Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

# MODELING AND COMPARISON OF IP AND FUZZY-PI REGULATORS OF SPEED CONTROL OF DFIM FOR SUPPLY OF POWER TO THE ELECTRICAL NETWORK

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Received: 08 June 2016/ Accepted: 29 November 2017 / Published online: 01 January 2018

## ABSTRACT

This paper deals with a comparison between a fuzzy logic controller and a conventional IP controller utilized for speed control with a direct stator flux orientation control of a doubly fed induction. The effectiveness of the proposed control strategy is measured under diverse operating conditions such as of reference speed and for load torque step changes at nominal parameters and in the presence of parameter variation. Results obtained from simulation indicte that the fuzzy logic controller is more robust than a conventional IP controller against parameter variation and uncertainty, and is less sensitive to external load torque disturbance with a fast dynamic response; the stator side power factor is controlled at unity level. Then, an intelligent artificial fuzzy control of a wind energy system based on DFAM for supply of power to the electrical network. Its simulated performances are then compared to those of a classical PI controller.

Specifically fuzzy systems are created to overcome the disadvantages of fuzzy systems. Results obtained in Matlab/Simulink environment show that the fuzzy control is more robust, have superior dynamic performance and hence found to be a suitable replacement of the conventional PI controller for the high performance drive applications.

**Key words:** Doubly fed asynchronous machine (DFAM); Field oriented control; Fuzzy control, Fuzzy PI controller, conventional IP controller.

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doi: http://dx.doi.org/10.4314/jfas.v10i1.13

## 1. INTRODUCTION

Doubly-Fed Asynchronous is an electrical asynchronous three-phase machine with open rotor windings which can be fed by external voltages. The stator windings are directly connected to the line grid, while the rotor windings are controlled by means of an inverter. This solution is very attractive for all the applications where limited speed variations around the synchronous velocity are present, since the power handled by the converter at rotor side will be a small fraction (depending on the slip) of the overall system power,[1]. Under optimal control conditions, the variable speed wind system can extract a maximum wind power for a wide range of wind [2]. The anemometers are used to measure the wind speed and derive the desired optimal speed turbine command.

There are two principle-connections of wind energy conversion. The first one is connecting the wind-generator to grid at grid frequency. While connected to grid, grid supplies the reactive VAR required for the induction machines. Often, a DC-link is required to interface the wind-generator system with a certain control technique to the utility grid. The second is connecting the wind-generator system to isolated load in remote areas [3].

A wound rotor induction machine, used as a Doubly Fed Induction Generator (DFIG) wind turbines are nowadays becoming more widely used in wind power generation. The DFIG connected with back to back converter at the rotor terminals provide a very economic solution for variable speed application. Three-phase alternative supply is fed directly to the stator in order to reduce the cost instead of feeding through converter and inverter. For the control of these converters different techniques will be adopted.

The network side converter control has been achieved using Field Oriented Control (FOC).

This method involves the transformation of the currents into a synchronously rotating dq reference frame that is aligned with one of the fluxes [4].

## 2. WIND TURBINE MODEL

Several models for power production capability of wind turbines have been developed. The mechanical power, captured $P_{mech}$ by a wind turbine, depends on its power coefficient Cp given for a wind velocity and can be represented by

$$P_{mech}=\frac{1}{2}C_P\,\rho\pi R^2V^3 \qquad (1)$$

Where **ρ** and **R** correspond to the air density and the radius of the turbine propeller, respectively [5]. The power coefficient can be described as the portion of mechanical power extracted from the total power available from the wind, and it is unique for each turbine. This power coefficient Cp is generally defined as a function of the tip-speed-ratio which, in turn, is given by **λ**

$$\lambda = \frac{wR}{V} \tag{2}$$

Where$w$ represents the rotational speed of the wind turbine. Figure1. Shows a typical relationship bet wean the power coefficient Cp and the tip-speed-ratio. It should be noted that there is a value of λ to ensure a maximum of Cp. Thus, it can be stated that, for a specified wind velocity, there is a turbine rotational speed value that allows capturing the maximum mechanical power attainable from the wind, and this is, precisely, the turbine speed to be followed[6].

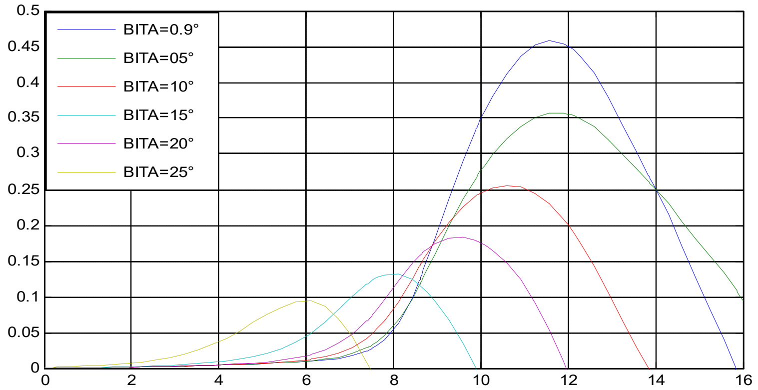

**Fig.1.** Typical Power Coefficient versus Tip-Speed-Ratio Curve

## 3. ACTIVE AND REACTIVE POWER CONTROL OF DFIG

$$S_s=P_s+jQ_s=V_sI^*_s \tag{3}$$

$$S_r=P_r+jQ_r=V_rI^*_r \tag{4}$$

The active and reactive powers are found by using the Equations as below.

$$\begin{cases} \mathrm{Ps} = -V_s \frac{M}{L_s}.I_{rq} \\ Q_s = \frac{V_s.\varphi_s}{L_s} - \frac{V_s M}{L_s} I_{rd} \\ P_r = gV_s \frac{M}{L_s}.I_{rq} \\ Q_r = gV_s \frac{M}{L_s}.I_{rd} \end{cases} \tag{5}$$

## 4. REACTIVE POWER CONTROL

The reactive power at grid terminals or the voltage is controlled by the reactive current flowing in the rotor converter. When the wind turbine is operated in vary regulation mode the reactive power at grid terminals is kept constant by a vary regulator.

The output of the voltage regulator or the vary regulator is the reference d-axis current that must be injected in the rotor by the rotor converter. The same current regulator as for the power control is used to regulate the actual direct rotor current of positive-sequence current to its reference value [7].

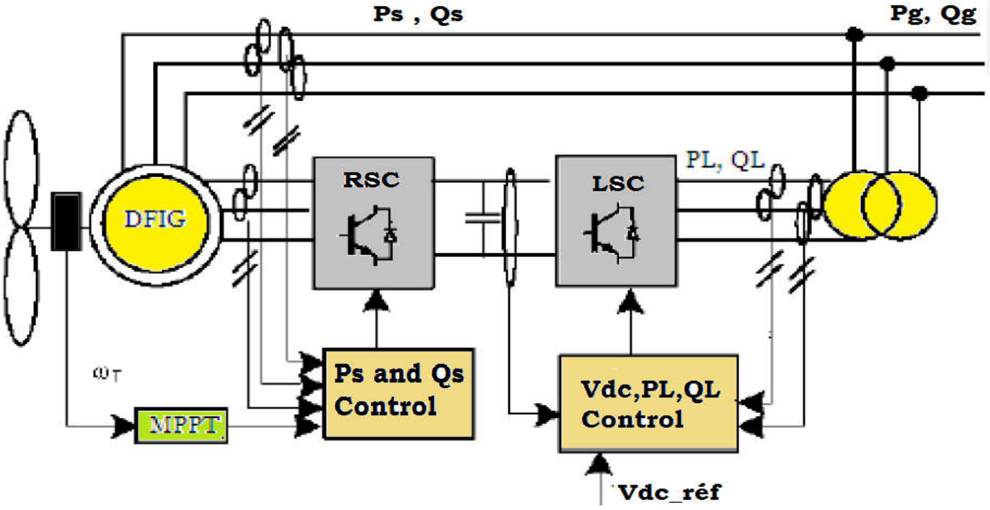

**Fig.2.** Powers exchange between DFIG, Converters and Grid

The rotor side converter ensures a decoupled active and reactive stator power control, Ps and Qs, according to the reference torque delivered by the Maximum Power Point Tracking control (MPPT). The grid side converter control the power flow exchange with the grid via the rotor, by maintaining the dc bus at a constant voltage level and by imposing the reactive power QL at zero [8].

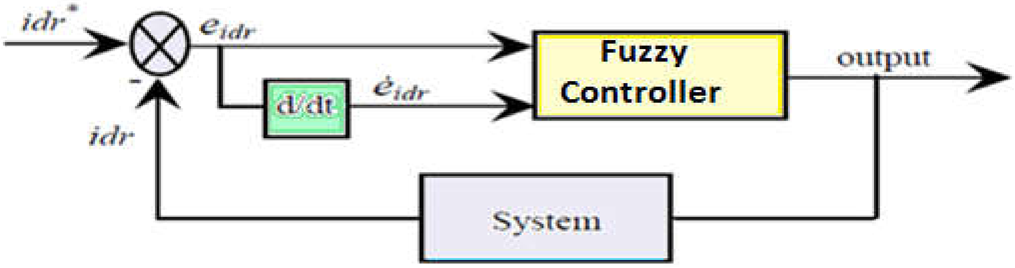

**Fig.3. Block** diagram of the fuzzy controller

## 5. SIMULATION RESULTS

Fig. 4 shows the block diagram of the DFIG fuzzy. The results. Fig.5 shows the results of rotor currents responses using fuzzy, respectively. The stator power Ps follows the current $I_{rq}$. These results in unity power factor on the grid as the stator reactive power Qs is zero are shown in Fig. 6. Rotor current errors are controlled at zero level. The reactive component of the stator current $I_{sd}$ is almost equal to zero during all the time as shown in fig. 7. As result, the stator phase current, reported in fig. 8, has an opposite phase angle to the line voltage indicating that the stator power is injected to the line grid. Reported in fig 10 and fig.12, shows the results of stator three Phase currents responses using fuzzy.

In order to test the robustness of the two controllers, the value of the rotor resistance *Rr* is augmented by 50%, $L_s$, $L_r$ and $M$ is decreased by 25% at $t = 0.5$s.Fig.13 to 15shows the effect of parameters variations on the DFIG response for the two controllers respectively. This robustness test shows that in the case of a PI regulator, the time response is strongly altered whereas it remains unmodified when the fuzzy is used.

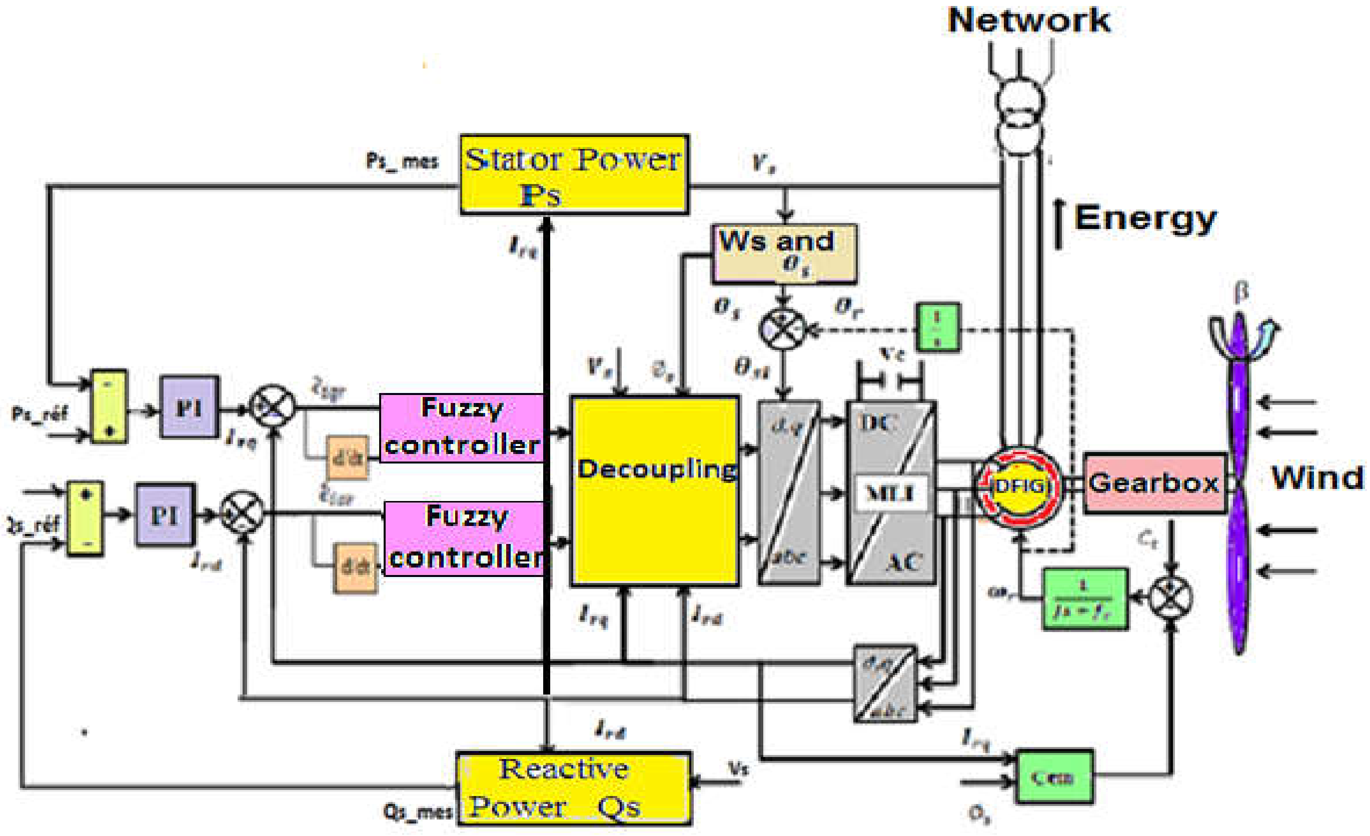

**Fig.4.** Block diagram of the DFIG Fuzzy-PI regulators of speed for supply of power to the electrical network

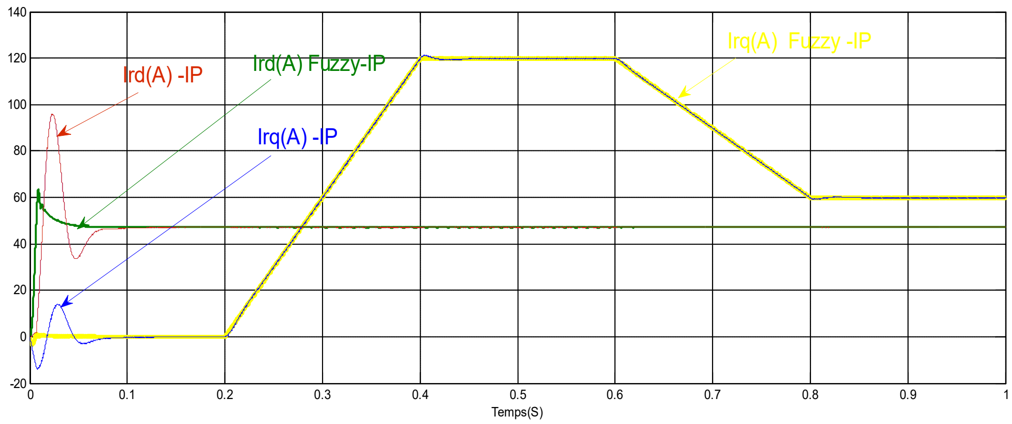

**Fig.5.** Rotor currents responses comparison of IP and Fuzzy-PI regulators of speed control of DFIG

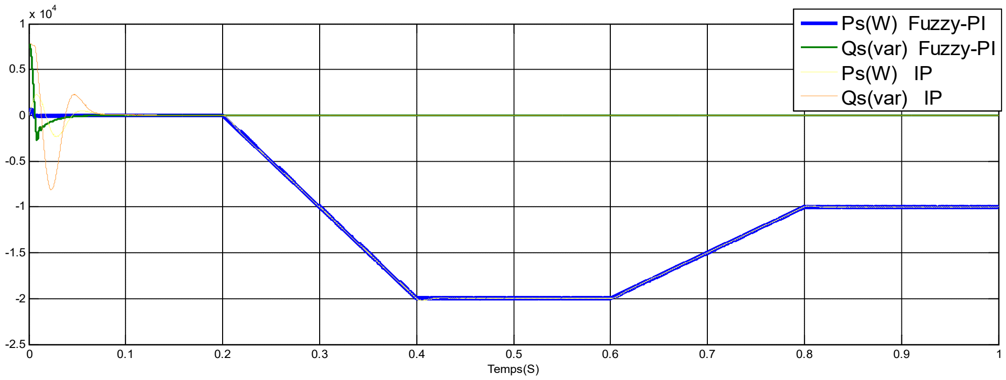

**Fig.6.** Active and reactive powers

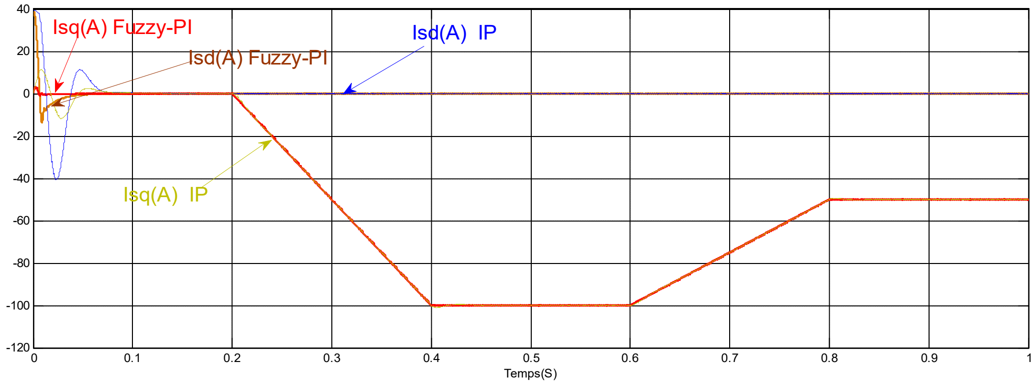

**Fig.7.** Stator currents response comparison of IP and Fuzzy-PI regulators of speed control of DFIM

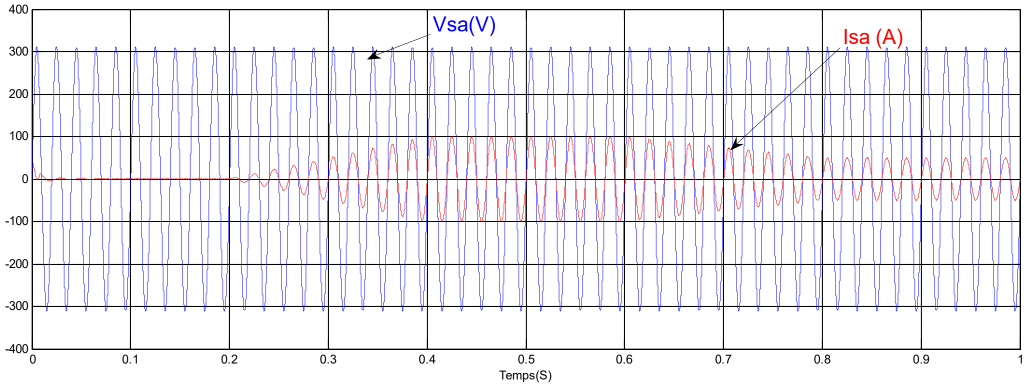

**Fig.8.** Stator voltage and current of Fuzzy-PI regulators

Of speed control

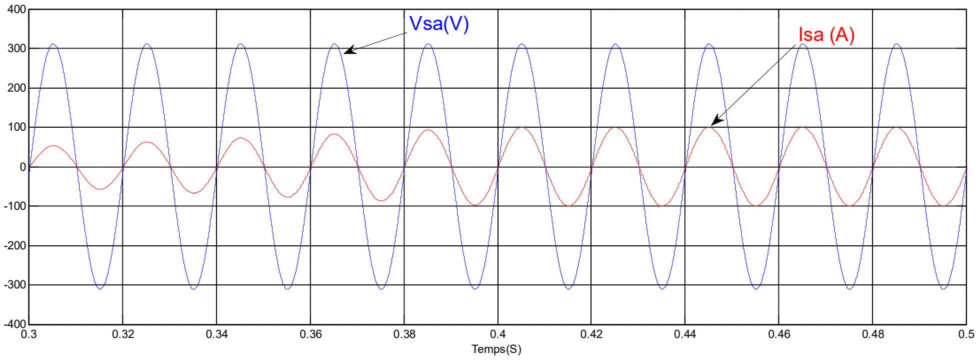

**Fig.9.** Zoom of figure 10

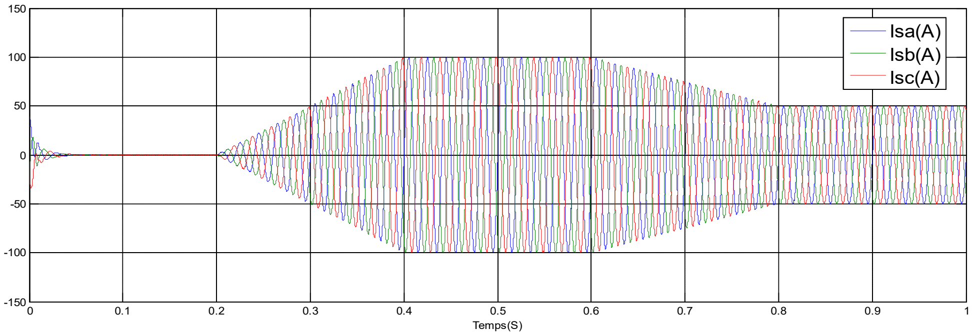

**Fig.10.** Stator Three Phase Currents (Is_ abc) Fuzzy-PI regulators of speed control of DFIG

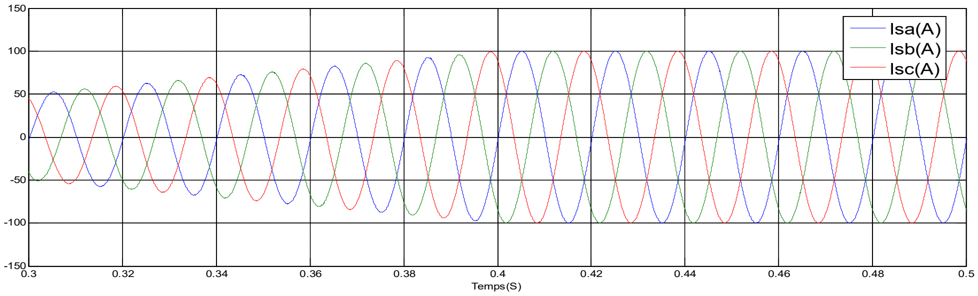

**Fig.11.** Zoom of figure 12

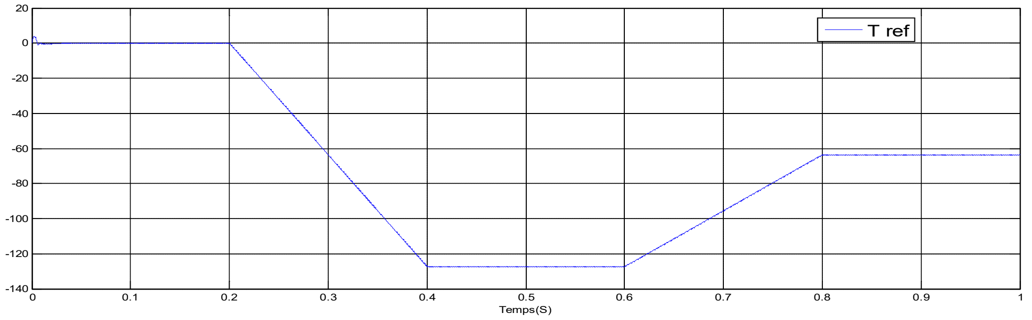

**Fig.12.** Torque reference

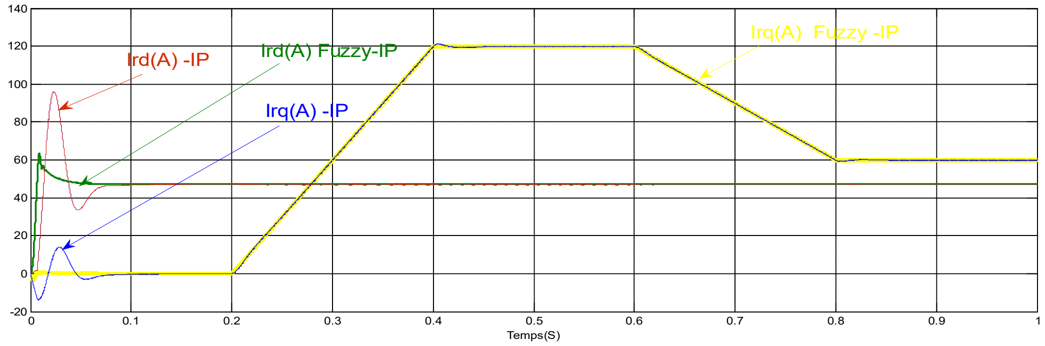

**Fig.13.** Rotor currents responses comparison of IP and Fuzzy-PI regulators of speed Control under load variation

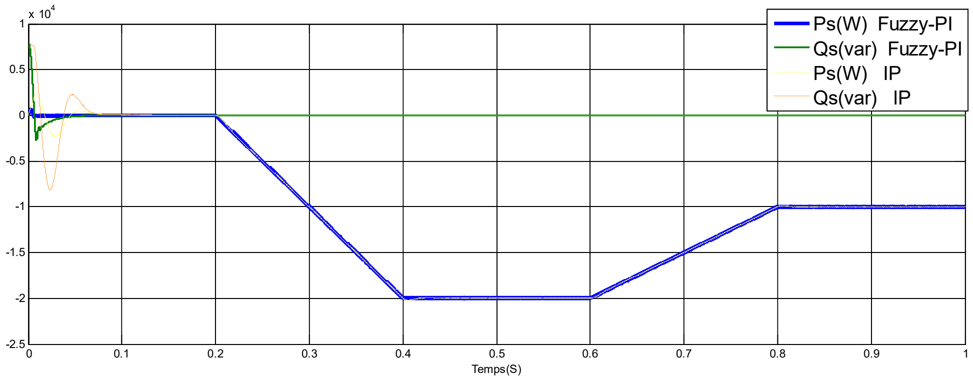

**Fig.14.** Active and reactive powers comparison of IP and Fuzzy-PI regulators of speed Control under load variation

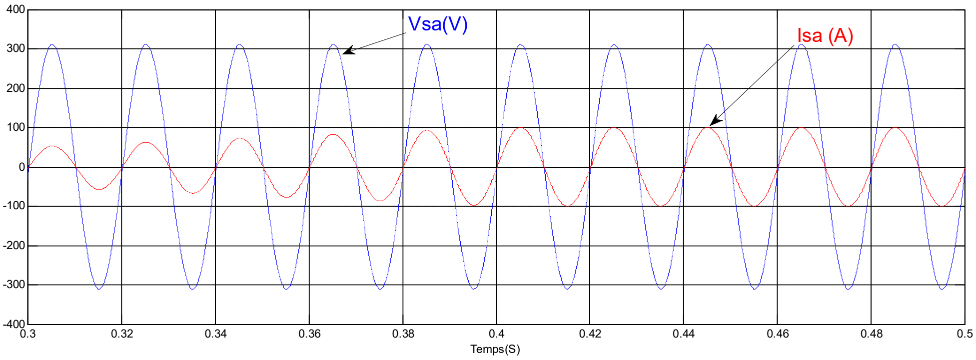

**Fig.15.** Stator voltage and current responses to parameters variations

With fuzzy

## 6. CONCLUSION

In this paper, we have proposed a fuzzy logic controller for the speed control of doubly fed induction motor with a direct stator flux orientation control. The effectiveness of the proposed controller has been tested on DFIM in comparison with conventional IP controller under different operating conditions. The fuzzy PI regulator proves robustness against rotor resistance variation and insensitivity to load torque disturbance as well as faster dynamics with negligible steady state error at all dynamic operating conditions. Simulation results have shown correct stator flux oriented control behavior and speed tracking performances.

## 7. ANNEXURE

Wound Rotor Induction Machine Parameters:-

| | |
|---|---|
| Nominal Power | Pn = 1.5 MW |
| Stator Voltage | vs = 300V |
| Stator Frequency | fs = 50 Hz |
| Stator Resistance | Rs = 0.012 Ω |
| Stator Inductance | Ls = 0.0205 H |
| Rotor Resistance | Rr = 0.021 Ω |
| Rotor Inductance | Lr = 0.0204H |
| Mutual Inductance | Lm = 0.0169 H |
| Inertia Constant | J = 1000 Kg-m2 |

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**How to cite this article**:
Guediri A, Ben Attous D. Modeling and comparison of ip and fuzzy-pi regulators of speed control of dfim for supply of power to the electrical network. J. Fundam. Appl. Sci., 2018, 10(1), *181-190.*