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Power Quality Improvement of a Grid Connected with Hybrid Energy System using Fuzzy Logic Controller

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Abstract: The proposed control scheme is used to improve power quality in the grid connected hybrid power generation system by using fuzzy logic controller and is simulated using MATLAB/ SIMULINK in control system block set. The control scheme has a capability to cancel out the harmonic parts of the load current and maintains the source voltage and current in-phase. The simulated Fuzzy logic controller (FLC) based inverter have improved the power quality of source current significantly by reducing the Total Harmonic Distortion (THD).

Keywords: Power Quality; Fuzzy Logic Control system; Total Harmonic Distortion; Hybrid Power generation System;

I. INTRODUCTION

In order to reduce the greenhouse gas emission from electric power generation system and for the growing demand of electricity, the environmental issues has led to one of the new trends of integration of renewable energy resources and energy storage systems. In particular, advantages in wind and PV energy technologies have increased their use in hybrid configurations, because of being emission-free and no cost of energy. Hybrid Wind/PV [1] , [2] , [3] systems are one of the most efficient solution to supply power either directly to a utility grid or to an isolated load . A wind turbine which converts kinetic energy into mechanical energy drives the wind generator to generate ac electric power, and it is converted into dc power to form the common dc link [5].

Solar PV panel is a non-linear power source, where the panel output power varies with temperature. Due to the low voltage of an individual solar cell (typically 0.6V), several cells are combined into photovoltaic modules, which are in turn connected together into an array. The output voltage from the array is low when compared to the dc link. To raise the output voltage of the array, dc-dc converter is used. In this paper buck-boost converter is used. MPPT controller is used to track the peak power from SPV module. The power extracted from the hybrid wind/PV system is transferred to the grid through a three - phase inverter at synchronized grid frequency.

Distributed generationis also called as onsite generation and it produces energy from many small energy sources. Since the generation of electricity occurs very near where it is used, the transmission loss is reduced. The concept of distributed generation also reduces the size and number of transmission lines that have to be constructed. Also it can produce highly reliable and good quality electrical power. Distributed production also reduces transmission and distribution costs. Distributed energy resource (DER) system can be considered as a smallscale power generation technology. A network implementation which can provide a better usage of distributed energy resources concept, is the electrical Microgrid (MG). A microgrid includes generation, energy storage unit and the associated loads. They usually operate connected to a macrogrid. It considers generation and associated loads as one system. A microgrid generates energy for the load using the DER connected to it. A microgrid includes a Generator, Renewable Energy Source (RESs), Distributed Energy Storage (DES) device and corresponding loads. It is as well interconnected to the main power system. During any disturbance or failure of any of the system unit, the generation and corresponding loads can separate from the distribution system.

Hybrid MGs [1] – [17] can work effectively if there is a switch which can open and isolate the load during unacceptable power quality conditions. During disturbances, the islanded loads must take supply from the distributed energy resources connected. It means that the distributed energy resource should be capable far enough to maintain appropriate voltage and frequency levels for the islanded subsystem. Hence the DER must be able to supply the active and reactive power requirements during islanded operation. Hence, efficient distributed energy storage must be used for maintaining the system stability.
Among renewable energies, the most appreciably growing form of electricity generation is the grid connected with wind power generation. But since the nature of wind is hardly predictable, the power generated will be high during high wind speed and will be less, below the cut-in speed of wind. Hence the high intervention of renewable

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energy sources especially wind generation in microgrids (MGs) causes fluctuations of power flow and significantly affects the power system (PS) operation. It leads to oscillations in the system frequency and makes the system unstable. With an effective DES device, which has the ability to rapidly and effectively exchange power with the microgrid, the problems in a microgrid incorporated with wind generation can be solved. For this, fuzzy controller can be used as an efficient Distributed Energy Storage device.

II. WIND TURBINE DESIGN

Currently there are three different wind turbine generating systems that are widely applied. For constant speed wind turbines, directly grid coupled squirrel cage induction generator is used. The wind turbine rotor is coupled to the generator through a gearbox. In this, the rotor is designed in such a way that its aerodynamic efficiency decreases in high wind speeds, thereby preventing the extraction of too much mechanical power from the wind. The second system is the doubly fed (wound rotor) induction generator, which allows variable speed operation. Like in the first system, the wind turbine rotor is coupled to the generator through a gearbox. The power extracted from the wind during high wind speeds, is limited by pitching the rotor blades.

The power output of the wind is given by the following equation,

$$P_W = \frac{1}{2}\rho \Pi R^2 V_\infty \qquad (1)$$

$$T_T = \frac{P_T}{\omega} \qquad (2)$$

$$P_T = \frac{1}{2}\rho \Pi R^2 V_\infty C_P \qquad (3)$$

$$P_{o/p} = \frac{1}{2}\rho \Pi R^2 C_P V_\infty{}^3 \qquad (4)$$

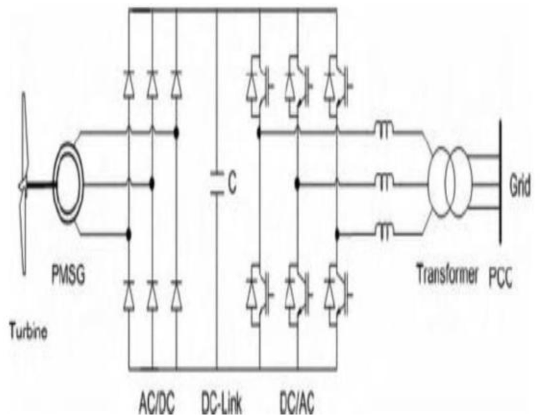

Fig. 2.1 Electrical scheme of a wind turbine with a direct-drive PMSG

The third system is a direct drive synchronous generator. It also gives variable speed operation. The synchronous generator can have a wound rotor or it may be excited using permanent magnets. It is grid coupled through a back-to-back voltage source converter or a diode rectifier and voltage source converter. The synchronous generator is a low speed multipole generator; therefore, no gearbox is needed. Like in the second system, the power extracted from the wind is limited by pitching the rotor blades in high wind speeds.

III. PERMANENT MAGNET SYNCHRONOUS GENERATOR DESIGN (PMSG)

The wind turbine generator considered here employs a direct-driven (without gearbox) PMSG which is directly coupled to the wind turbine and connected to the electric grid through the PCS. The stator windings of the PMSG are directly connected to the PCS which consists of a full-scale power converter. The power converters are built using a back to- back ac/dc/ac converter topology which includes a machine- and grid-side converter with an intermediate dc link.

The mathematical model of the PMSG for power system and converter system analysis is usually based on the following assumptions: The stator windings are positioned sinusoidal along the air-gap. Stator winding is symmetrical. Stator slots cause no appreciable variations of the rotor inductances with rotor position. Magnetic hysteresis and saturation effects are negligible. Damping windings are neglected. Capacitance of all the windings can be neglected and the resistances are constant. The stator windings are positioned sinusoidal along the air-gap. Stator winding is symmetrical. Stator slots cause no appreciable variations of the rotor inductances with rotor position. Magnetic hysteresis and saturation effects are negligible. Damping windings are neglected. Capacitance of all the windings can be neglected and the resistances are constant.

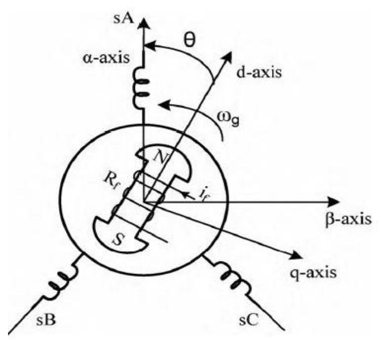

Fig 3.1 d-q reference frame of a synchronous machine

The mathematical model of the PMSG in the synchronous reference frame is given by ,

$$u_d = R_S i_d + \frac{di_d}{dt} L - \omega_e L i_q \qquad (5)$$

$$u_q = R_s i_d + L\frac{di_q}{dt} + \omega_e L i_d + \varphi_m \omega_e \qquad (6)$$

$$\frac{di_d}{dt} = -\frac{R_s}{L} i_d + \frac{P}{2} i_q \omega_r - \frac{1}{L} u_d \qquad (7)$$

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$$\frac{d\omega_r}{dt} = \frac{T_m}{J} - \frac{k_t i_q}{J} - \frac{B\omega_r}{J} \quad (8)$$

$$\frac{di_q}{dt} = -\frac{R_s}{L} i_q - \frac{P}{2}\left(i_d - \frac{\varphi_m}{L}\right)\omega_r - \frac{1}{L} u_q \quad (9)$$

IV. PHOTOVOLTAIC (PV) DESIGN

Power system designed to supply usable solar power by means of photovoltaics consists of solar panel, solar inverter, mounting and cabling to set up a working system. It uses a solar tracking system (maximum power point tracker MPPT) to improve the systems overall performance and include an integrated battery solution.A typical solar photovoltaic system employs solar panels each, comprising a number of solar cells, which generate electrical power. The first step is the photoelectriceffect followed by an electrochemical process where the crystallized atoms ionized in a series, generate an electric current. PV Installations may be ground-mounted, rooftop mounted or wall mounted.

Current through the diode is given by

$$I_D = I_0\{\exp\left[\frac{q(V + IR_S)}{AKT_C}\right] - 1\} \quad (10)$$

$$I = I_L - I_0\{\exp\left[\frac{q(V + IR_S)}{AKT_C}\right] - 1\} - \frac{V + IR_S}{R_{Sh}} \quad (11)$$

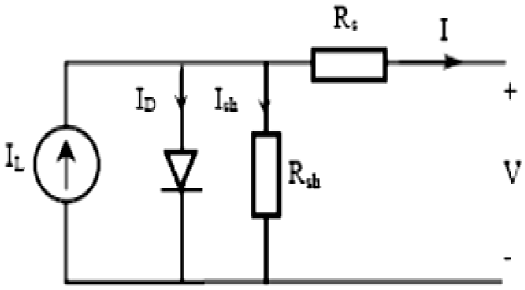

Fig 4.1 Equivalent circuit of PV sytem

V. HYBRID WIND - SOLAR ENERGY SYSTEM WITH FLC

Hybrid Wind-Solar System for the rural exchanges can make an ideal alternative in areas where wind velocity of 12-14 m/s is available. Solar-wind power generations are clear and non-polluting. Also they complement each other. During the period of bright sunlight the solar energy is utilized for charging the batteries, creating enough energy reserve to be drawn during night, while the wind turbine produce most of the energy during monsoon when solar power generation is minimum. Thus the hybrid combination uses the best of both means and can provide quality, stable power supply for sustainable development in rural areas.

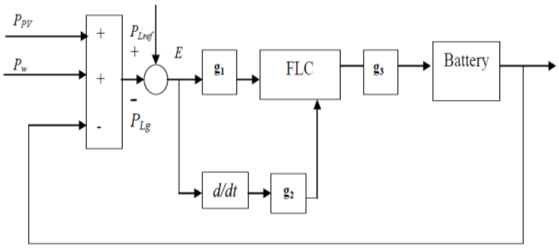

Fig 5.1 Block diagram representation of HES with fuzzy logic control system.

VI. SIMULATION RESULTS

TABLE 6.1 System Parameters

Turbine Power	3 MW
Air density	1.225 Kg/m3
Cp	.54
Distribution system	25 kv
Load	120 kw
Wind speed	15m/s
DC voltage	1100 V
Solar Power	100 kw
Grid	25 kv
Sun Irradiance	1000 W/m2

The Simulink models of the hybrid solar-wind generation system, a detailed model of a fuzzy logic controller for stabilizing the voltage, power and current are given along with relevant waveforms.

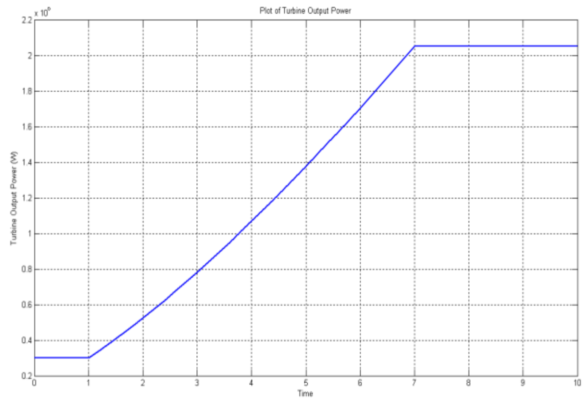

Fig 6.1 simulation result of wind turbine power

Fig 6.1 shows the plot of turbine output power for a variable speed wind turbine and it can be observed that the turbine power varies with speed. The value of Cp for the turbine obtained is 0.54 and λ = 6.357. The maximum value of Cp is obtained for blade pitch angle β = 0 and λ =6.357. The turbine power output obtained is 3 MW.

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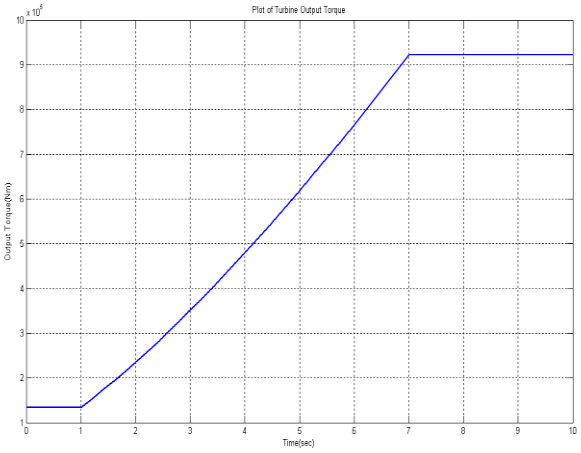

Fig 6.2 simulation result of wind power torque

Fig 6.2 shows the plot of turbine output torque for a variable speed wind turbine. It can be observed that the developed torque is variable with speed.

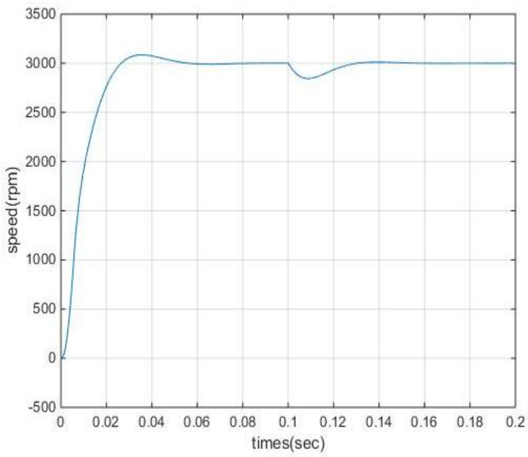

Fig.6.3 Simulation result on speed of PMSG

Fig 6.3 shows the plot of PMSG for speed with respect to time. The maximum speed obtained is 3000 rpm.

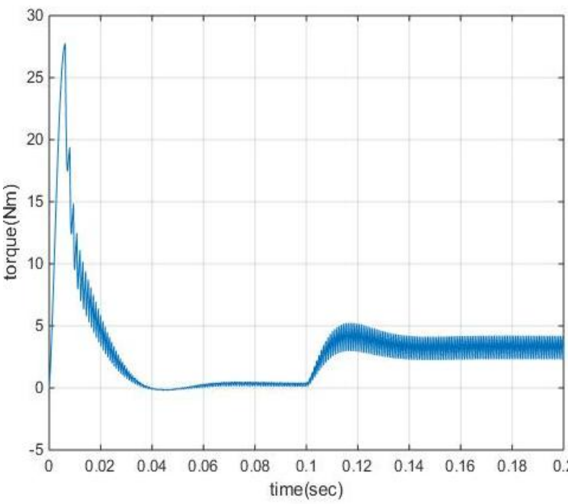

Fig 6.4 simulation result on toque of PMSG

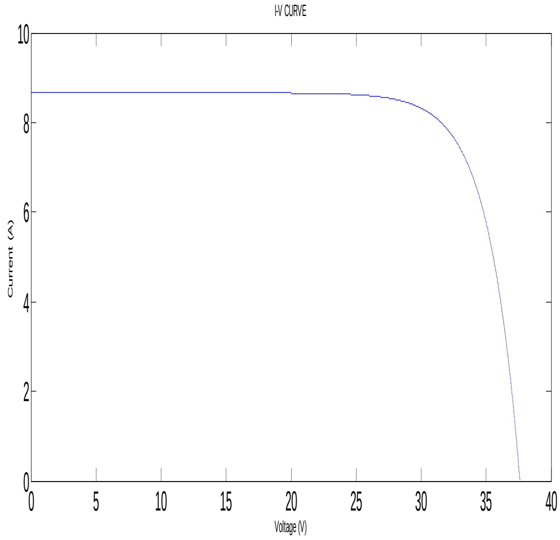

Fig 6.5 P-V curve of PV array

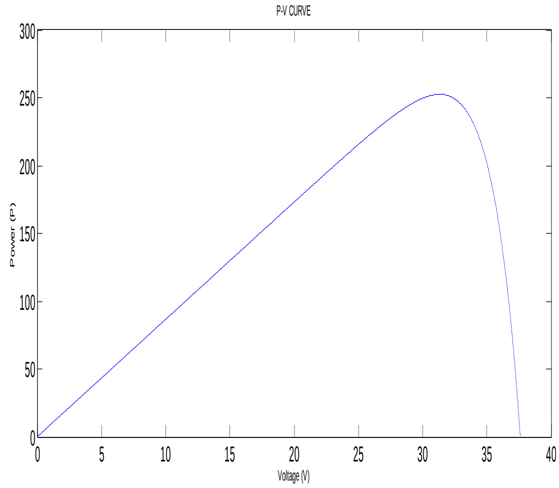

Fig 6.6 i-v curve of pv array

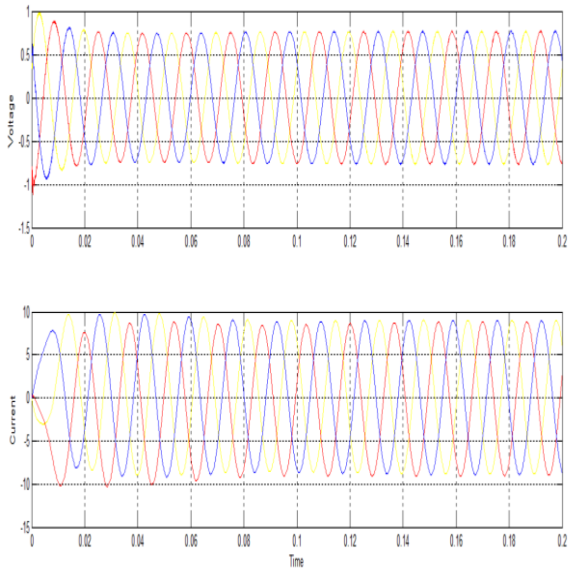

Fig 6.7 V and I waveforms of FLS controlled HES

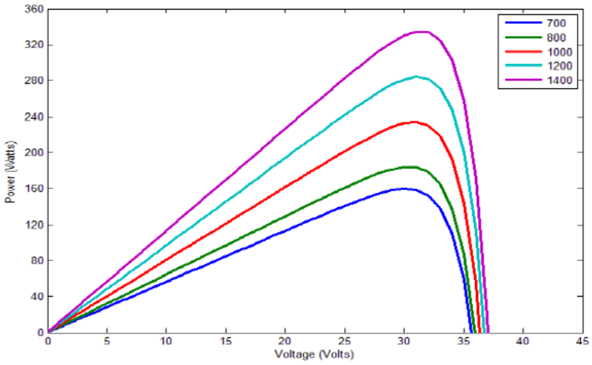

Fig 6.8 Power output of an FLS controlled HES

Fig 6.7 shows the source voltage and current waveforms of the test system with FLC based control and the Figure 6.8 and shows the power analysis waveform. Thus, it is observed that there is a further reduction in the THD value of the source voltage and current waveforms thereby increase in power quality.

VII. CONCLUSION

The Fuzzy Logic controller based control strategy has been developed for grid connected wind-solar hybrid system. Distributed Generation produce harmonics when integrate with grid sources. By using suitable control circuit this harmonics are reduced. The proposed FLC based system have improved the power quality of source current significantly by reducing the THD. It is clearly presented that inverter with fuzzy logic controller gives better performance.

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