FUZZY LOGIC CONTROL OF WIND ENERGY CONVERSION SYSTEM

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Abstract

Wind energy has gained an increasing worldwide interest due to the continuous increase in fuel cost and the need to have a clean source of energy. The main objective of most of the wind energy systems is to extract the maximum power available in the wind stream. In order to achieve maximum power point tracking (MPPT) for wind power generation systems, the rotating speed of wind turbines should be adjusted in the real time according to wind speeds. In this paper, we will be focusing on some of the revolutionary changes that took place in the control scheme of wind energy which has got enough potential to meet the energy requirements of the world in the present scenario. When we are deficit of the natural resources like coal, water etc. Thus presently it serves as the most reliable source of energy for our future generations.

***IndexTerms* – FLC, PMSG, Wind Power System, Converter. MPPT**

1.INTRODUCTION

Electrical energy is the energy which is used in each and every field and every corner of the world. Energy is the measure of the development of the country and property of its citizen. In the developing and developed countries, energy crisis is a major problem which blocks the economic growth. This has been essential because the present usage needs an energy infrastructure, with a eye on tapping of energy from non-conventional sources of energy with more sustainability. The fossil fuels like coal, petrol, natural gas will be depleted in the coming years. Energy consumption is increasing day by day by the increasing population, resulting in rates and energy shortage. So we have to find out the solution of this inflation and energy shortage. A solution for this problem is to use renewable source of energy like solar energy and wind energy. Wind energy conversion systems convert the kinetic energy of the wind into electricity or other forms of energy. The use of non-conventional sources for small grid or large grid are economically and feasible. They are cost effective and reliable. They are eco-friendly as well as abundant in the nature. Wind power generation has experienced tremendous growth for the past years.

The main objective of most of the wind energy systems is to harness the maximum power point for the wind steam is the main aim of wind power system. The rotating speed of wind turbines have to be adjusted with the variation of the speed of wind in getting maximum power point tracking. The power electronic plays an important role in wind power systems; they have to integrate the variable-speed wind power generation units to achieve high efficiency and high performance in power systems. It was observed that the wind turbines behavior is significantly affected by the control strategy used. Typically, aerodynamic loop and power electronics are used to control torque, speed and power. The main control objective of variable speed wind turbines is power extraction maximization. To operate at its maximum power point, the tip-speed ratio should be maintained at its optimum value despite wind variations. The artificial intelligence techniques, such as fuzzy logic control, neural network control and genetic algorithm optimization are recently showing a lot of promise in the application of power electronic systems.

The design of a maximum power point tracking (MPPT) strategy for a variable speed, small scale, wind turbine systems based on a fuzzy logic controller (FLC). The FLC has as input variables the change in mechanical power (ΔPm), the change in rotor speed (Δω), and the sign of ΔPm/Δω. The change of reference generator current (ΔI*) is the output variable. When the turbine inertia is comparatively small for small power applications and the wind speed changes continuously, it is important to consider the transients in order to develop an accurate theoretical model and to attain optimal operation. Therefore, the mechanical power (Pm) is composed of the generator mechanical (input) power (Pg) plus the dynamic power, resulting in the dynamic power versus rotating speed curve. The maximum power point is traced by the controller for changing wind conditions. The FLC is described, analyzed and validated by digital simulations.

The algorithm of tracking the maximum power in a wind energy conversion system (WECS) is presented, which is doesn't depend on turbine parameters and air density. The algorithm searches for the peak power by varying the speed in the desired direction. Control based on a fuzzy logic control is proposed for the PMSG system. The Fuzzy logic controller extracts the maximum output power from the wind generator system by tracing the maximum power point when speed of wind changes continuously. Two real time measurements dP and dω are used as the control Input signal and the output of the controller is the new Speed reference variation. The proposed algorithm is experimentally verified for a small-scale laboratory setup.

We can harnessed wind energy with the help of different methods such as pitch- control, MPPT control and with help of different generators like induction generator, permanent magnet synchronous generators DFIG etc. But converting kinetic energy of the wind in to electrical power is the main aim of the main the wind energy system. The electrical energy is then fed in the grid, which is then utilized in power machinery like washing machines, pump, electronics equipment etc.

2. MODELLING OF THE SYSTEM

Power produced by a wind turbine is given by [1]

$$P = 0.5\pi\rho C_p(\lambda,\beta)R^2 V_W{}^3 \qquad (2.1)$$

Where R is the turbine radius, Vw is the wind speed, ρ is the air density, Cp is the power coefficient, λ is the tip speed ratio and β is the pitch angle. In this work β is set to zero.

The tip speed ratio is given by:

$\lambda = \omega R / V_w$

where, ωr is the turbine angular speed. The dynamic equation of the wind turbine is given as

$$\frac{d\omega_r}{dt} = \left(\frac{1}{j}\right)(T_m - T_L - F\omega_r) \qquad (2.2)$$

where J is the system inertia, F is the viscous friction coefficient, Tm is the torque developed by the turbine, T_L is the torque due to load which in this case is the generator torque. The target optimum power from a wind turbine can be written as

$$P_{max} = K_{opt}\omega_r^3 - opt \qquad (2.3)$$

$$K_{opt} = 0.5\pi\rho C_{pmax}R^5 \qquad (2.4)$$

$$\omega_{opt} = \frac{\lambda_{opt} v_w}{R} \qquad (2.5)$$

Maximum power is attain at some value of rotor speed and this speed is known as called optimum rotor speedω_{opt}. This speed is therefore corresponds to opt λ_{opt} (optimum tip speed ratio).In order to have maximum possible power, the turbine should always operate at λ_{opt}. The rotor is rotated at optimum speed of rotation for maximum power.

The structure of a low power variable speed wind turbine system (VSWT), presented in Fig. 3.4, consists of a permanent magnet synchronous generator (PMSG) driven by a five blades fixed pitch wind turbine, a diode bridge rectifier (DB), a hybrid DC-DC converter (HDC) - the element that regulates the turbine speed through the controlled PMSG current, and the load . As the wind speed varies, the wind turbine output torque Twt and power Pwt varies as:

$$T_{wt} = \frac{1}{2}.C_t(\lambda).v^2.A.R \qquad (2.6)$$

where the tip-speed ratio λ is defined as:

$$\lambda = \omega.R/v \qquad (2.7)$$

and

A : blade swept area [m2]; ρ : specific density of air [kg/m3]; v : wind speed [m/s];

R : radius of the turbine blade [m]; ω : rotating speed [rad/s]; C_T: wind turbine torque coefficient; expression (8) was obtained from the wind turbine test.

$$C_T = C_{T_0} + a.\lambda - b.\lambda^{2.5} \qquad (2.8)$$

where a, b, $C_{T0}$are the constants for the nominal tip-speed ratioλ_0.

The maximum power is obtained if [4]:

$$C_p(\lambda) - C_{p(\lambda_{opt})} \qquad (2.9)$$

From:

$$P_{\omega t}^{max} = \frac{1}{2}.C_p(\lambda_{opt})\rho.A.R^3.\frac{1}{\lambda^3}.\omega^3 = K_{opt}.\omega^3 \qquad (2.10)$$

where CP is the wind turbine power coefficient.

To obtain the desired rotating speed of the wind turbine, the generator torque must be changed. The HDC works as a current controller, i.e. the converter controls the PMSG output current through the DB, in order to change the PMSG torque Tg. The converter is implemented as an ideal, fast current source (the measured current will always be equal with the reference current). Fig.3.3 illustrates the Matlab Simulink block diagram of the variable speed wind turbine (VSWT), including the MPPT control. Because the wind speed changes with environmental conditions, the system should seek a maximum power operation point. P1, P2 and P3 in Fig.3.4 are the maximum power operating points at the corresponding ω1, ω2 and ω3 rotating speeds for three different wind speeds v1, v2 and v3 in the steady state regime.

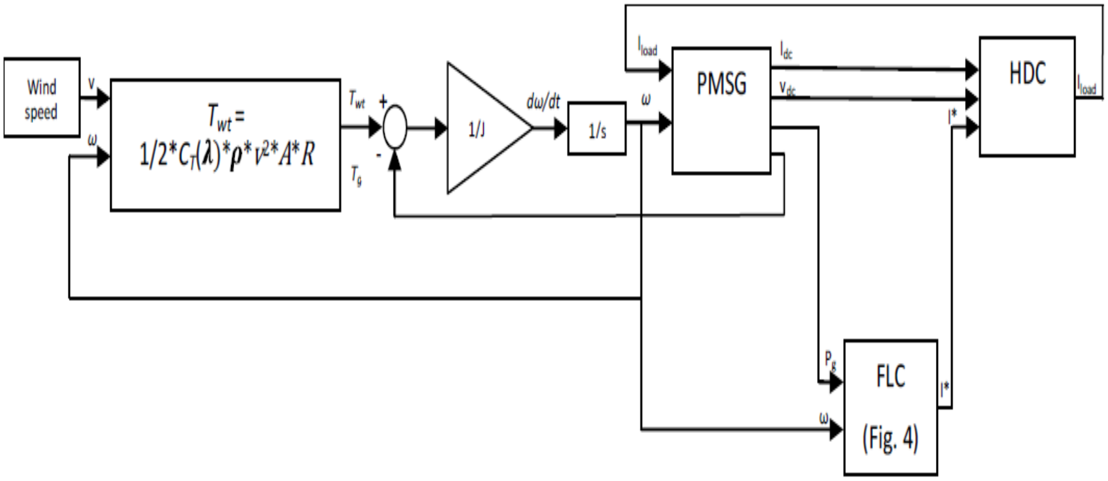

Fig.2.1 Block Diagram Wind Turbine Of Control System

In the controlling, the FLC is used as a controlling for tracing MPPT, It can be done by increasing or decreasing the rectified PMSG current which is used as a reference.

When the PMSG current changes, PMSG torque also changes which results in changing the rotating speed of the shaft of the turbine.

When the operating point is found to be on left side of the MPPT curve, the controller has to decrease the reference current this results in obtaining the optimum power operating point. When the operating points is found to be on right side of MPPT curve, the controller has to increase the reference current which results in obtaining the optimum power operating point.

The two input variables are:-

- Change in rotating speed (Δω)
- Change in mechanical power (ΔPm)

The change in dc reference current (ΔI*) is the output variable.

The mechanical power (Ps) consists of:

$$P_m = j.\omega \frac{d\omega}{dt} + P_g$$

where

Pg : Permanent Magnet Synchronous Generator mechanical power [W],

The result of the dynamic power as opposed to turning speed curve. The scope of the input and output factors is normalized to [-1 1], bringing about the framework conduct thusly that the FLC block to be general for other wind turbine frameworks. The utilized scale coefficients are kw, kp and the integrator gain k. The FLC manage is characterized by "if then" principles as appeared in Table. The fuzzy fundamental lead, which relates the fuzzy output to the fuzzy input, is gotten from the coveted framework conduct and the planned control system. The guidelines are made as that the controller dependably gets a most extreme power point, without stopping. N(negative), NS (negative small), Z (zero), PS (positive small) and P (positive) are the fuzzy esteems. A fuzzy implication strategy identified the output fuzzy sets, which is a MIN-MAX method. The membership elements of the FLC utilized are triangular and trapezoidal. The center of gravity (or centroid) defuzzification system was then implemented.

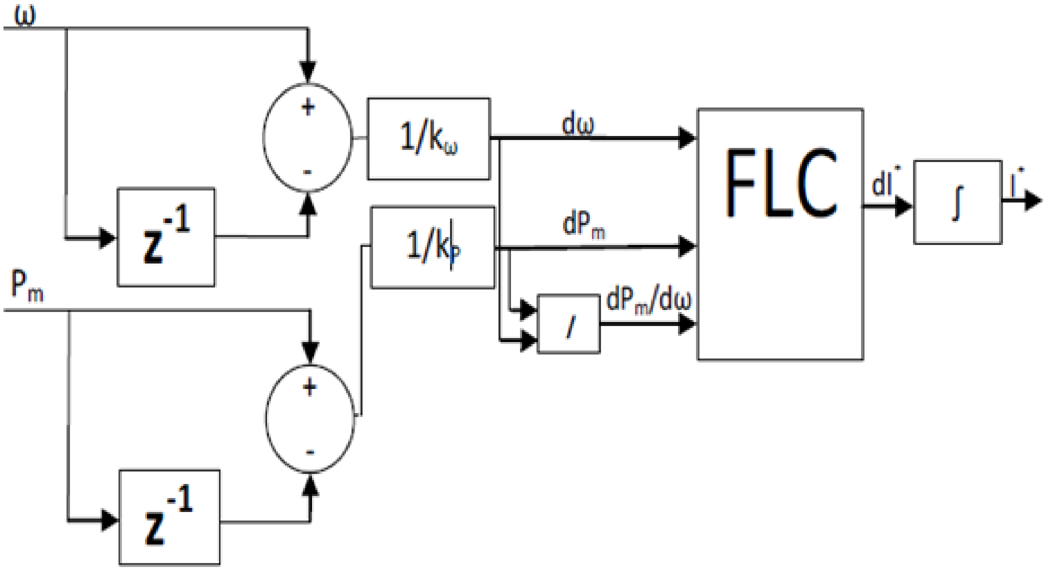

Fig 2.2. MPPT FLC Used For The Wind Turbine Control System

Table.2.1 Basic Rules Of The FLC

BASIC RULES OF THE FUZZY LOGIC CONTROLLER

dI*		dP_m									
		N		NS		Z		PS		P	
dω	N	N		N		N	N		N		N
	NS	N		NS		N	N		N		N
	Z	N	N	NS	NS	NS	PS	P	N	P	N
	PS		P		PS	P	PS	P		P	
	P		P		P	P	PS	P		P	
Fuzzy values in red are for $dP_m/d\omega > 0$ (P) and in blue are for $dP_m/d\omega < 0$ (N)											

The above govern base is utilized as fuzzy logic control. Where dω(change in rotor speed) and dPm (change in PMSG control) are the sources of info and the yield is dI* (reference current).

The available quadratic converters are used to compare their performance. The advantage of the new hybrid converters is less energy in the magnetic field resulting in saving in the size and cost of the inductors, less current stresses in the switching elements and smaller conduction losses. Theoretical analysis is compared to experimental results and experimental results confirm the Theoretical analysis. A method with a high step down/up conversion voltage ratio was presented for developing hybrid converters .The new hybrid gives good results which is comparable to complexity with available quadratic converters, voltage stresses on the transistors and diodes and voltage stresses on the transistors and diodes.

3.MODELLING OF WIND ENERGY SYSTEM

In the wind energy conversion system , firstly the kinetic energy is converted in the mechanical energy by giving energy to rotor blade which is then converted into electrical energy by means of generator. The electrical power is then fed to the electrical utilities through converter. The parameters taken in the system are as follows:

Table 3.1 Parameters Of Turbine-Generator System

PARAMETER	VALUE
Wind turbine power	Pn=5.5[Kw]
Wind speed	V0=11[m/s]
Maximum speed	N=126[rpm]
Pole pairs	Pp= 16
Turbine inertia	Jwt=140[kg.m2]
PMSG inertia	Jg=1.05[kg.m2]
Blade swept area	A=19.6[m2]
Radius of the turbine blade	R=2.5[m]
Maximum coefficient of power conversion	CP=0.42
Nominal tip-speed ratio	(λ0=3) a=0.0986, b=0.0113, CT0=0.0222
Specific density of air	ρ =1.225[Kg/m3]
Permanent magnet flux	ΨPM=1.32[Wb]
Stator resistance	Rs=1.1[Ω]
Stator inductance	Ls=0.045[mH]
Diode voltage drop	Vdon= 0.8[V]
Filter capacitance	Cf =1e-3[F]

4. SIMULATION RESULTS AND DISCUSSION

Simulation of PMSG (permanent magnet synchronous generator)at no load with wind speed parameter as shown in figure 4.10 and 4.15 .

1.Power Waveform- From the figure 4.1 we concluded that the power depends on the speed of turbine as the given in the equation 4.4.

$$p_{\omega t}^{max} = \frac{1}{2}.C_p\left(\lambda_{opt}\right)\rho.A.R^3.\frac{1}{\lambda^3}.\omega^3 = K_{opt}.\omega^3 \qquad (4.4)$$

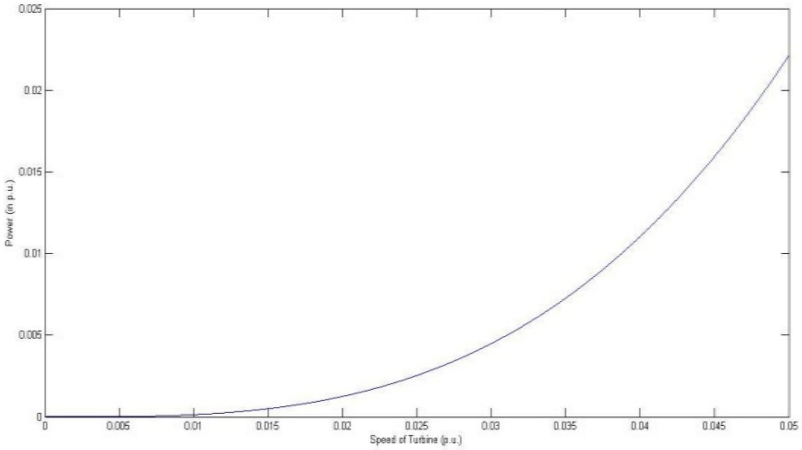

Fig 4.1Power waveform

2. Stator Waveform- From the fig 4.2, we have seen that the voltage increases linearly with time and becomes constant at a time 0.01 second.

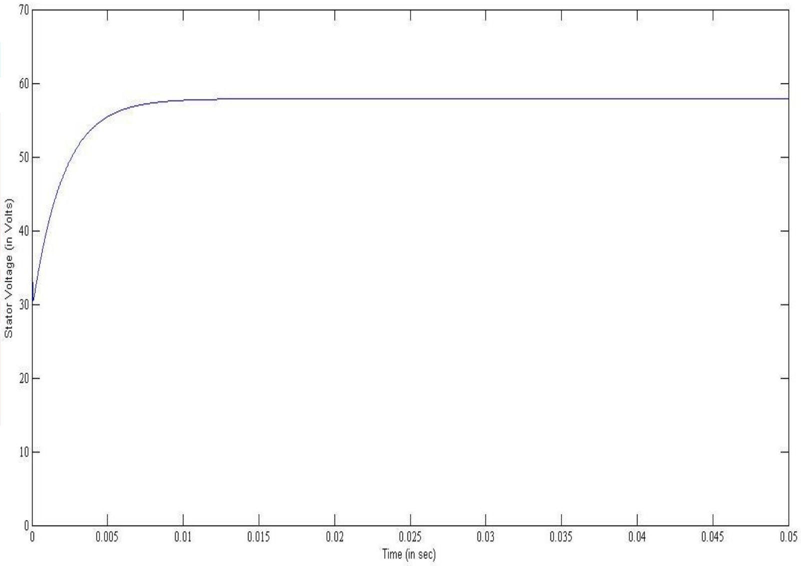

Fig 4.2 Stator Voltage waveform

3.Torque Waveform- From the fig 4.3 we have seen that the torque becomes negative because the machine used is a generator and the wave becomes constant at the time interval o.o1 second.

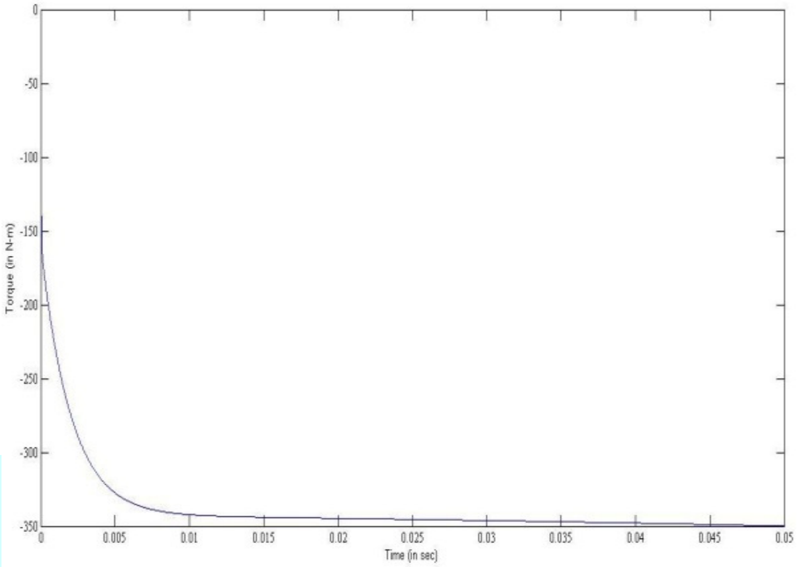

Fig 4.3 Torque Waveform

4.Fuzzy Logic Controller Output- The output variable of the FLC is the change in dc reference current (ΔI*). Its input variables are: change in mechanical power (ΔPm), change in rotating speed (Δω) and the sign of ΔPm/Δω. From the fig 4.14 we concluded that the change in dc reference current (ΔI*) is increasing linearly with respect to time.

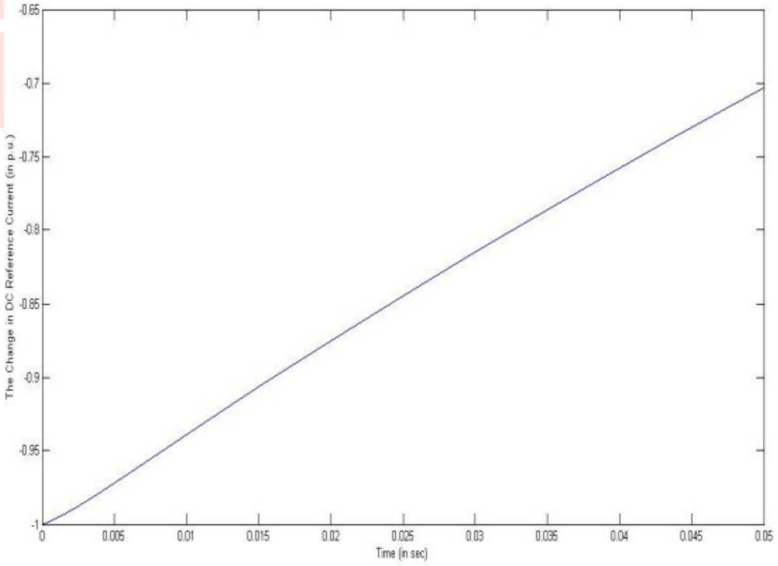

Fig 4.4 Fuzzy logic controller output

By utilizing a hybrid dc-dc converter (HDC) which filled in as a fast current controller, we controlled the yield parameters of the PMSG (permanent magnet synchronous generator) i.e. generator torque, which was managing the turbine speed. Along these lines, the turbine torque and power differing with the turbine speed.

Maximum power is obtained from the wind energy system when the wind speed changes. The fuzzy logic controller can be used when we don't know the wind parameters are unknown. FLC do not need any knowledge of rule, we have to just makes rules and controller control the mechanism according to that rules. So it is possible to obtain optimum performance from the wind generator system which has to deal with the high level of non linearity and variability of speed and thereafter it can be synchronized to the grid.

5.CONCLUSION

In this paper , a concise survey of MPPT control presented in different literature for controlling WECS with PMSG has been proposed. A model in MATLAB has been made which gives successful results. The simulation study introduced in this paper demonstrated a decent MPPT technique can be executed with a fuzzy logic controller. by utilizing a hybrid dc-dc converter (HDC) which filled in as a fast current controller, we controlled the yield parameters of the PMSG i.e. generator torque, which was managing the turbine speed. Along these lines, the turbine torque and power differing with the turbine speed.

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