# Design the Fuzzy Controller Tuning PID Controller Parameter for Wind Generator System

Dang Danh Hoang[#1], Tran Xuan Minh[*2], Tran Xuan Dung[#3]
[1,2,3] *Thai Nguyen University of Technology – Thai Nguyen University*
*Thai Nguyen , Vietnam*

***Abstract***

*Wind energy power systems are increasingly being used to harness the vast amount of renewable energy that nature offers to people, such as wind power. In this system, the use of a wind generator is a three-phase asynchronous power generator. In order to improve the quality of control it is necessary to have suitable controllers to ensure that the working conditions of the system such as the grid, power output as well as the required reactive power (within the allowable range of the system). This article presents the method of designing a fuzzy controller that defines a PID controller parameter to improve quality compared to classic PID controllers. The simulated results show that the quality of the system has been ensured in the synchronous modes and when the active and reactive power are changed by requirement of the load (within the allowable range).*

**Keywords** — *Wind power; PID; Fuzzy; Fuzzy-tuning PID parameters; cling to power.*

### *Abbreviation*

| | |
|---|---|
| GTT | Calculate Value |
| GTD | Setpoint Value |
| TSP | Setpoint Current Value |
| PLL | Phase Lock |

## I. INTRODUCTION

The wind generator system used Doubly Fed Induction Generator (DFIG) with PID controller as a controller for system. It's necessary to find the solution forimproving the control quality PID controller. Because the classic PID controllerhas advantages in design and manufacture, it is still used in systems (including nonlinear systems). This article indicate the design of controller by using the fuzzy methor to tune PID controller parameter [3] for the DFIG control system. The results of the research are shown by simulation results on the software Matlab - Simulink - Plecs that ensured the quality on working mode synchronous and the generating electricity to the grid ensures that the power respond to the load requirement (within allowable range).

## II. MAIN CONTENT

### *A. The Fuzzy Controller Design Method Defines the PID Controller Parameters [3]*

The classic PID controller are designed according to some methors such as synthesis system Ziegler and Nichols, Offerein, Chien Hrones Reswick, total time Kuhn, optimization module, optimally symmetric. A PID controller with a deviation input e(t), a output u(t) have the mathematical model as follows:

$$u(t) = K_P\left[e(t) + \frac{1}{T_I}\int_0^t e(\tau)d\tau + T_D\frac{de(t)}{dt}\right] \qquad (1)$$

Or described as a transfer function:

$$G_{PID}(s) = K_P + \frac{K_I}{s} + K_D s \qquad (2)$$

With PID controller parameters are designed for nonlinear objects and asynchronous dual power generators, we nomally designed the system following empirical method. That is why the controller parameters were not optimized. Moreover, in working process, the objects are changed, then the PID controller will work with low efficiency. It is necessary to have a control methor to tune PID controller parameter. According to [3], the methor to control PID controller parameter as shown in Fig 1:

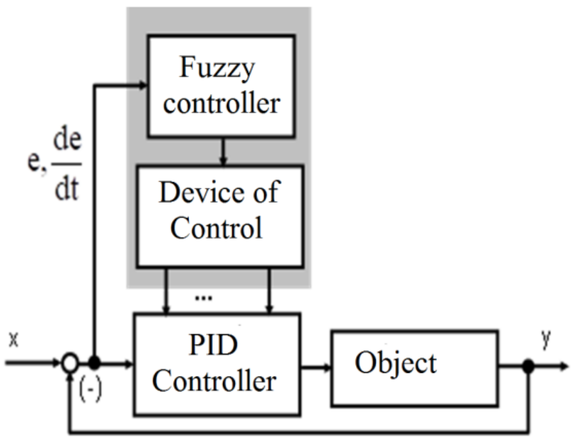


**Fig 1: Fuzzy control method for tuning PID controller parameters**

In which, the structure of the fuzzy tuner shown in Fig 2:

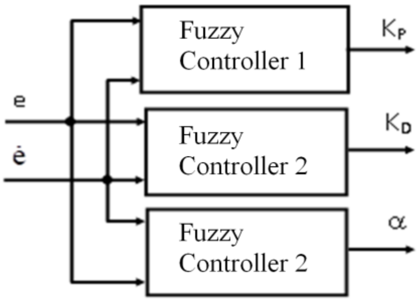


**Fig 2: Internal structure of the fuzzy tuned PID controller parameters.**

The PID controller parameters $K_P$, $K_I$, $K_D$ are tuned based on analysis of dominant signal and output signals of system. That is more correcly than deviation e (t) and derivative $\frac{de}{dt}$ of deviation.The PID controller parameter are tuned by this method such as goal function. It was directly tuned but this methor must be groping and not responsible when parameters are changed.To simple and easy for applying, we used the tuner methor of Zhao, Tomizuka and Isaka (Fig. 1). With assuming the parameters $K_P$, $K_D$are limited, it mean [3]:

$$K_P \in \left[K_P^{min}, K_P^{max}\right] \text{and } K_D \in \left[K_D^{min}, K_D^{max}\right] \quad (3)$$

Zhao, Tomizuka and Isaka have standardized the parameters as follows:

$$K_P = \frac{K_P - K_P^{min}}{K_P^{max} - K_P^{min}} \text{ and } K_D = \frac{K_D - K_D^{min}}{K_D^{max} - K_D^{min}} \quad (4)$$

to have $0 \leq K_P, K_D \leq 1$

In which:

$$\alpha = \frac{T_I}{T_D} \Rightarrow K_I = \frac{K_P^2}{\alpha K_D} \quad (5)$$

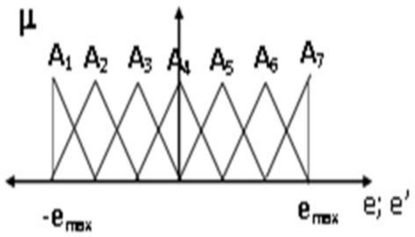


**Fig 3: Fuzzy imputs of fuzzy tuner**

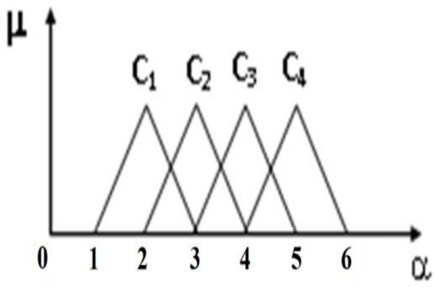


**Fig 4: Fuzzy outputs of fuzzy tuner α**

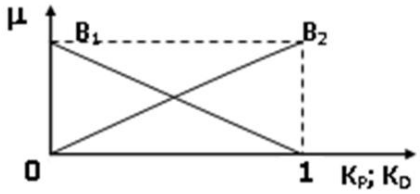


**Fig 5: Fuzzy outputs of fuzzy tuner $K_P$, $K_D$**

We designed three fuzzy controller to tune each parameter of PID controller, then combine them to be the fuzzy tuner with 2 inputs are e (t), $\frac{de(t)}{dt}$ and 3 outputs are $K_P$, $K_D$ và α (Fig. 2). With 7 fuzzy inputs (Fig. 3), 2 outputs for variables $K_P$, $K_D$ (Fig. 6) and 4 fuzzy outputs α (Fig 5).

Set up the equation according to the Max-prod principle andfuzzy solved by altitude method.

### *B. Structure of Control System*

The system based on 2 main parts controller (see Fig 1), ([4], [5]):

+ Control on the grid.

+ Control on the generatorusing asynchronous dual source (Doubly-Fed Induction Generators - DFIG).

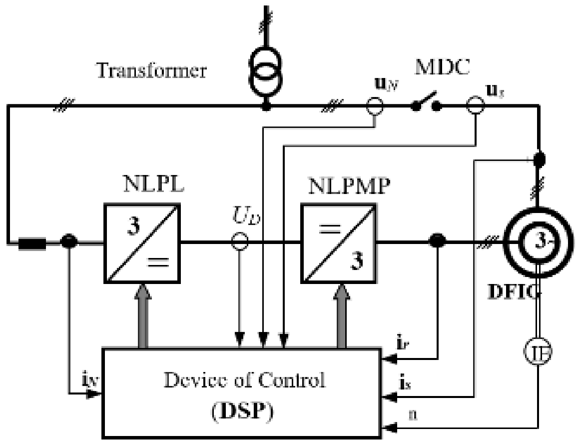


**Fig 6: Structure diagram of the generator system using DFIG**

NLPL: Inverter on the grid.
NLPMP: Invertor on sides of the generator.
MDC: Switches.
IE: Measure the speed by carving the pulse The control system includes 2 parts: control on the side of generator and grid. Because the control on the grid was acknowledged by other researches, this article focus on control on the side of generator.

### *C. Designing Fuzzy Controller Tune the PID Controller Parameters with Inverter on the Side of Generator*

According to [4], [5], [6], the control structure of the whole system of wind generators uses the dual source asynchronous generator as shown in

Fig 7. The structure of system of wind generators shown in Fig 7 includes 2 paths: control on the side of generator and grid. Because the requirement of the grid is controlling the DC voltage stability $U_{DC}$ supply for intermediate DC circuit, in the article, the simple linear design method chosen is the normal Dead-Beat linear method [4], [5], [6]. Therefore, the main content of the article is focused on the design of the transmitter rotor generator control ($RI_2$) along with the external control of two conventional PI controllers for torque and reactive power ([4], [5], [6]).

### 1) *Design of PID Controllers*

Before the design fuzzy controllers tuning PID parameters, we design a classic PID controller for the inverter on the side of generator current controller.

Design of rotor current controller using PID controller for the generator according to the method chosen extreme resistance [1] follow the steps for the control structure diagram Fig 8 as follows:

**Step 1:** Determine the transfer function of the system with feedback through the positive resistor $R_a$ (selected according to the parameters of the control

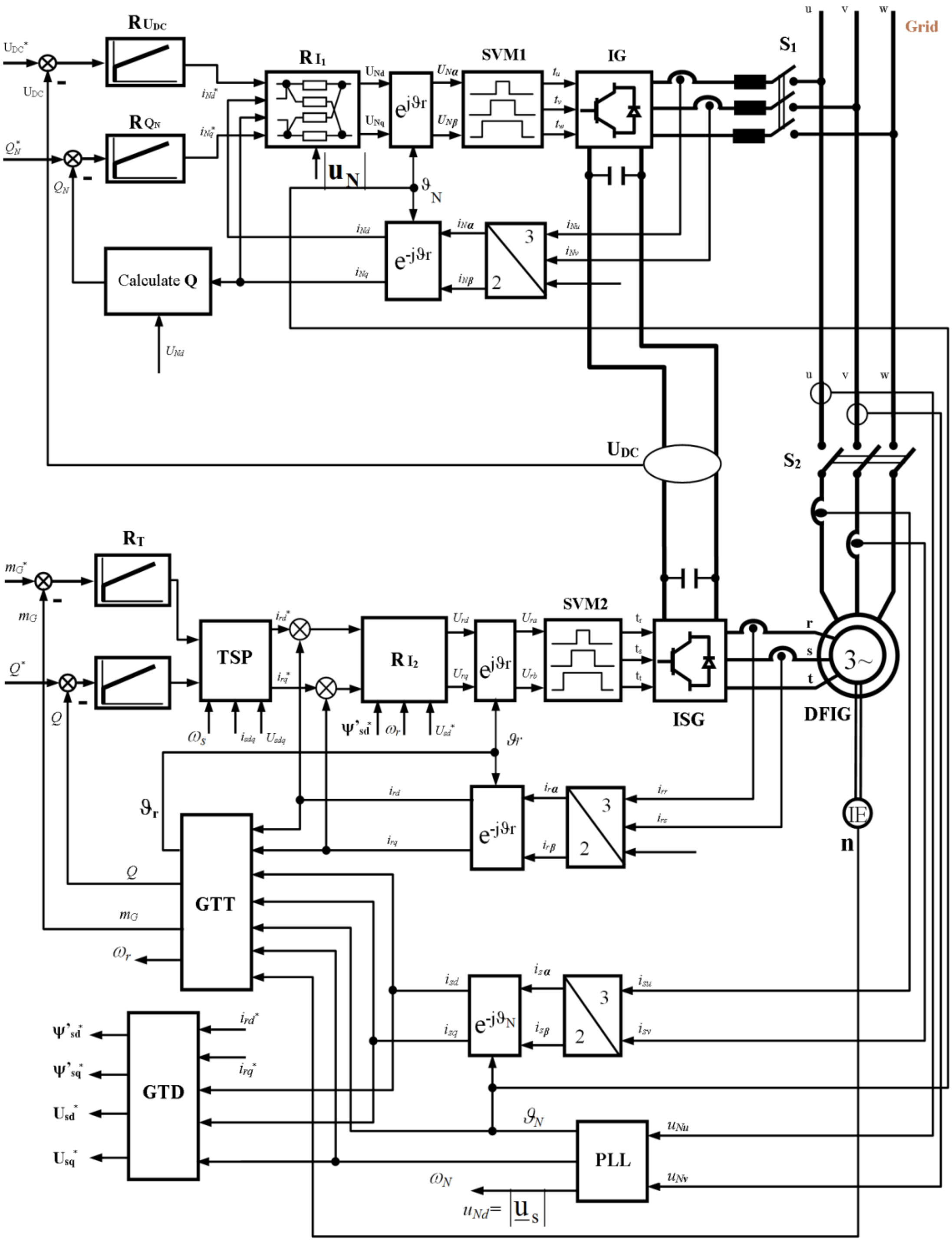


**Fig 7: The system-wide control structure with the current controller on the side of wind generator**

object).

**Step 2:** Determine the parameters of PID controller according to resistor $R_a$.

**Step 3:** Calculating the value of $R_a$ following theestimates parameter ofthe control object.

**Step 4:** Tuning the PID controller parameters through simulation.

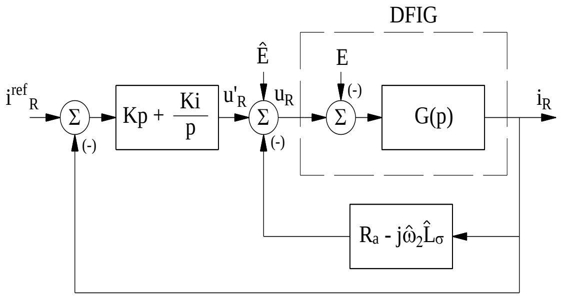


**Fig 8: The diagram of loop control structure of rotor current using PI**

In Fig 8, PI controller is selected,we have:

$$L_\sigma \frac{di_r}{dt} = u'_r - (R_r + R_s + R_a)i_r \qquad (6)$$

Thus, the transfer function from $u'_r$to $i_r$ will be:

$$G(p) = \frac{1}{pL_\sigma + R_R + R_s + R_a} \qquad (7)$$

According to [1] the parameters of PI controller are:

$$K_p = \alpha_c \tilde{L}_\sigma ;\ K_i = \alpha_c(\tilde{R}_r + \tilde{R}_s + R_a) \qquad (8)$$

In which:

$\alpha_c$: Bandwidth of closed-loop of the current dynamics system

$$R_a = k_R(\alpha_c \tilde{L}_\sigma - \tilde{R}_r - \tilde{R}_s) \qquad (9)$$

### *2) Fuzzy Control Design Tuning PID Parameters*

With the fuzzy controller tuning PID controller parameter design method,that are described in Section 1). We design the fuzzy tuner law of fuzzy controllers for tuning the three $K_P$, $K_D$ and α parameter as follows:

* $K_P$ Tuner law:

| e \ $\dot{e}$ | $A_1$ | $A_2$ | $A_3$ | $A_0$ | $A_4$ | $A_5$ | $A_6$ |
|---|---|---|---|---|---|---|---|
| $A_1$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ |
| $A_2$ | $B_1$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_1$ |
| $A_3$ | $B_1$ | $B_1$ | $B_2$ | $B_2$ | $B_2$ | $B_1$ | $B_1$ |
| $A_0$ | $B_1$ | $B_1$ | $B_1$ | $B_2$ | $B_1$ | $B_1$ | $B_1$ |
| $A_4$ | $B_1$ | $B_1$ | $B_2$ | $B_2$ | $B_2$ | $B_1$ | $B_1$ |
| $A_5$ | $B_1$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_1$ |
| $A_6$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ |

* $K_D$ Tuner law:

| e \ $\dot{e}$ | $A_1$ | $A_2$ | $A_3$ | $A_0$ | $A_4$ | $A_5$ | $A_6$ |
|---|---|---|---|---|---|---|---|
| $A_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ |
| $A_2$ | $B_2$ | $B_2$ | $B_1$ | $B_1$ | $B_1$ | $B_2$ | $B_1$ |
| $A_3$ | $B_2$ | $B_2$ | $B_2$ | $B_1$ | $B_2$ | $B_2$ | $B_2$ |
| $A_0$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ | $B_2$ |
| $A_4$ | $B_2$ | $B_2$ | $B_2$ | $B_1$ | $B_2$ | $B_2$ | $B_2$ |
| $A_5$ | $B_2$ | $B_2$ | $B_1$ | $B_1$ | $B_1$ | $B_2$ | $B_2$ |
| $A_6$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ | $B_1$ |

* α Tuner law:

| e \ $\dot{e}$ | $A_1$ | $A_2$ | $A_3$ | $A_0$ | $A_4$ | $A_5$ | $A_6$ |
|---|---|---|---|---|---|---|---|
| $A_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |
| $A_2$ | $C_2$ | $C_2$ | $C_1$ | $C_1$ | $C_1$ | $C_2$ | $C_2$ |
| $A_3$ | $C_3$ | $C_2$ | $C_2$ | $C_1$ | $C_2$ | $C_2$ | $C_3$ |
| $A_0$ | $C_4$ | $C_3$ | $C_2$ | $C_2$ | $C_2$ | $C_3$ | $C_4$ |
| $A_4$ | $C_3$ | $C_2$ | $C_2$ | $C_1$ | $C_2$ | $C_2$ | $C_3$ |
| $A_5$ | $C_2$ | $C_2$ | $C_1$ | $C_1$ | $C_1$ | $C_2$ | $C_2$ |
| $A_6$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ | $C_1$ |

### *D. The Outer Control Panel and Calculator Real Value and Set*

The design of the external control loops are digital PI controllers including: the control loop momen mG and control loop reactive power Q. When design according to [4], [5], that have to mention about the output signal goes into the saturation region and is determined:

$$R(Z) = V\frac{1 - MZ^{-1}}{1 - Z^{-1}} \qquad (10)$$

The real valueand prevalueare defined by block GTT and GTD. These blocks are responsible for calculating the real value and prevaluethat sendto controllers andstitch transfer coordinates.. This section was already in the documentation [4], [5].

## III.EVALUATING THE QUALITY OF SYSTEM CONTROL BY MATLAB/SIMULINK SIMULATION

### *A. Simulation System Diagram*

Using software Matlab / Simulink / Plecs, the simulation diagram as shown in Fig 9.

Simulation with the generator parameters:

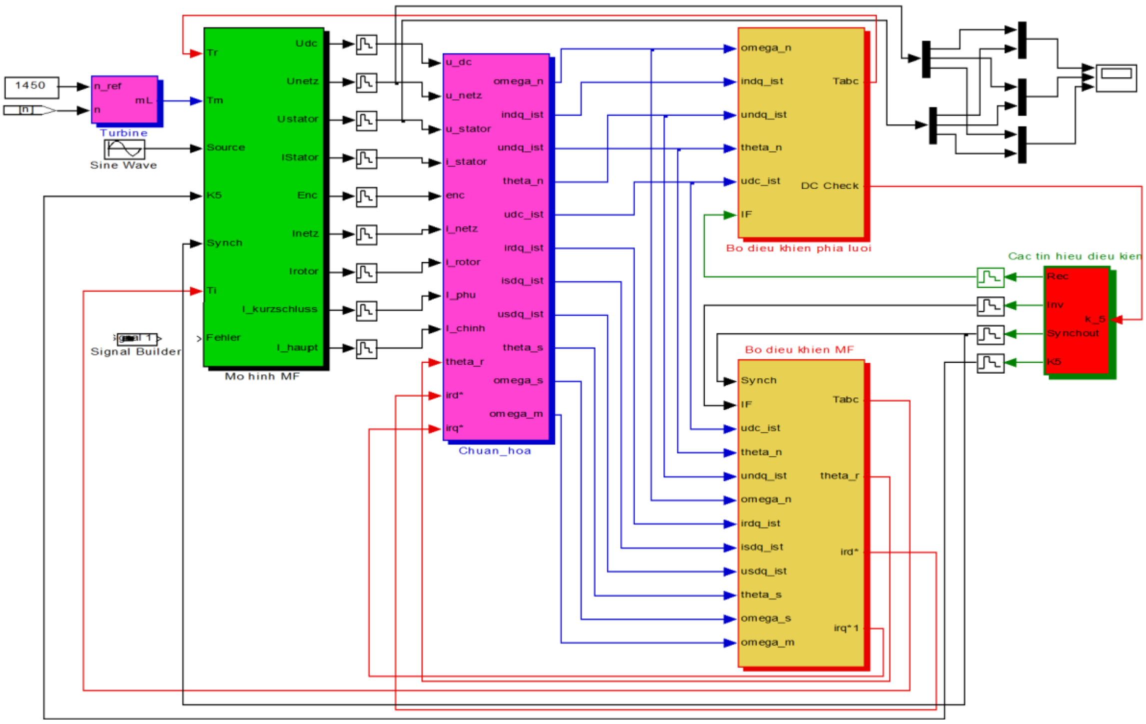


**Fig. 9: The simulation diagram Matlab/Simulink/Plecs**

| | | |
|---|---|---|
| $P_{dm}$ = 1.1 KW | $U_{dmr}$ = 345 V | $R_r$ = 3.7 Ω |
| $U_{dms}$ =220/380(Δ/Y) | $n_{dm}$ =950 V/ph | $L_{\sigma s}$ = 0.013H |
| $f_{dm}$ = 50 Hz | Rs =4.2 Ω | $L_{\sigma s}$ = 0.0089H |
| $z_p$ = 3 | $Cos\varphi_{dm}$ =0.657 | $L_m$ = 0.34H |
| J = 0.064Kgm2 | $I_{dm}$ = 3.5A | Code: VM Vietnam |

***B. Quality Evaluation of System through Simulation between the Fuzzy Controller Tuning PID Parameter and PID***

*- Testing the synchronization of the generator on the grid:*

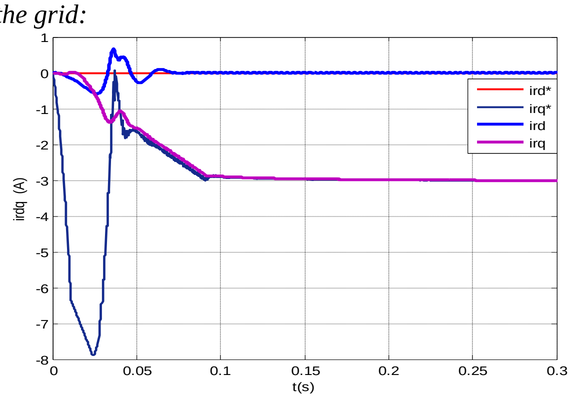


**Fig 10a: Current response with PID controller**

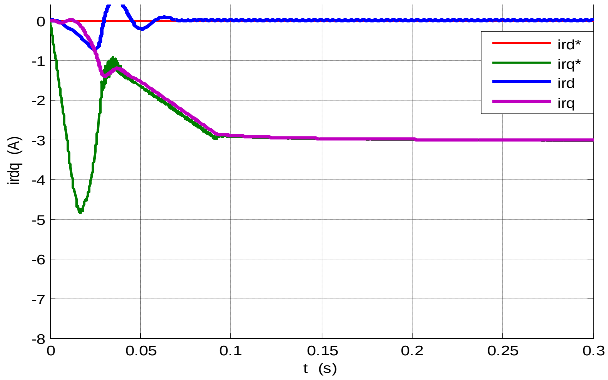


**Fig 10b: Currentresponse with fuzzy controller**

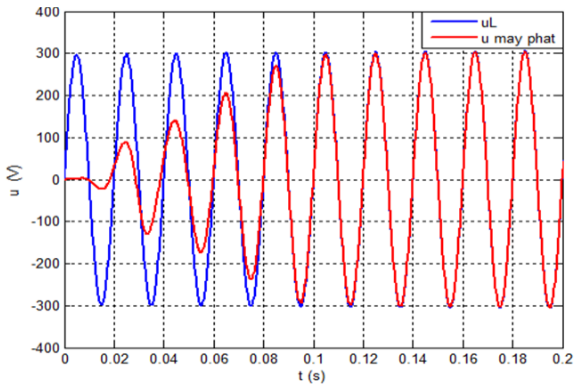


**Fig 11a: Voltage response of stator with the PID controller**

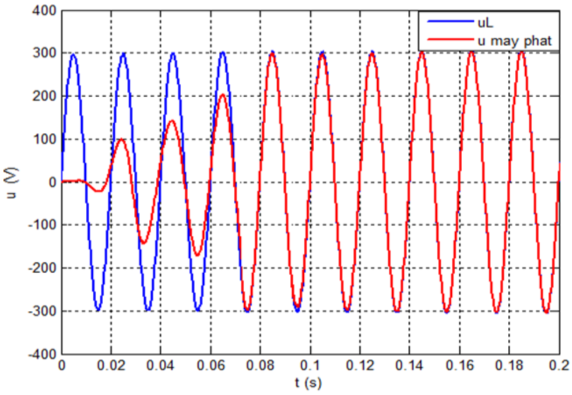


**Fig 11b: Voltage response of stator with the Fuzzy controller**

**Comment:** The simulation results show that the fuzzy controller tuning the PID controller parametershas improved the quality of control compared to PID controllerssuch asbetter rotor current response (Fig. 10ab),Time to phase of the grid and the generator coincident is shorter (Fig. 11ab) and the largest deviation after synchronization is 1%, while the PID controller is 1.1%.

*- Testing momen response(active power) after synchronization:*

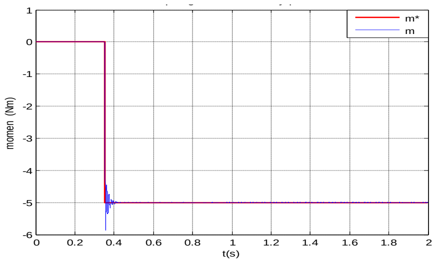


**Fig 12a: Momen response with PID controller**

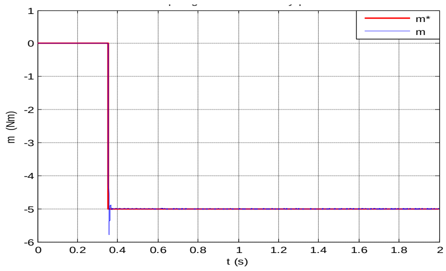


**Fig. 12b: Momen response with fuzzy controller**

*- Testing the Reactive power Q response after synchronization:*

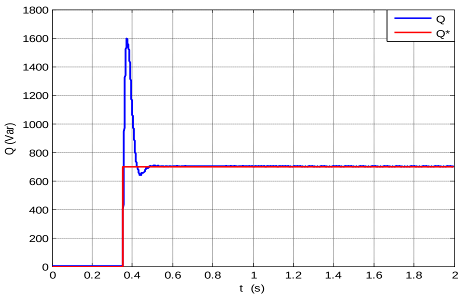


**Fig 13a: Reactive power Q response with PID controller**

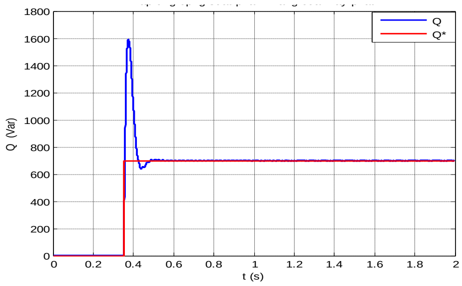


**Fig 13b: Reactive power Qresponse with fuzzy controller**

*- Check the momen response (active power) after synchronizing:*

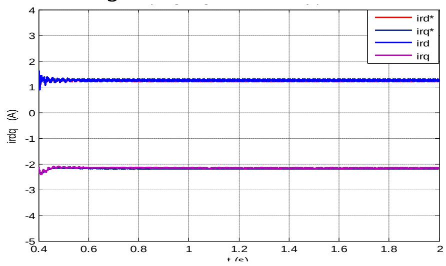


**Fig 14a: Current response of the generator rotor with the PID controller**

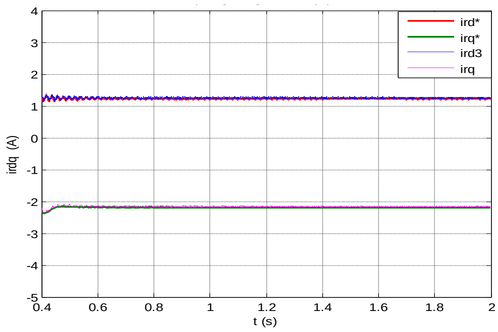


**Fig 14b: Current response of the generator rotor with the fuzzy controller**

## COMMENT

Simulation results of electric current, momen (active power P) and reactive power Q in working after synchronizing from Fig. 12ab to Fig. 14a,b shown that the control quality of the fuzzy controller has improved the PID controller parameters, which confirms the correctness of the algorithm.

## IV. CONCLUSION

This article was given the control algorithm that ensured the wind generator system cling to active power and reactive power on the grid as requested (within the allowable range).

The simulation results show that the rotor current controller has been controlled $i_{rd}$, $i_{rq}$cling to preset value $i_{rd}$*, $i_{rq}$* when synchronous as well aspower supply mode on the grid.With simulation results, the quality control of the system has been ensured andthe fuzzy controller tuning PID controller parameters are better quality than the classic PID controller.

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