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Dynamic Demand Management in an Airconditioner System by Frequency Control in Smart Grid Environment

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Abstract

As there is a rapid growth both in the number of power consumers and also the limitations energy resources, it is clearly accepted that the old version of power grid must change into smart grid from head to toe. One of the most important advantages of smart grid which makes it much more exclusive rather than other typical systems is the two-way connectivity between the utility and the costumers. Taking energy efficiency programs for domestic consumers which are considered with the most important role in raising the rate of energy consumption of all, is accepted as an applicable techniques of demand-side management. In this thesis an identical frequency method control of the electrical motor of an air-conditioner (AC) system based on Fuzzy-PID controller is proposed in order to maximizing energy efficiency. Referring to the statistics which are published about the rate of energy consumption of AC systems would have the highest role in demand response and the two-way cooperation between the utility and costumers. To evaluate the results much more applicable, the proposed method is simulated with MATLAB software and the results have shown that the system have the great success.

Keywords: Air-conditioner, Demand response, Frequency control, Fuzzy-PID controller, Smart grid

1. Introduction

Considering the growing number of electricity consumers and the limitation of the resources of energy production, development of traditional networks to smart grid, is accepted as a fundamental principle. One of the most important applications of smart grid that distinguish it from other conventional systems is a two-way communication with consumers; this feature provides the condition for demand response in the smart grid. Energy productivity in residential consumers that always have a great share in electricity consumption per capita is considered as one of the main management techniques of the demand-side. According to the statistics that have been reported about the consumption of various equipment that have been used in the household and non-household sector, it is clearly observed that the optimization of consumption in the air conditioning systems can be highly effective and useful in the demand response programs and mutual participation of customers and electricity companies.

Air conditioning systems have always been a basic requirement for the welfare of human life, therefore when we speak of these systems we should also discuss the way of controlling them, thus control of these systems has found a special place among the control engineers. The problem that is often observed in the design of such systems is their high consumption of energy when turned on. In the present study, by identifying the factors that are involved in the temperature of an environment like home area, wall area, the rate of energy flow and the introduction of fuzzy logic, it has been tried to design a fuzzy controller in order to optimize energy consumption. The objective of the project is to maintain the temperature close to the desired value and also to provide thermal comfort range, along with reducing the energy consumption of the compressor / fan system, in a way that all available resources are used in the most efficient model, accordingly, huge savings in energy can be realized in the form of reducing the duty cycle of compressor and the fan and quick provision of the comfort conditions.

2. Literature Review

Air conditioning systems are nonlinear and dynamic systems; therefore there exist nonlinear control methods for controlling them. Design of these systems can be performed by designing nonlinear controllers with an estimate of loads entered into the system [1]. Artificial neural networks have been used to control these systems [2].In reference [3],[4] by using the intelligent control, it has been attempted to improve control of the air conditioning system. In this reference, in order to control the air conditioning system and also the air condition, Fuzzy Neural Network methods have been utilized. Also, the controller parameters are determined by the neural network. Another method of control is to use a conventional PID; with the difference that the PID coefficients at any point of time, through the mechanism of adaptation, are calculated in a way that the values of ζ and ω_n of system response, have desirable values [5],[6].Since the main purpose of the design is to achieve the desired stability, therefore, the mechanisms of determining the coefficients of PID can be performed by the condition of the stability of the system[7],[8].In reference [9],due to the fact that the optimal control of air conditioning systems and optimal adjustment of parameters of these systems is not an easy task, a fuzzy PI controller is used. In order to improve the efficiency of air conditioning systems in the industry, the drive motor process, in a way that the speed is controlled, play an important role. The most famous and most functional controller used in the industry is PID controllers and this is due to the simplicity of their structure and being resistant. Hence, there are many ways to find the optimal parameters of the controllers including the proportional coefficient, integral coefficients and derivative coefficients. However, finding the optimal parameters is difficult and time consuming. Classical conventional techniques, such as Ziegler Nichols method and placement of poles etc. have disadvantages such as being time-consuming, low accuracy and low efficiency.

3. The Proposed Model

Today, most controllers that are used in industry are PID controllers. Among the important functions of PID controllers, we can mention the provision of feedback, the ability to remove the steady state offset by integration and also the ability to predict the state after differentiation. For many applications, especially when dynamic processing is propitious and the needs of work are normal, classical PID controller is able to maintain the favourable conditions. Hence, there are many ways to find the optimal parameters of this controller, that is, proportional coefficient, integral coefficients and derivative coefficients. However, finding the optimal parameters is difficult and takes a lot of time of the designers. Classical conventional techniques, such as Ziegler Nichols method and placement of poles etc. have disadvantages such as being time-consuming, low accuracy and low efficiency; therefore we try to optimize the control process by using fuzzy control, also by reducing the overshoot percent and rise and settling time as compared to the classic controllers, we will increase the efficiency and useful life of the system. In the present study, fuzzy logic has been used as an efficient tool in determining the controlling coefficients of the conditioning system of buildings. The results indicate that the designed fuzzy controller is able to adjust the best coefficients for PID controller and maintain the favourable conditions and in comparison to classic PID controllers, in addition to reducing energy consumption, it can increase efficiency and useful life of the system. After reviewing various references, it was found that one of the most common motors used in conventional air conditioning systems is induction motors and it was clearly observed that the frequency control is most appropriate method for the drive of these motors. Using this technique will be helpful in this respect that this method can quickly respond to dynamic changes of the load.

The model implemented in MATLAB Simulink environment is as Fig.2.

4. Simulation

According to the diagram, reference speed is green and engine speed is blue, we can observe that PID controller has not been able to follow the reference speed and adapt itself to it.

Figure 7 shows the level of Total Harmonic Distortion (THD) of stator current signal. THD is the level of harmonic distortion signal that whatever its amount is lesser, it means that distortion and instability of the signal is less.

5. Simulations By Using Fuzzy PID Controller

The utilized fuzzy PID controller presents results that are as follows:

Like the results of the PID controller, reference speed is green and engine speed is blue. It can be observe that fuzzy PID controller is able to follow the reference speed and adapt itself to it.

6. Analysis Of The Data Of Simulation

Electrical losses in the presence or absence of harmonics in the network:

Without THD:

$$P_{Loss} = 3RI^2 \tag{1}$$

With THD:

$$P_{Loss} = 3RI^2 + K_{se}RI^2(THD)^2 \tag{2}$$

The coefficient of K_{se} determines the amount of skin effect Where h is the harmonic order.

In the comparison of the two amounts of THD, the difference between the losses in the two states is equal to:

$$\Delta P_{Loss} = K_{se}R_{ac}I^2(THD_2^2 - THD_1^2) \tag{3}$$

Where R $_{ac}$ is the effective resistance of wire in the presence of harmonics, in other words, due to the high level of skin effect at high frequencies, the amount of resistance, decreases in proportion to the effective radius, in following, we have presented the process of calculating effective resistance [10]:

$$\delta = \sqrt{\frac{\rho}{\pi\mu f}} \tag{4}$$

Parameter of δ is a coefficient of the wire diameter that is provided due to the skin effect for the transit of flow.

So in order to obtain effective resistance we will have:

$$d_{eff} = \delta d \tag{5}$$

$$R = \rho\frac{l}{A} = \frac{4\rho l}{\pi d^2} \tag{6}$$

$$R_{eff} = \frac{4\rho l}{\pi\delta^2 d^2} \tag{7}$$

$$R_{eff} = \frac{4l\mu f}{d^2} \tag{8}$$

According to the equation, it is observed that effective resistance of the wire has a direct relationship with frequency. Now, by comparing harmonic spectrum of the signal in two cases, harmonic orders of signals are observable.

By comparing the harmonic spectrum of the signal in two cases, it is observed that harmonic orders of 7, 9 and 11 are non-negligible; therefore it can be concluded that on average, the mode of frequency signal is about 10 times greater than the base frequency. Hence, the effective resistance is almost 10 times greater than the nominal resistance in the base frequency.

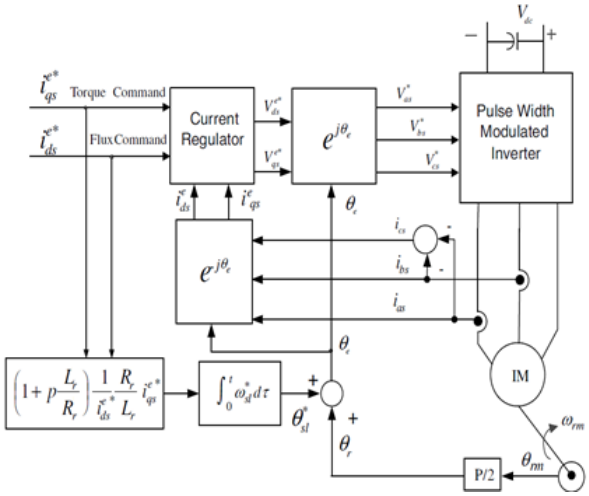

Fig. 1. Overall block diagram of Rotor Flux Oriented Control (FOC)

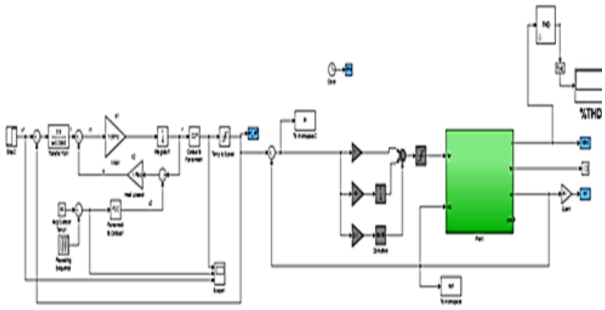

Fig. 2. Block diagram of simulation in Simulink environment in the presence of PID controller

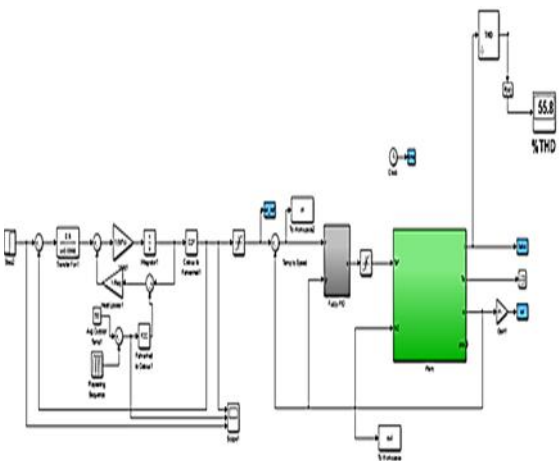

Fig. 3. Block diagram of simulation in Simulink environment in the presence of fuzzy PID controller

On the other hand, as it was observed, in this study, the level of THD in the non-use and use of fuzzy controller is about 9/527 and 1/127, respectively. As a result of this issue, even by assuming the equality of K_{se} in two cases, the amount of difference between the losses becomes equal to:

$$\Delta P_{Loss} \alpha 10(9.527^2 - 1.127^2) \cong 1000w \tag{9}$$

This means that in the case of using the fuzzy controller, the loss power will be lower about 1kW. Also harmonic losses will have a significant impact in Foucault losses of transformers, which is directly associated with the frequency:

$$P_{eddy} = K_e f^2 B_m^2 \tag{10}$$

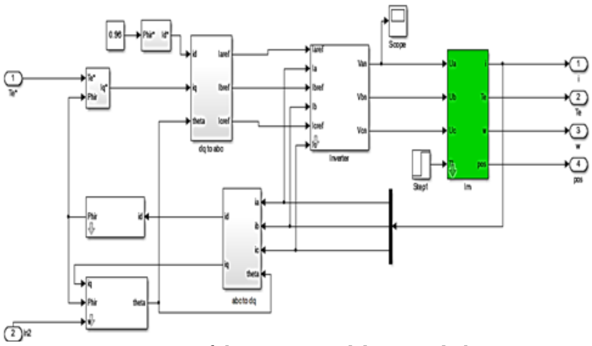

Fig 4. A representation of the system model in Simulink

Table.1.
Fuzzy Rules

e \ ė	Negative	Zero	Positive
Negative	Large Negative	Small Negative	Zero
Zero	Small Negative	Zero	Small Positive
Positive	Zero	Small Positive	Large Positive

7. Conclusion

According to the figures, it is observed that the fuzzy controller shows much more appropriate behaviour than the classic controllers. Fuzzy controllers are used when the detailed design or the prediction of load changes of system is difficult. Also the results represent the appropriate responding of PID fuzzy controller for following the speed reference in comparison to PID controller. This indicates that the motor is able to adjust its performance with the reference speed. This circumstance is specifically significant when the controller is not used for the drive of conditioning system motor; in other words, in the traditional systems where the motor is equipped with the on /off switches, in such circumstances, inevitably, the motor of conditioning system should be operated continuously with constant torque and speed.

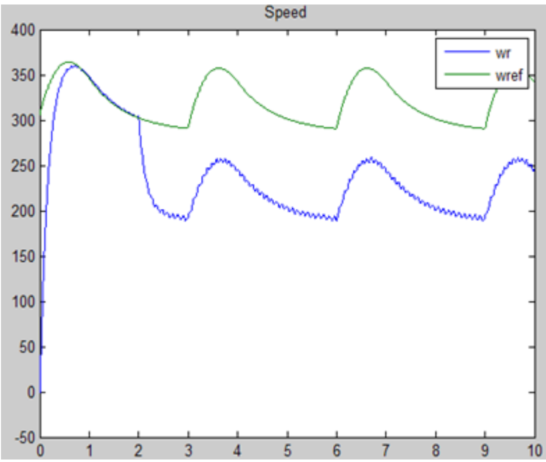

Fig. 4. The results of tracking reference speed by PID controller

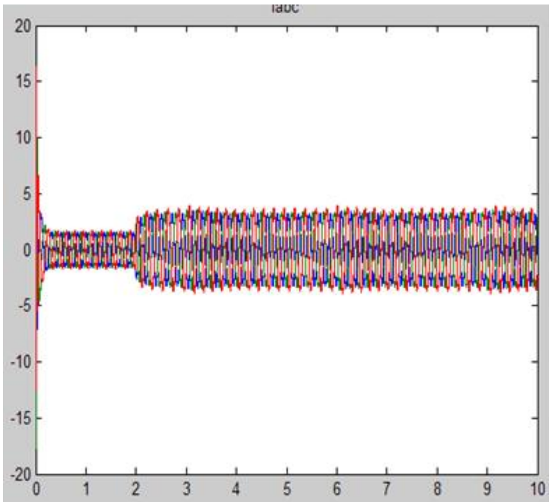

Fig. 5. The flow for installing three-phase motor terminal

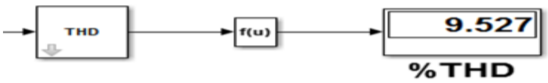

Fig. 6. Level of THD of stator current signal

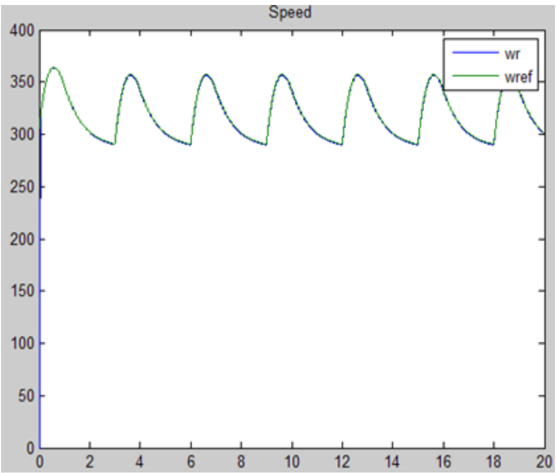

Fig. 7. Tracking of reference speed by fuzzy PID controller

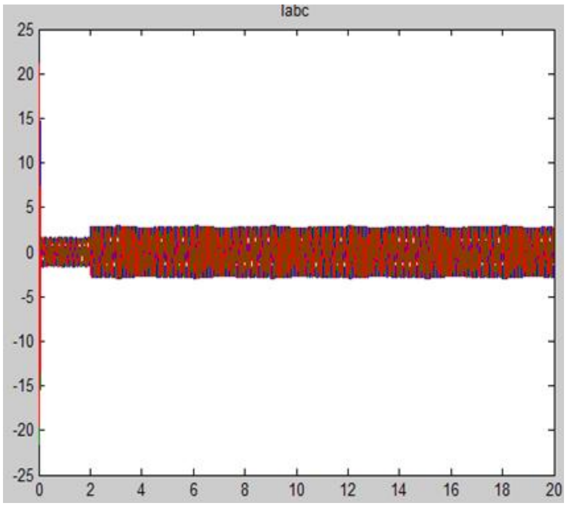

Fig. 8. Three-phase motor terminal flow

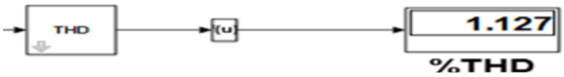

Fig. 9. Level of THD of stator current signal

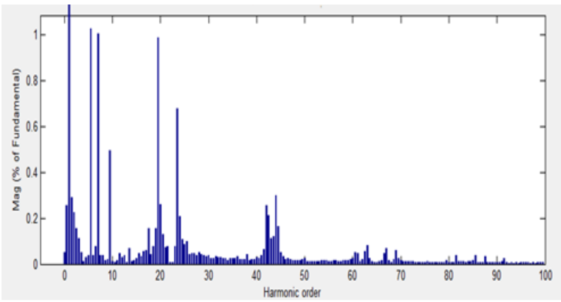

Fig. 10. Diagram of the harmonic spectrum of the signal in the case of using PID controller

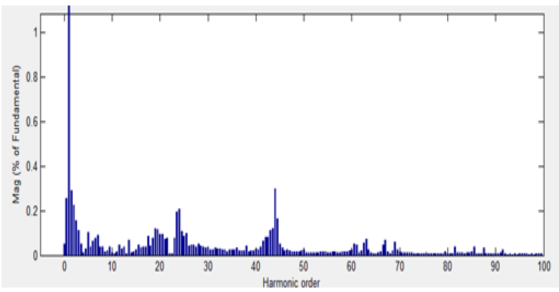

Fig. 11. Diagram of the harmonic spectrum of the signal in the case of using fuzzy PID controller

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