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Grid Power Management with Fuzzy Logic Based MPPT with Hybrid power Energy system

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Abstract - **Now a day's renewable energy resources are essential energy alternative to be used instead of conventional resources. Due to the presence of non-linear loads in utility grid, resulting current and voltage harmonics and affects power quality of entire power system. For the power quality improvement mixed energies are accommodated in the grid. In this paper, hybrid generating system consists of Photovoltaic (PV) and Wind system. In order to obtain steady and dynamic behavior of power system and maximum power transfer capability, an improved fuzzy logic controller based MPPT is employed for the hybrid system. The entire model consist fuzzy logic controller based MPPT, LC filter, converter and inverter. Simulations are performed in MATLAB and simulated results are presented.**

Keywords — ***Renewable energy resources, Non-linear loads, Utility grid, Power Quality,*** *Photovoltaic,* ***Fuzzy logic controller based MPPT, LC filter.***

I. Introduction

Renewable energy sources (RES) [1] will become an important part of power generation to keep the fossil fuels for the next generation. Among all the RES's solar and wind sources are the best option as they are freely available and environment friendly. Although these technologies improving in various aspects, also the drawbacks associated with them are high capital cost and other aspects [2]. The familiar disadvantage of both solar and wind power plants are producing unstable power [3]. In order to compress this drawback a new technology is employed i.e. maximum power point tracking (MPPT) with modified fuzzy logic controller (FLC) which is applicable for both wind and solar [4-7].

The FLC is powerful and need not require any mathematical model of controlled object. The modified FLC helps to attain maximum power transfer capability, stable and consistent power from generating system to the grid [8-10]. Due to non-liner loads in the hybrid system, resulting current and voltage harmonics. In order to overcome the overshoot of current and voltage fuzzy based control strategy is used and simulated results are comparing to other conventional controllers [11-14]. The simulation control strategies and operational block diagrams have been presented and MATLAB simulation results were shown for execution explanation.

The proposed utility grid connected hybrid power system is mainly employed for power quality improvement in test system at point of common coupling, utility grid connected system shown in Figure 1.

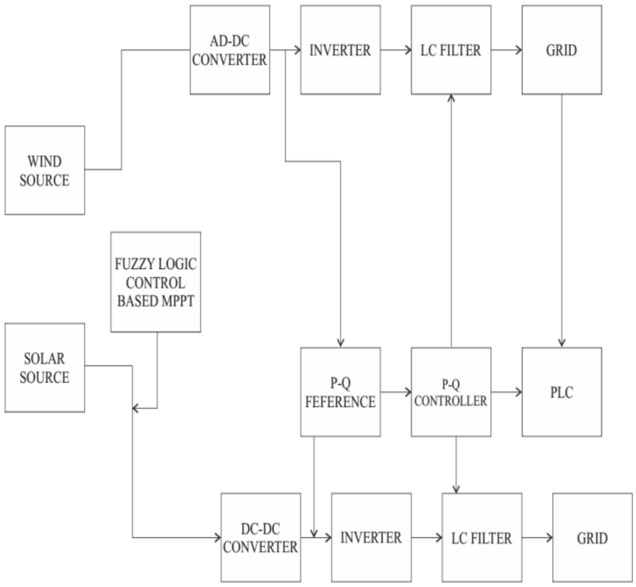

Fig.1. Grid connected hybrid power system

II. System Modeling

A. PV Array

The equivalent circuit of PV Array is shown in Figure 2. The R_s resistance represents internal resistance which depends on p-n diode junction impurity and depth. The R_{sh} is inversely related to the leakage current to ground.

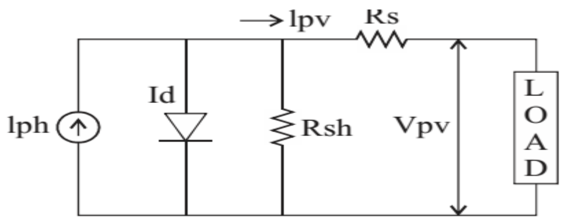

Fig.2. Equivalent circuit of a PV-Array

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The mathematical model of a PV array is developed using the following equations:

$$I_{pv} = I_{ph} - I_{rs} * \left(\exp\left(q*\left(V_{pv} - I_{pv} * R_s\right)/(k * n_s * T_r * A)\right) - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh} \quad (1)$$

$$I_{rs} = I_{rr} * [T/T_r]^3 * \exp((q * E_g/(k * A) * (1/T_r - 1/T)) \quad (2)$$

$$I_{ph} = I_{scr} + k_i * (T - T_r)) * S/1000 \quad (3)$$

Where

n_s = No.of cells in series.
k = Boltzmann's constant.
q = charge of an electron.
A = p-n junction ideality factor.
I_{rs} = cell reverse saturation current.
T_r = cell reference temperature.
I_{rr} = reverse saturation current at reference temp.
E_g = band gap energy of semiconductor used in solar cell.
S = solar radiation in w/m^2.
I_{scr} = cell short circuit current at reference temp and radiation.
K_i = short circuit current temp co-efficient.

B. Wind Turbine

In order to convert linear kinetic energy (K.E.) into rotational K.E. rotor blades are used in wind turbine. This rotational K.E. converted into electrical energy by generator. To determine overall effectiveness of energy conversion we need to find the energy present in wind first.

The kinetic energy of a wind turbine is found by,

$$E_{kin} = \frac{1}{2} mV^2 \quad (4)$$

Substituting particle mass m via air density, wind speed v, time t, and round cleared region of sweep r we can compose condition (an) as

$$m = \rho Avt = \rho\pi r^2 vt \quad (5)$$

$$E_{kin} = \frac{1}{2} \rho\pi r^2 v^2 t \quad (6)$$

From (6) we find out the actual wind power for any time instance

$$P_{wind} = \frac{1}{2} \rho\pi r^2 v^2 \quad (7)$$

The actual wind power capture by the turbine [9] depends on power co-efficient as

$$\frac{P_{turbine}}{P_{wind}} = C_p \quad (8)$$

Where Pc is the power co-proficient in condition (e) Pc isn't consistent for all turbines. It relies upon 2 parameters specifically (1) tip speed ratio λ (2) pitch angle controller β . Where

$$\lambda == \frac{\text{Tip speed}}{\text{Wind speed}} = \frac{r\omega_r}{v} \quad (9)$$

Subsequently, extraordinary wind speeds require ideal estimation of tip speed and additionally blade pitch for accomplishing a powerful coefficient in this way achieving most astounding force yield at different accessible wind speeds.

III. CONTROL STRATEGY OF A SYSTEM

A. An Improved Fuzzy Logic Controller based MPPT:

The fuzzy logic controllers are used in so many applications for MPP Tracking like the systems with nonlinearities [12].To realize two-input signal and output the fuzzy controller is used, which is flexible to change fuzzy rules, membership functions, and control gains. Here error and change in error are the input signals to controller. The fuzzifier is in the shape of 'V' overlapping functions.

Fuzzy logic controllers are based on three stages, Fuzzification – is to convert the crisp input values into fuzzy values, Fuzzy Rule Base – It stores the knowledge about the operation of the process of domain, Defuzzification – the role of this is to convert the fuzzy values into crisp values getting from fuzzy inference engine.

The error (E) and change in error (ΔE) are the inputs to the controller. The output of the controller is nothing but the change in duty ratio (D). The membership function for input1 (E) is shown in Figure 3, another input2 (ΔE) is shown in Figure 4, the output is shown in Figure 5.

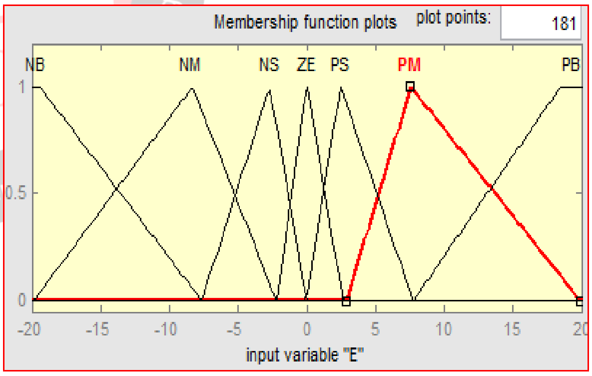

Fig. 3. Membership function for error (E)

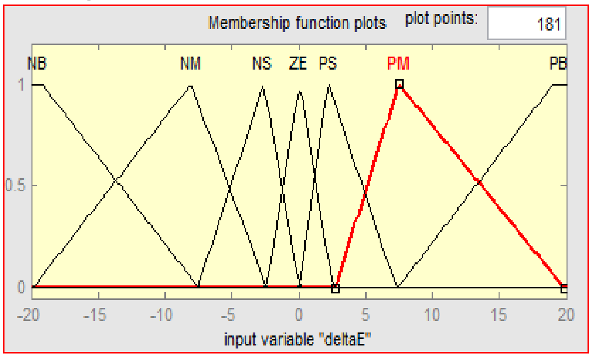

Fig. 4. Membership function for change in error (ΔE)

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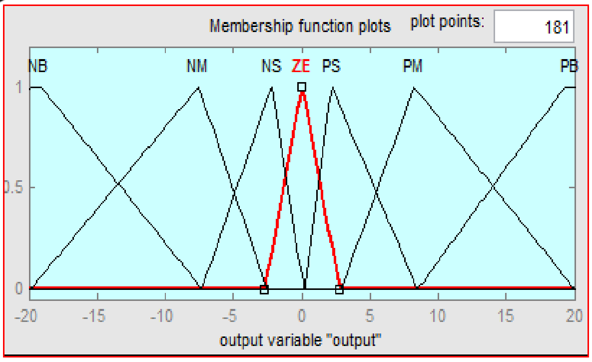

Fig. 5. Membership function for output

The classes of membership functions are NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE(zero), PB (Positive Big) , PM(Positive Medium and PS(Positive Small)). The possible combination of fuzzy logic rules based on membership functions are presented in Table 1.

Table 1: Fuzzy logic rules based on membership functions

E / ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	PB	PM	ZE	NB	NB	NB
NM	NB	PB	PM	ZE	NM	NB	NB
NS	NB	PB	PS	ZE	NS	NM	NM
ZE	ZE	ZE	ZE	ZE	ZE	ZE	ZE
PS	NB	NM	NS	ZE	PM	PM	PB
PM	NB	NB	NM	ZE	PB	PB	PB
PB	NB	NB	NB	ZE	PB	PB	PB

B. The PV Side Control:

The PV inverter control of grid is three parts which are 1) Direct and Quadrature axis current generator, 2) PLL and 3) PWM generator.

When error signal is given to PI controller d-axis reference is generated then q-axis is set to zero. By using park's transformation, current and voltage of a-b-c are converted to d-q-o components when grid voltage and current are given to three phase PLL. The conversion voltage is calculated from the d-q-o current reference. The grid connected PV side controller is shown in Figure.6.

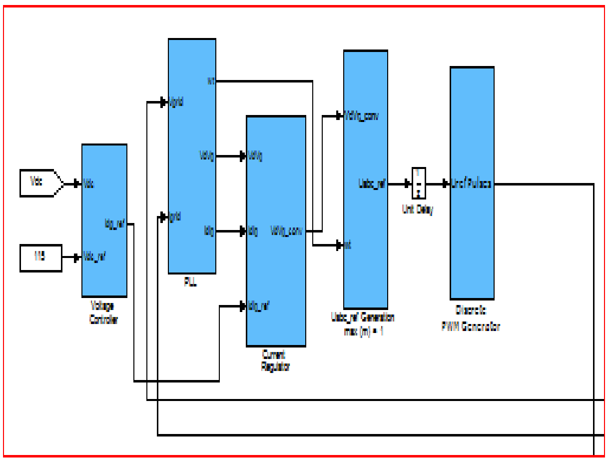

Fig.6. Simulation diagram of grid connected PV side controller

C. The Wind Turbine Power Control:

The control strategy of wind turbine has two inputs reference and actual dc-link voltage. The grid side d-axis current is generated by comparing the two inputs of PID controller and this grid d-axis current is compared with actual d-axis current which produces q-axis current, similarly the q-axis voltage is produced by comparing the actual and reference d-axis voltages using PID controller.

The power control is done by giving an external dc voltage to d-axis current, which exchange all the powers from rectifier to the grid by inverter. The reference voltage for the inverter is generated by including rational EMF remuneration terms.

IV. SIMULATION, RESULT AND DISCUSSION

The overall simulation model for PV and wind hybrid system is shown in Figure 7.

In the hybrid system PV side control containing Voltage regulator, Phase Locked Loop (PLL), current regulator and PWM generator. When error signal is given to PI controller in voltage regulator, d-axis reference is generated then q-axis is set to zero. PLL is used to synchronize a set of variable frequency and three phase sinusoidal signal. When error signal is given to PI controller in current regulator the voltage is generated which connected to unit reference and PWM generator generates pulses.

The wind system is connected to a three-phase load through converter AC/DC, LC filter is used in order to reduce the harmonics in the converter. I have tabulated all the maximum powers by varying one of the inputs among temperature, irradiation and wind speed.

The operational conditions for hybrid system considered as, operating temperature is 35^0 C, irradiation is 400 W/m^2 and wind speed is 12 Km/s. The simulation result duty cycle Vs power is presented in Figure 8. From Figure 8, the maximum power obtained at above operating conditions is 652 watts. Similarly simulation results for grid current, inverter voltage and power waveforms are presented in Figure 9.

The hybrid system also tested at various operating conditions in order to get maximum power and simulation results are tabulated in Table 2. The test conditions are specified as keeping the wind speed and irradiation as constant and varying the temperatures in order to get the MPPT point in hybrid system. Repeatedly perform the test on hybrid system at three different wind speeds and four irradiation conditions by varying the temperatures and results presented in Table 2. From the simulation results conclude that at higher wind speed, lower irradiation and lower temperature operating situations getting maximum power, in other operating conditions maximum power decreases.

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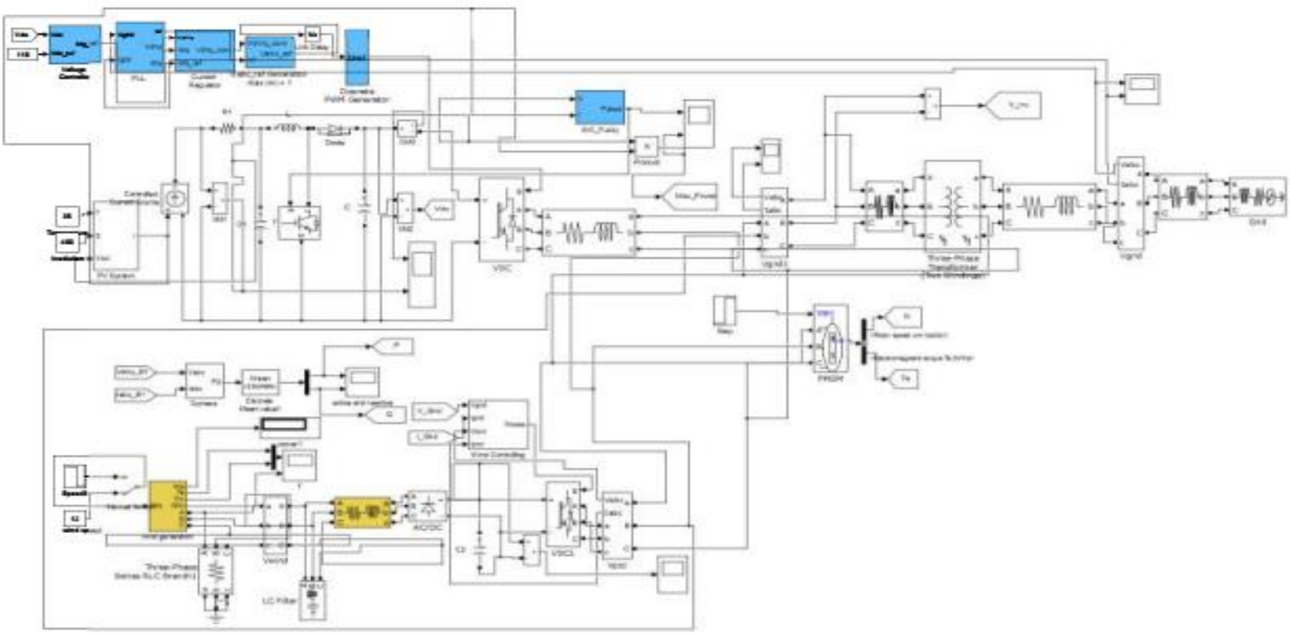

Fig.7. Matlab/Simulink setup of Hybrid system

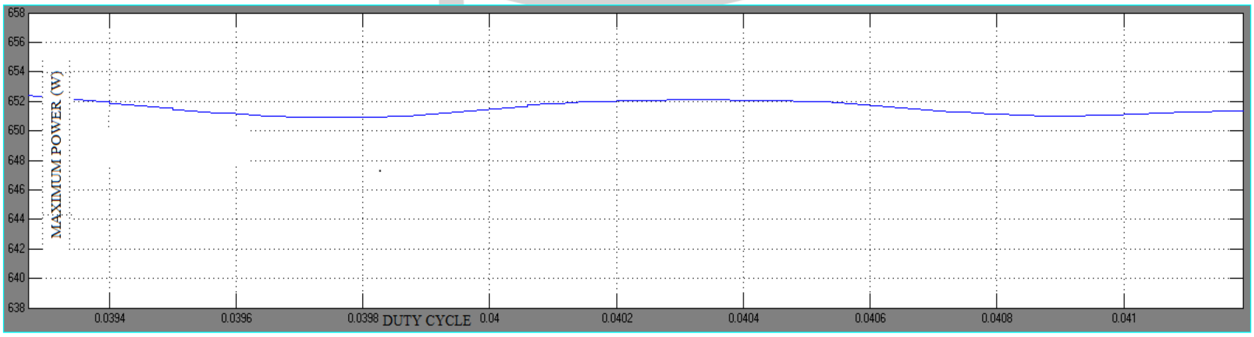

Fig.8. Power Vs Duty Cycle

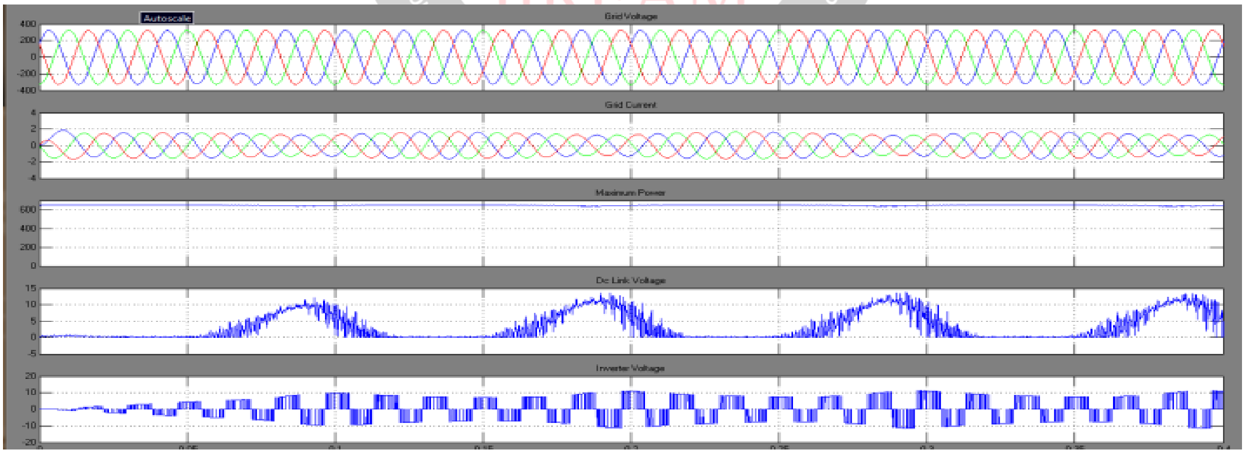

Fig.9. i) Grid voltage, ii) Grid current, iii) Power, iv) DC link voltage, v) Inverter voltage

Table 2: Simulation results for Hybrid System at various operating conditions

Irradiation (W/m^2)	Wind Speed=10 km/s		Wind Speed=12 km/s	Wind Speed=14 km/s
	Temperature (^0C)	Max.Power (W)	Max.Power (W)	Max.Power (W)
400	20	660	672	680
	30	644	657	667
	35	638	**652**	660
	40	631	643	649

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600	20	580	597	608
	30	558	580	584
	35	551	570	579
	40	547	565	574
800	20	468	472	484
	30	442	455	473
	35	437	450	468
	40	430	440	462
1000	20	347	353	375
	30	330	345	352
	35	322	330	345
	40	317	320	331
1200	20	212	245	322
	30	202	232	284
	35	195	220	248
	40	187	206	237
1400	20	138	155	167
	30	116	143	159
	35	103	136	147
	40	98	128	132
1600	20	92	84	95
	30	87	79	87
	35	68	73	82
	40	56	69	77

V. CONCLUSION

The power quality of hybrid system which connected to grid was studied. The maximum power is generated by using control techniques. The maximum power is tabulated for different temperatures by keeping Irradiation and wind speed as constant and also performed at various wind speeds and various irradiation conditions. The hybrid system modeling and simulation was done in Matlab2010. The performance of simulation results are showed for different wind speeds, and for different PV inputs. Control and investigation of mixture frameworks with battery storage will be followed later on works and also the improved fuzzy logic controller can be followed by ANFIS MPPT.

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