Optimal Efficiency Control of Wind Generation System Using Fuzzy Logic Control

Ahmed G. Abo-Khalil, Dong-Choon Lee
a_galal@yahoo.com, dclee@yu.ac.kr
Department of Electrical Engineering, Yeungnam University

ABSTRACT

This paper presents a variable speed wind generation system where fuzzy logic controllers is used as efficiency optimizer. The fuzzy logic controller increments the machine flux by on-line search to improve the generator efficiency in case of light load. The speed of the induction generator is controlled according to the variation of the wind speed in order to produce the maximum output power The generator reference speed is adjusted according to the optimum tip-speed ratio. The complete control system has been developed by simulation study.

1. Introduction

In recent years there has been a growing interest in wind energy as it is a potential source for electricity generation with minimal environmental impact With the evolution of aerodynamic designs and material wind turbines which can capture a few M W of power are commercially available When such wind energy conversion systems (WECS are integrated to the grid they can supply a substantial amount of power which can supplement the base power generated by thermal nuclear and hydro power plants [1].

The wind turbine blade has its own optimum operating speed at which the maximum power can be captured from wind energy By controlling the generator speed at this value it can produce the output power maximally [2]. However there is still a potentiality to increase the output power by reducing the machine loss itself for the same mechanical input power It is well known that the operating efficiency of the motor drive system can be improved by reducing the flux level which results in the significant decrease of the core loss [3]-[5]. There are two kinds of method to find the flux level giving the maximum output power One is the model based method [4], [5] and the other is the search based method [3]. In the former the ratio of V f or the d axis current level for the maximum output is calculated from the machine model at the given speed and torque It gives fast transient responses However its performance depends on the machine parameter variation

In this paper an on line loss minimization control based on a fuzzy logic control is proposed to adjust the generator flux level so as to reduce the core loss The generator reference speed is adjusted according to the optimum tip speed ratio to extract the turbine maximum output power . The proposed algorithm is verified by simulink matlab simulation

2. System Modeling

In order to control the grid connected induction generator system the back to back PWM converter is used as shown in Fig 1 . The generator side converter works as an inverter which is operating in regenerative mode and the grid side converter functions as an ac dc boost converter capable of reversing the power flow

2.1 Control of induction generator

The generator controller controls the rotational speed so as to produce the maximum output power The control part consists of a speed controller and the d q current controllers The d axis current component is adjusted according to the minimum power loss condition The total power loss is in a function of the stator d q currents and the loss curve is illustrated in Fig 3.

The iron loss is decreased by reducing the flux at a given constant machine torque and speed The

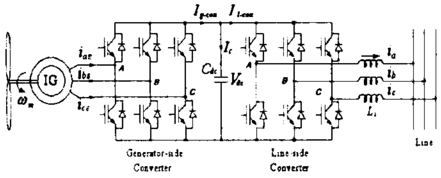

Fig. 1 Back to back PWM converter system for grid connection

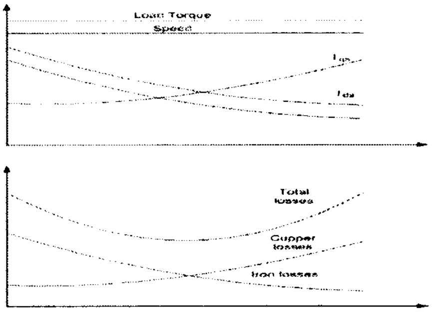

Fig. 2 Generator loss minimization with d-axis current control

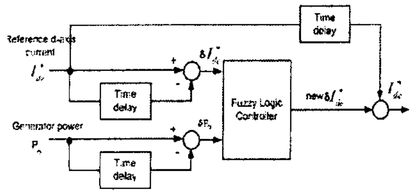

Fig 3 Inputs and output of fuzzy controller

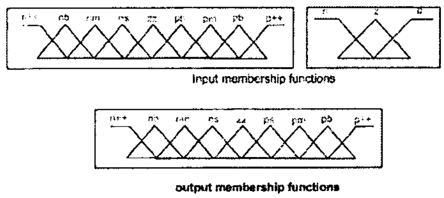

Fig 4 Membership functions of fuzzy controller

machine flux can be reduced by decreasing the d axis current Since the electromagnetic torque is proportional to the product of the rotor flux and the q axis current under vector control condition the q axis current should be increased in order to maintain the same torque at the reduced rotor flux The d axis current decreases while the q axis current increases However the total stator current is reduced leading to a decrease in stator cupper loss and a slight increase in rotor cupper loss

The speed control loop generates the q axis current component to control the generator torque and speed at different wind speed The reference speed is calculated by

$$\omega_m^* = \frac{\lambda_{opt} v}{R} \quad (1)$$

where λ_{opt} is the optimum tip speed ratio v is wind speed m s and R is the blade radius m

In this case the maximum available power at any wind speed is given by

$$P_{max} = 0.5 C_{pmax} \pi R^2 v^3 \quad (2)$$

Fig 2 shows the control block diagram of the induction generator

2.2 Control of grid side converter

To achieve the full control of the grid side current the dc link voltage must be boosted to a level higher than the amplitude of the line line voltage The power flow of the grid side converter is controlled so as to keep the dc link voltage constant To maintain the dc link voltage constant and to ensure the reactive power flowing into the grid at null the grid side converter currents are controlled using the d q vector control approach The dc link voltage is controlled tothe desired value by using a PI controller and the change in the dc link voltage represents a change in the q axis current For unity power factor the demand for the d axis current is zero Fig 6 shows a control block diagram of the grid side converter

3. Fuzzy Logic Controller

The fuzzy logic control is applicable to search the generator optimum d axis current reference value to minimize the generator total losses The FLC block diagrams is shown in Fig 3. The principle of the FLC is to perturb the generator reference d axis current I_{de}^* and to estimate the corresponding change of output power P_o. If the output power increases with the last increment the searching process continues in the same direction On the other hand if the d axis current increment reduces the output power the direction of the searching is reversed The fuzzy logic controller is efficient to track the d axis minimum value which corresponds to the less core loss value

The inputs (P_o and δI_{de}^*) and output ($n\delta I_{de}^*$) membership functions are shown in Fig 4. Triangular symmetrical membership functions are suitable for the input and output which give more sensitivity especially as variables approach to zero value The width of variation can be adjusted according to the system parameter

4. Simulation Results

In this section we compare between the generator output power with constant flux level and the case of optimum flux level control using fuzzy logic control The optimum d axis current is adjusted to its optimum value while the generator reference speed is adjusted according to the optimum value of the wind speed ratio

Fig 5 shows the performance of the system when the wind speed suddenly down from 7 to 6[m s Fig 5(a . The generator speed is changed instantaneously as shown in Fig 5(b to the value which produce the maximum output power Fig 5(c Fig 5(d shows generator the d axis current in case of no loss minimization control

Fig 6 shows the performance the system with fuzzy logic controller for loss minimization The d axis current in Fig 6(d changes with the speed change in the direction which minimize the generator losses

Th output power in this case is higher then the constant flux current as shown in Fig 5(b and Fig 6(b

5. Conclusions

This paper proposed a complete control algorithm to extract the maximum power from wind energy conversion system considering the generator loss The induction generator was controlled in indirect vector control method and its speed reference was determined according to the wind speed based on the tip speed ratio The d axis current of the generator controls theexcitation level which minimizes the total loss using a fuzzy logic controller The back to back PWM converter was used to connect the generator and the grid The grid side converter controls the dc link voltage

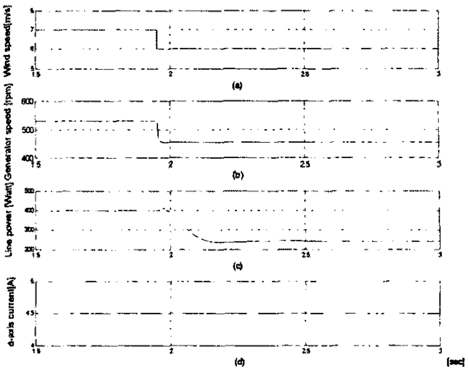

Fig. 5 Constant d -axis current

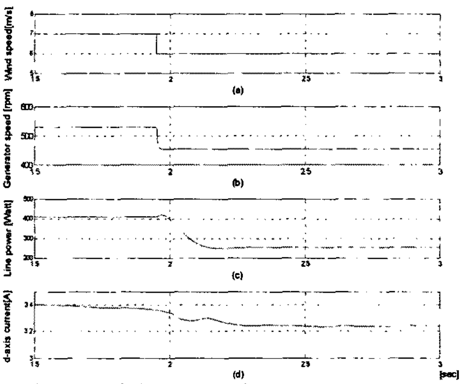

Fig. 6 Loss minimization control

and the ac current at unity power factor The validity of the proposed algorithm has been verified by simulation results

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