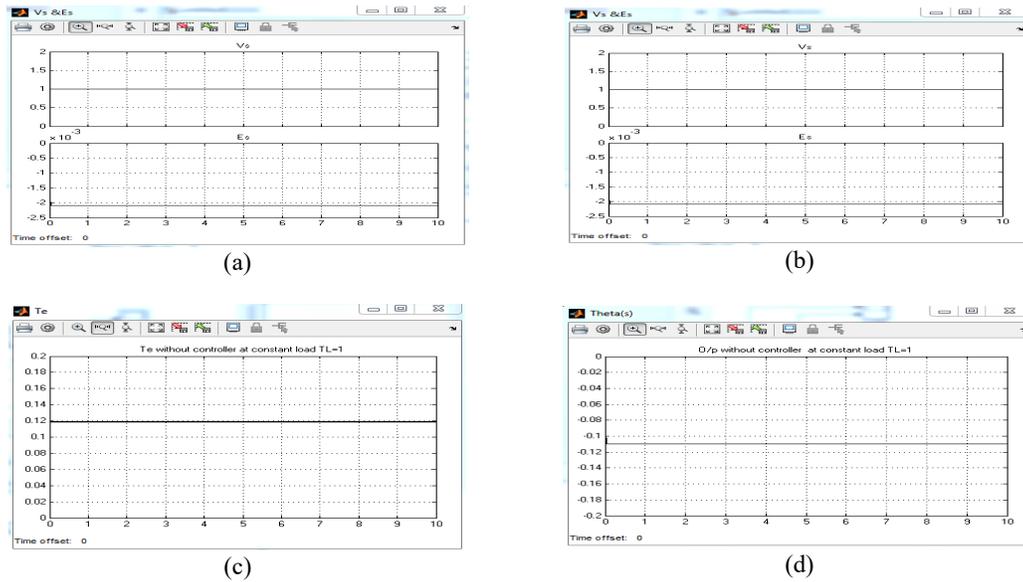

(a)   (b)

(c)   (d)

Figure 15. Simulation response of the system at constant load without controller,
(a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te,
(d) Simulation response of o/p

(a)   (b)

(c)   (d)

Figure 16. Simulation response of the system at constant load with PI controller,
(a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te,
(d) Simulation response of o/p

(a)

(b)

(c)

(d)

Figure 17. Simulation response of the system at constant load with FLPI controller, (a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te, (d) Simulation response of o/p
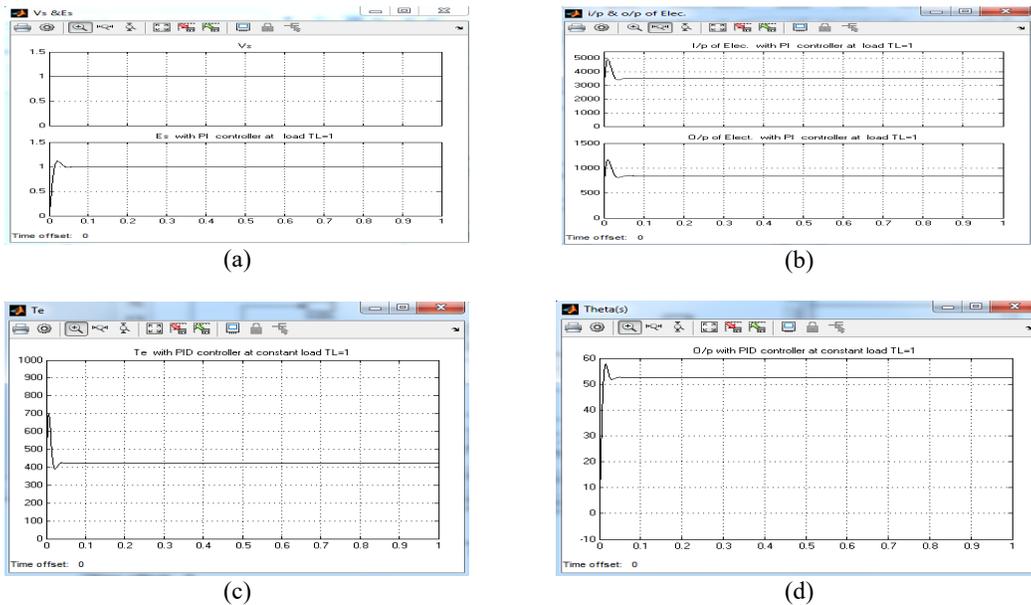
4.2.3. The Simulation results at variable load include:
         First, simulation results without control at variable load and the simulation response of the system at no load without any controllers can be show in the Figure 18. Second part includes simulation results with PI controller at variable load; figure (19) shows the simulation response of the system. Third part discuss the system by using fuzzy-PI (FLPI) controller at variable load condition, the simulation results of this part can be shown in Figure 20.

(a)

(b)

(c)

(d)

Figure 18. Simulation response of the system at variable load without controller,
(a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te,
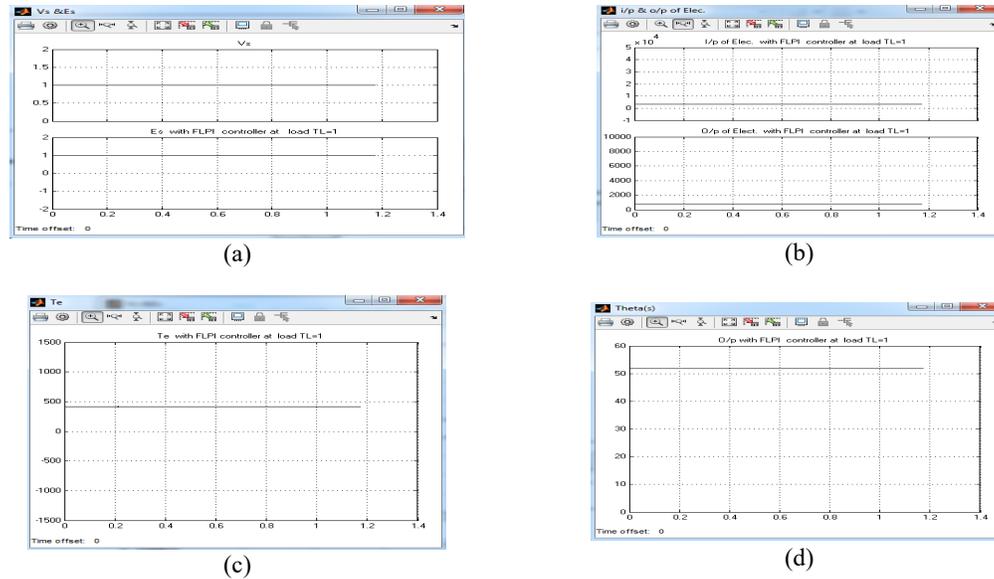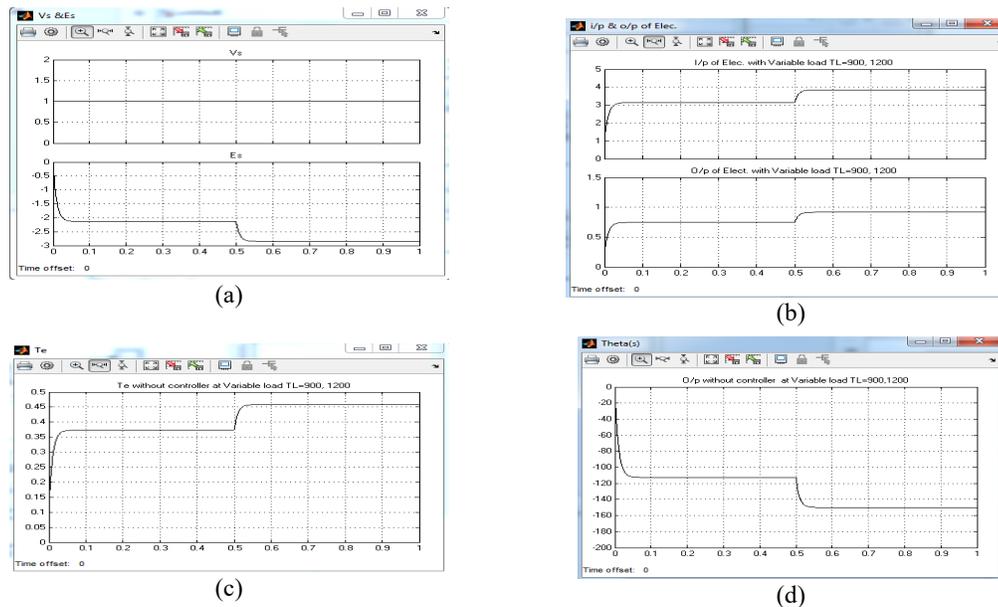(d) Simulation response of o/p

(a)

(b)

(c)

(d)

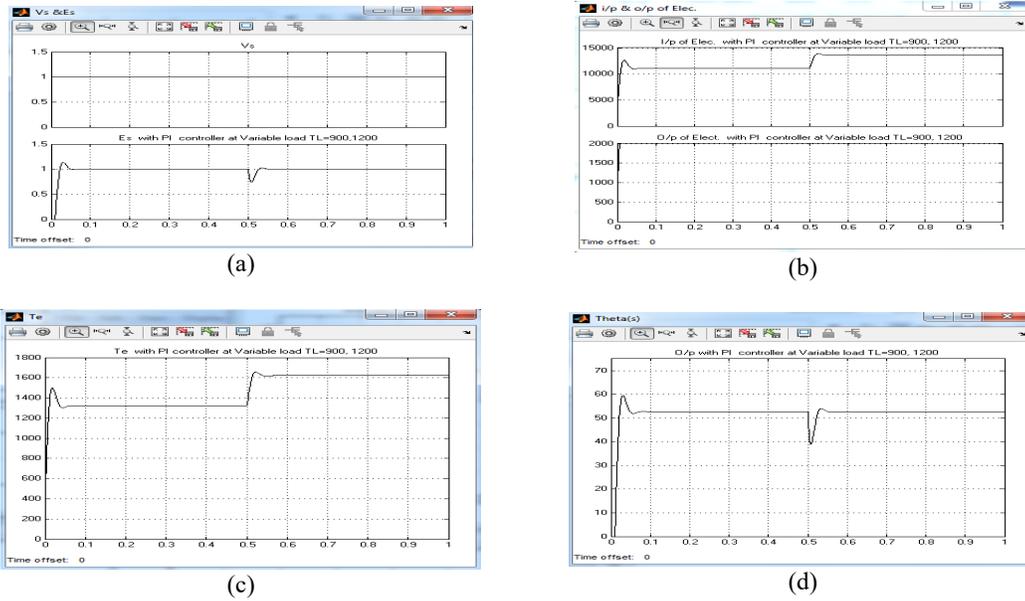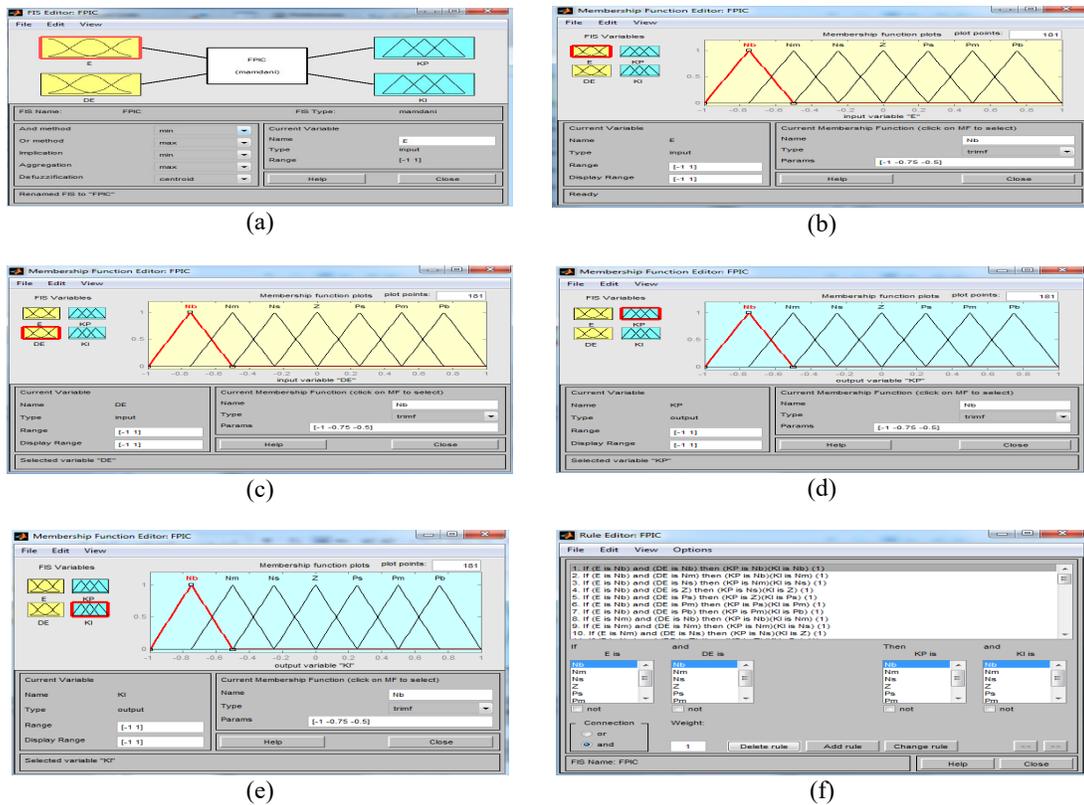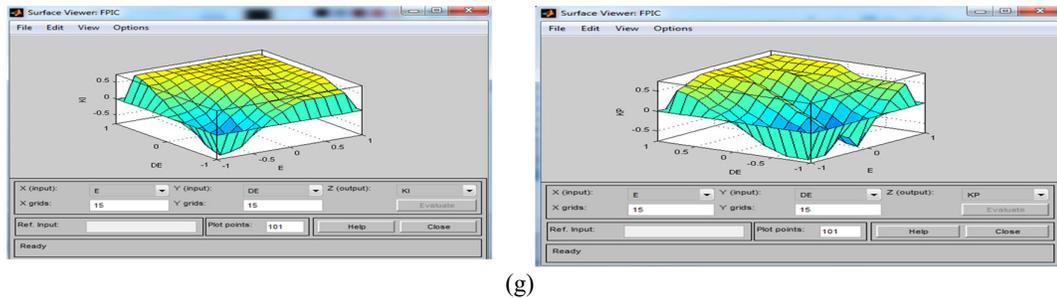Figure 19. Simulation response of the system at variable load with PI controller,
(a) Simulation response of the Vs & Es, (b) Simulation response of i/p & o/p, (c) Simulation response of Te,
(d) Simulation response of o/p

This part includes the simulation results of the system by using fuzzy-PI controller Figure 20 shows each of FIS, memberships, rules, surface viewers respectively.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

Figure 20. Simulation response of the system at variable load with FLPI controller, (a) FIS of FLPI, (b) membership function of (error), (c) Membership function of I/P (change of error), (d) Membership function of O/P (Kp), (e) Membership function of O/P (Ki), (f) Rules of FIPI, (g) Surface viewer of FIPI

The difference between the different simulations can observe by responding to each case and comparing it with the response of any other case that simulates the operation of the engine with different states. When looking at all cases in terms of response: close symmetry appears, and when looking at the response clearly. A slight difference can be observed. It is almost an override of 2 rad / s, and then it can be said that a better response has obtained. A slight difference can observe by taking the time to reach the stable state and these are the system specifications to demonstrate the differences and to determine better performance. It includes Steady state error (ess), Peak Overshoot (Mp) and Settling Time (tss) that shows the better state by using fuzzy logic controller compared to conventional PID.

5. CONCLUSION

The main object of this paper is to implement a controller based on adaptive fuzzy-PI and conventional PI by using MathLab Simulink environment in order to improve the performance of three-phase induction motor under different operation conditions represent in (no-load, constant and variable loads), simulation results refer to successful techniques with high accuracy by using fuzzy-PI than conventional PI.

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