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IMPLEMENTATION OF A NOVEL MULTILEVE LDC-AC INVERTER USING FUZZY CONTROLLER

1. BHUKYA RAMANA NAIK, 2.M.V LAKSHMAIAH
1. M. Tech Student, Dept. Of EEE, ABR College of Engineering and Technology, Kanigiri , A.P
2. Guide, Dept. Of EEE, ABR College of Engineering and Technology, Kanigiri , A.P

Abstract-
The main objective of this paper is to analyze the performance of a variable speed wind generation system by using fuzzy logic principles for efficiency optimization and performance enhancement control. A squirrel cage induction generator feeds the power to a double-sided pulse width converter system, which feeds power to either an utility grid, or to an autonomous system. The generation system uses three numbers of fuzzy logic controllers. The first fuzzy controller tracks the generator speed with the wind velocity to extract maximum power. The second fuzzy logic controller programs machine flux for light load efficiency improvement. The third fuzzy logic controller provides robust speed control against wind vortex and turbine oscillatory torque. The ability of fuzzy-based speed controller can reduce the undesirable sustained oscillations in speed of induction motor drive and also provide better machine performance than conventional linear controller.

INTRODUCTION

GRID-connected wind electricity generation is showing the highest rate of growth of any form of electricity generation, achieving global annual growth rates in the order of 20 - 25%. It is doubtful whether any other energy technology is growing, or has grown, at such a rate. Global installed capacity was 47.6 GW in the year 2004 and 58.9 GW in 2005 [1], [2]. Wind power is increasingly being viewed as a mainstream electricity supply technology. Its attraction as an electricity supply source has fostered ambitious targets for wind power in many countries around the world.

Wind power penetration levels have increased in electricity supply systems in a few countries in recent years; so have concerns about how to incorporate this significant amount of intermittent, uncontrolled and non-dispatchable generation without disrupting the finely-tuned balance that network systems demand.

Grid integration issues are a challenge to the expansion of wind power in some countries. Measures such as aggregation of wind turbines, load and wind forecasting and simulation studies are expected to facilitate larger grid penetration of wind power.

In this paper simulation studies on grid connected wind electric generators (WEG) employing (i) Squirrel Cage Induction Generator (SCIG) and (ii) Doubly Fed Induction Generator (DFIG) have been carried separately. Their dynamic responses to disturbances such as variations in wind speed, occurrence of fault etc. have been studied, separately for each type of WEG.

A. Power from Wind

The power that can be captured from the wind with a wind energy converter with effective area *Ar* is given by [2]

$$P = \frac{1}{2}\rho_{air} C_p A_r v_w^3 \quad (1)$$

where ρair is the air mass density [kg/m3], vw is the wind speed and Cp is the so-called power coefficient which depends on the specific design of the wind converter and its orientation to the wind direction. Its theoretical maximum value is 16/27 = 0.593 (Betz limit). For a wind turbine with given blades it can be shown that the power coefficient Cp basically depends only on the tip speed ratio l, which equals the ratio of tip speed vt [m/s] over wind speed vw [m/s] and the so-called blade pitch angle q [deg]. This pitch angle is defined as the angle between the cord of the blade and the plane of the wind rotor. So, for a wind rotor with radius r, (1) can be rewritten as:

$$P = \frac{1}{2}\rho_{air} C_p(\lambda,\theta)\pi r^2 v_w^3 \quad (2)$$

As an example, Fig. 2 shows the dependency of the power coefficient *Cp* on the tip speed ratio *l* and the blade pitch angle *q* for a specific blade. For this blade maximum energy capture from the wind is obtained for *q* =0 and *l* just above 6. To keep *Cp* at its optimal value for varying wind speed, the rotor speed should be proportional to the wind speed. In practice both constant *l* (variable speed) and constant speed operation is applied.

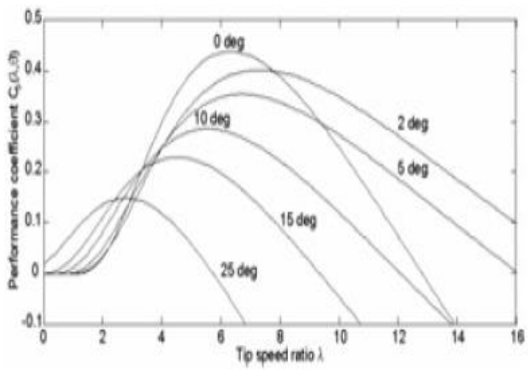


Fig: Power coefficient Cp as a function of tip speed ratio l and pitch angle q for a specific blade [3].

For on shore turbines, the blades are designed such that the optimal tip speed is limited to roughly 70 m/s. This is done because the blade tips cause excessive acoustical noise at higher tip speeds. For offshore turbines, the noise does not play an important role, and higher speeds are used leading to slightly higher optimal values of *Cp*.

The relation between wind speed and generated power is given by the power curve, as depicted in Fig. 3. The power curve can be calculated from (2) where the appropriate value of *l* and *q should* be applied. In the power curve, four operating regions can be distinguished, that apply both to constant speed and variable speed turbines:

1. No power generation due to the low energy content of the wind.
2. Less than rated power generation. In this region, optimal aerodynamic efficiency and energy capture is aimed at. The wind speed at the boundary of region 2 and 3 is called the rated wind speed and all variables with the subscript rated refer to design values at this wind speed.
3. Generation of rated power, because the energy content of the wind is enough. In this region, the aerodynamic efficiency must be reduced, because otherwise the electrical system would become overloaded.
4. No power generation. Because of high wind speeds the turbine is closed down to prevent damage.

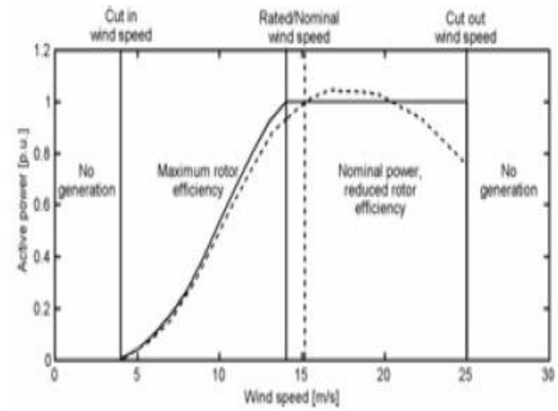


Fig: Typical power curve of a constant speed stall (dotted) and a variable speed pitch (solid) controlled wind turbine [4].

Features of wind power systems:

There are some distinctive energy end use features of wind power systems

i. Most wind power sites are in remote rural, island or marine areas. Energy requirements in such places are distinctive and do not require the high electrical power.
ii. A power system with mixed quality supplies can be a good match with total energy end use i.e. the supply of cheap variable voltage power for heating and expensive fixed voltage electricity for lights and motors.
iii. Rural grid systems are likely to be weak (low voltage 33 KV). Interfacing a Wind Energy Conversion System (WECS) in weak grids is difficult and detrimental to the workers' safety.
iv. There are always periods without wind. Thus, WECS must be linked energy storage or parallel generating system if supplies are to be maintained.

Power from the Wind:

Kinetic energy from the wind is used to turn the generator inside the wind turbine to produced electricity. There are several factors that contribute to the efficiency of the wind turbine in extracting the power from the wind. Firstly, the wind speed is one of the important factors in determining how much power can be extracted from the wind. This is because the power produced from the wind turbine is a function of the cubed of the wind speed. Thus, the wind speed if doubled, the power produced will be increased by eight times the original power. Then, location of the wind farm plays an important role in order for the wind turbine to extract the most available power form the wind.

The next important factor of the wind turbine is the rotor blade. The rotor blades length of the wind turbine is one of the important aspects of the wind turbine since the power produced from the wind is also proportional to the swept area of the rotor blades i.e. the square of the diameter of the swept area.

Hence, by doubling the diameter of the swept area, the power produced will be four fold increased. It is required for the rotor blades to be strong and light and durable . As the blade length increases, these qualities of the rotor blades become more elusive. But with the recent advances in fiberglass and carbon-fiber technology, the production of lightweight and strong rotor blades between 20 to 30 meters long is possible. Wind turbines with the size of these rotor blades are capable to produce up to 1 megawatt of power.

The relationship between the power produced by the wind source and the velocity of the wind and the rotor blades swept diameter is shown below.

$$P_{wind} = \frac{\pi}{8} dD^2 v_{wind}^3$$

The derivation to this formula can be looked up in [2]. It should be noted that some books derived the formula in terms of the swept area of the rotor blades (A) and the air density is denoted as δ.

Thus, in selecting wind turbine available in the market, the best and efficient wind turbine is the one that can make the best use of the available kinetic energy of the wind.

Wind power has the following advantages over the traditional power plants.

- Improving price competitiveness,
- Modular installation,
- Rapid construction,
- Complementary generation,
- Improved system reliability, and
- Non-polluting.

FUZZY LOGIC CONTROLLERS

The heuristic way of searching the maximum could be based on a rule called as “Fuzzy Metarule”, which is given as follows: “If the last change in the input variable (x) has caused the output variable (y) to increase, keep moving the input variable in the same direction; if it has caused the output variable to drop, move it in the opposite direction.”

The Wind generation system consists of three no.s of fuzzy logic controllers [11]:

A. FLC-1 (GENERATOR SPEED TRACKING CONTROLLER)

For a particular wind velocity FLC-1 function is search the generator speed until the system settles down at the maximum power output condition. For wind velocity Vω4 in fig. 6, the output power will be at A if the generator speed is ωr1. The FLC-1 will alter [1], [8] the speed in steps until it reaches the speed ωr2, where the output power is maximum at B. If the wind velocity increases to Vω2, the output power will jump to D, and then

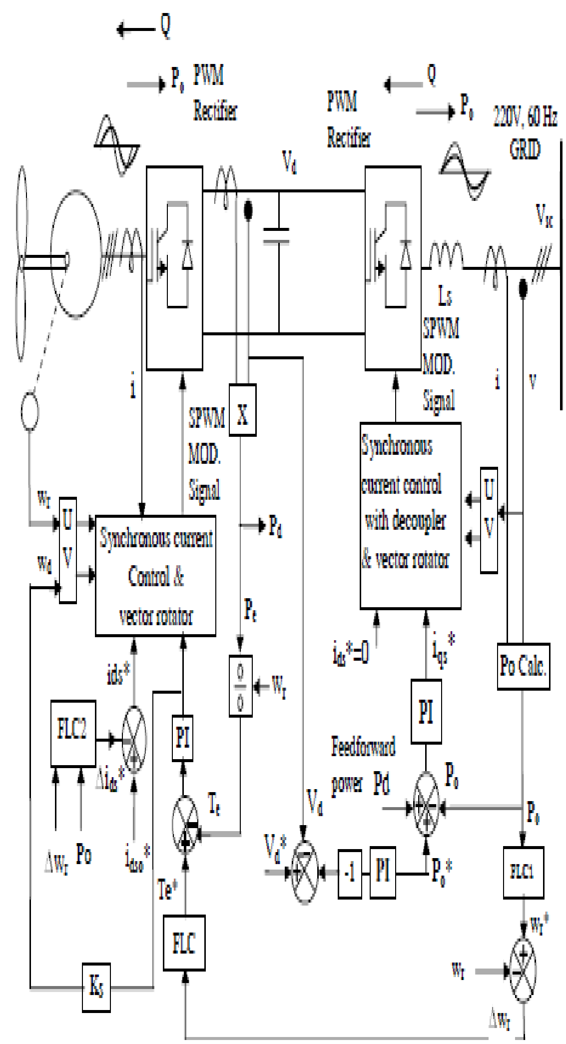


Fig. 5: Fuzzy logic based control block diagram of wind generation system

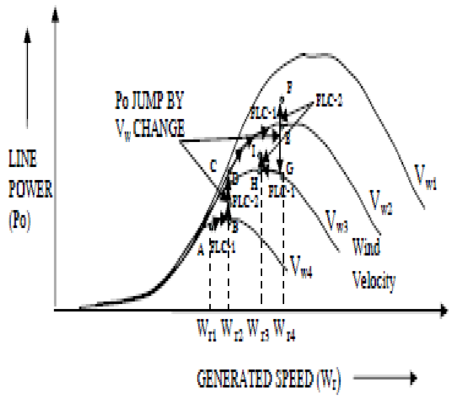


Fig. 6: Fuzzy Controllers FLC-1 and FLC-2 operation showing maximization of power.

FLC-1 will bring the operating point to E by Searching the speed to ωr4. Similar is the case of decrease in wind velocity. With an incrementation (or decrementation) of speed, the corresponding incrementation (or decrementation) of output power is estimated. The controller operates on a per-unit basis so that the response is insensitive to system variables and the algorithm are universal to any system. The wind vortex and torque ripple can lead the search to be trapped in a minimum

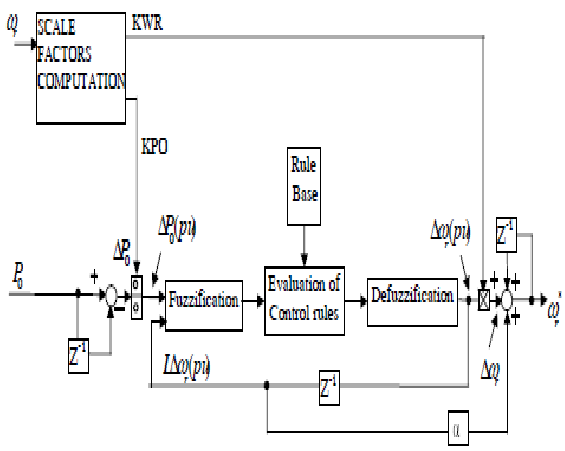


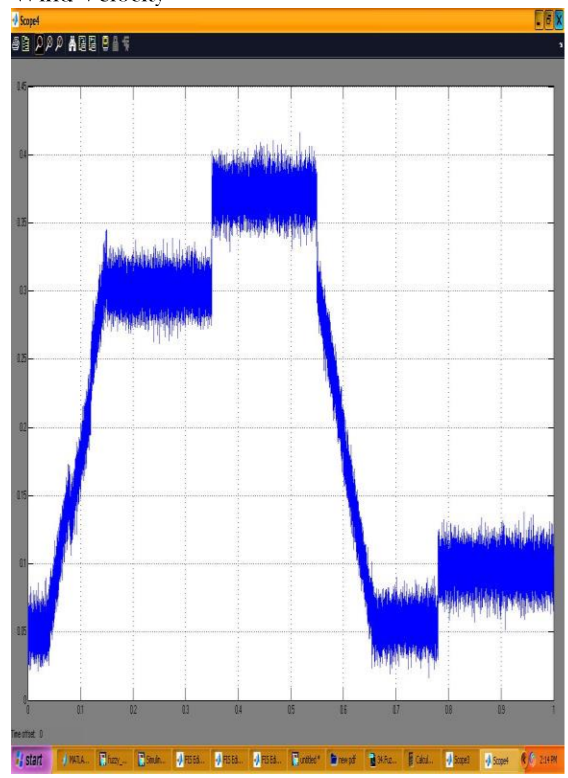
Fig. 7: Block diagram of FLC-1

which is not global, so the output is added to some amount of LΔωr in order to give some momentum to continue the search and to avoid such local minima[10]. The scale factors KPO and KWR , are generated as a function of generator peed so that the control becomes somewhat insensitive to speed variation. The scale factor expressions are given,

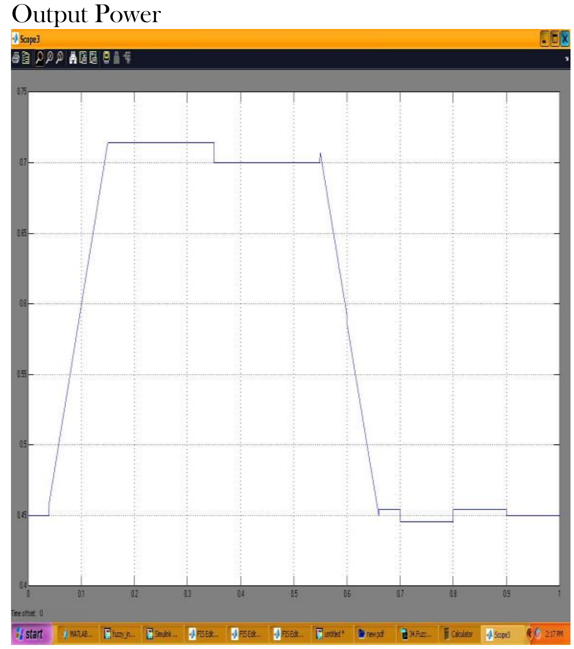
In FLC-1, there are two inputs ΔP0 and LΔωr* and one output Δωr* .In the implementation of fuzzy control, the input variables are fuzzified ,the valid control rules are evaluated and combined and finally the output is defuzified to convert to the crisp value. In this paper , the above block diagram of FLC-1 was simulated using triangular membership function and the centroid method was used for defuzzification.

RESULT:

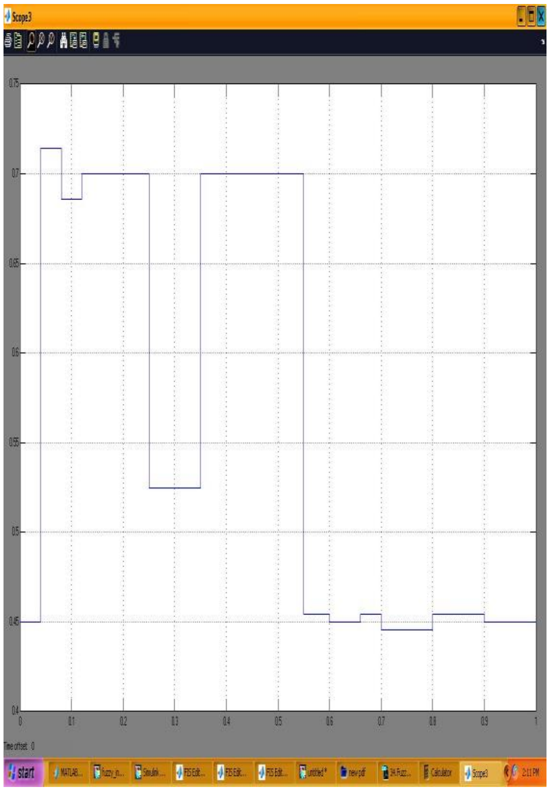
Wind Velocity



Output Power



Generator speed



CONCLUSION:
The fuzzy logic based variable speed cage machine wind generation system has been analyzed. The system\ performances has been studied with matlab- simulation to validate all the theoretical concepts. There are three fuzzy logic controllers in the generation system : • The first fuzzy controller FLC-1 searches on line the optimum generator speed so that the aerodynamic efficiency of the wind turbine is maximum. • The second fuzzy controller FLC-2 programs the machine flux by an on line search so as to optimize the machine converter efficiency. • The third fuzzy controller FLC-3 performs robust speed control against turbine oscillatory torque and wind vortex.

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