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RESEARCH ARTICLE

POWER QUALITY IMPROVEMENT IN GRID TIED HYBRID PV-WIND SYSTEM USING FUZZY CONTROLLER

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ABSTRACT

The main difficult in present power system is that, it fails to meet increasing load demand and growing of population. Consideration of environmental problems and greenhouse effect, renewable energy sources are alternative to meet this requirement. So that, DG systems to become a future energy source due to advantage of environmental conditions and energy costs linked with addition of existed energy systems. Out of all DG systems, PV and Wind energy systems are alternative to each other to maintain the load supply reliability. A DC-DC converter with MPPT technique is used to regulate the DG systems. A INC algorithm is proposed as MPPT technique in this paper. The inverter of hybrid system is implemented with Fuzzy technique to improve power quality. This hybrid system is tested in Matlab/Simulink environment and verified the results for various load conditions to meet the demand.

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INTRODUCTION

Distributed Generation (DG) has gained lot of importance because of the limitation of conventional power generation. The DG system can give more productive, better quality, and dependable power to commercial loads that require continuous administration. The grid-associated converter in a distributed system normally gives dynamic and responsive power to the primary grid by controlling a grid current. At present proportional resonant controller is used with least square error. A proportional integral (PI) control scheme is employed for active damping of the LCL filter or high dynamic performance under rapidly changing atmospheric conditions (1). The predictive current control provides robustness against the computation delay time inherent in the digital implementation, and also offers a fast-current response at a grid-connected inverter with an LCL filter. If any fault occurs in the main grid system, the compensation formulae for voltage sag/swell or in any severe current references are considered for delivering active and reactive powers to the grid as per the grid connection requirements. Another alternative technique under grid fault conditions is for the DG system to be disconnected from the main grid and to operate in the islanding operation mode (2). In this islanding operation, for providing desired voltage to the local sensitive loads the DG system has capable of changing its control strategy from voltage control mode to current control mode. When the main grid voltage recovers to the normal voltage, the DG system switches back to grid-connected operation. Generally, with increase in the power demand due to increase in population, utilization, the Generation of power was really a challenge now a day. Due to high utilization of non-conventional energy sources as a one of the distribution energy sources, may causes the stability problems such as voltage regulation and other power quality problems. Therefore, the power electronic based forced commutated converters are preferred in distribution system for maintaining the system stability, reliable performance and efficient work and also improving the quality of power at coupling junction point (3). To maintain synchronization between grid and this hybrid pv-wind energy systems a suitable pwm based control diagram is designed for three phase inverter. The reference signals required for this inverter controller is chosen from grid system.

PROPOSED STRUCTURE OF HYBRID SYSTEM: In this system, a DC-DC bidirectional boost converter is employed followed by DC-AC converter and the complete system is integrated to the low voltage ac grid. The supply from battery is given to DC-DC converter as an input. Thus, the integration of the battery-based energy storage to the grid is achieved. The line frequency transformer is required in order to match the voltage magnitude of the converter with the grid. A DC-DC bidirectional converter uses MOSFET as a semiconductor switch and operates at a frequency of 25khz, while DC-AC converter uses IGBT as semiconductor device and operates at 5Khz, the configuration is shown in Figure 1.

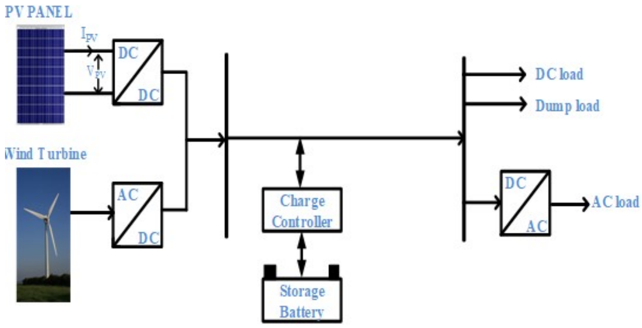

Figure 1. Structure of Grid Interfaced Hybrid System

This structure consist of dc-dc converters for both PV and Wind Energy systems to maintain constant output from the systems (3). To improve the reliability and continuity of supply to load demand a battery energy systems also implemented in this structure. PV, wind and battery systems are interconnected at DC-bus and converted to AC using PWM based inverter. The purpose of this PWM controller is to maintain synchronization between grid and hybrid system (4).

Photovoltaic System: Photovoltaic system is one of the energy source in renewable family, as compared to all DG systems it play a key role in the present power generation systems because of it freely available in environment and its durability. The PV system converts sun irradiance into electrical current with photon effect. This current is converted into electrical voltage with the help of solar electrical equivalent circuit (5). And a DC-DC MPPT converter is used to extract maximum output from the solar system. The structure of solar system is shown in Figure 2.

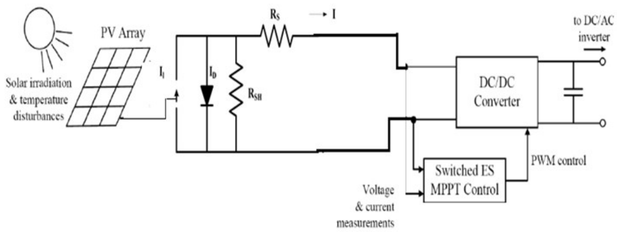

Figure 2. Structure of Solar Energy System

The expression for Photovoltaic system current is shown in equation (1),

$$I = I_{ph} - I_D - I_{sh} \qquad (1)$$

$$I = I_{ph} - I_o[e^{(\frac{qV_D}{nKT})}] - (\frac{V_D}{R_s})$$

Figure 3, shows the characterestics of P-V and I-V of photovoltaic system. From this the maximum power point of system in identified.

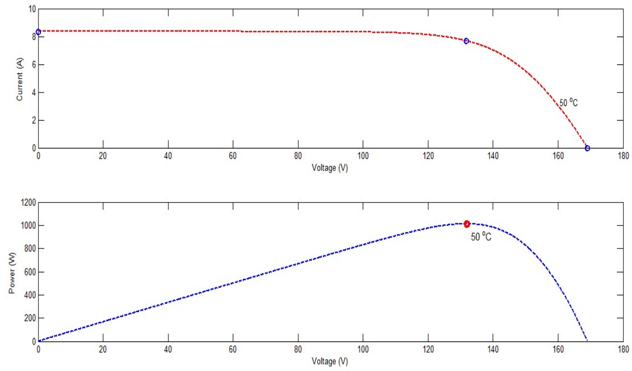

Figure 3. V-I Characterestics of PV system

The structure of closed loop control diagram from dc-dc converter using MPPT technique is shown in figure 5 (6). Here, the reference signal obtained from MPPT is compared with PV system voltage and applied to PWM converter to generate duty cycle required for dc-dc converter.

Wind Energy System: The other alternative solution to the renewable energy system is wind turbine. In W.E.S the wind turbine converts wind speed energy to kinetic energy to maintain high speed from wind turbine a gearbox mechanism is used this gearbox converts low speed shaft to high speed shaft and applied to generator which converts to electrical generation here, a synchronous generator (induction generator) (6). Generally there are two types of induction generator's (i.e SGIS and DFIG). The main advantage of induction generator to use in wind turbine as it generates power at variable speed it has simple in construction and has capable to recycle the wasted rotor power with help of back - back converters. Along with this W.E.S is also implemented with an mppt based DC to DC boost converter to extract maximum power from the W.E.S.

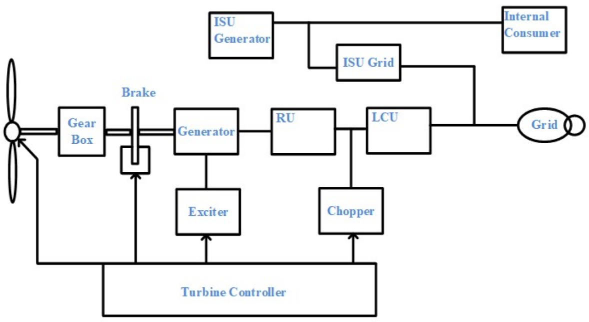

Figure 4. Basic diagram of wind turbine

The structure of wind turbine shown in figure 4, consists of following components, the gear box is used to convert the low speed shaft to high speed shaft and applied to generator, the output of the generator is converted to dc using rectifying unit and connected to Line Control Unit (LCU), which is used to regulate the wind output to meet grid requirement (8). An extra units is used to give the power to internal auxiliaries of wind turbine (like motor, battery etc.), this is called Internal Supply Unit (ISU). The mathematical analysis for wind energy system is expressed in equation (2) and coefficient of power in equation (3). The mechanical output power from the wind turbine as (7)

$$P_{mech} = 0.5\rho A V^3 C_p \qquad (2)$$

Where, C_P is the coefficient of power

$$C_p = 0.53(\lambda - 0.2)(0.7 - \lambda) \tag{3}$$

DC-DC Converter: The solar converter, is nothing but a DC-DC boost converter which is used to regulate solar power with MPPT control diagram. In this paper a cuckoo based MPPT technique is proposed. The control diagram for DC-DC boost converter is shown in Figure 5. As the solar panel voltage /current increases, the PWM generator increases its repetition rate thus resulting in increased output current. At the same time, additional voltage is applied to the inductor thus increasing its charge current. Where the initialization is based on voltage and power calculations that are based on current and voltage values acquired from sensors (9). Once the actual power is calculated, then the next cycle of the measurement is compared to previous value to change the reference voltage Vref.

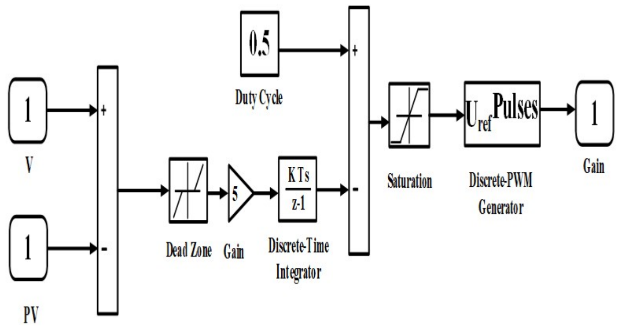

Figure 5. MPPT based PWM controller for DC-DC converter

Fuzzy Logic Controller: The major complexity in conventional PID controller is mathematical analysis with multiple variables and constant interfacing. The major three issues with conventional PID controller is (a) time delay, (b) step function response and (c) ramp or soak function response. In order to overcome these issues, this paper is implemented with soft computing controller called as Fuzzy logic Controller. Fuzzy Logic is one type in artificial intelligence and it is based on the information which is either true or false. FLC is a function or group of flexible set of if-then rules.

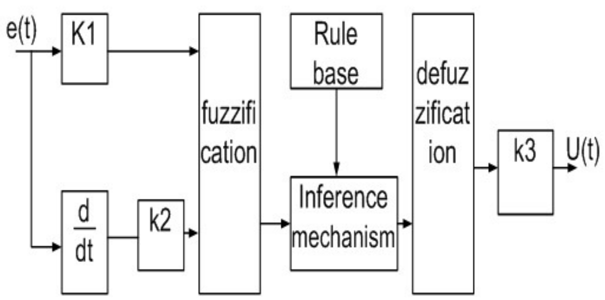

Figure 6. Architecture of FLC system

Figure 6, shows the basic structure of fuzzy logic controller with two inputs namely error of dc link voltage and change in error. Each input of FLC is a set of 5 memberships (i.e MS, S, Z, H, VH). The minimum of the two inputs of Medium small, small, zero, high and medium high are chosen which ultimately try to fire the set of IF-THEN rules. If error input is Z AND change in error input is H then the output is MH.

Table 1. Rule-Base formation for 5*5 input FLC

e/ce	MS	S	Z	H	MH
MS	MS	S	Z	H	MH
S	MH	H	Z	S	MS
Z	S	Z	H	MH	MS
H	S	S	MS	H	H
MH	S	Z	H	H	MH

MATLAB RESULTS

The proposed hybrid system using PSO MPPT controller and P&O MPPT controller strategies for inverter optimization techniques is tested and verified in Matlab/Simulink Environment. The parameters for designing of wind and PV system is shown in table-I and table-II. Table-I gives the system parameters required for PV system and table-II shows the system parameters for Wind Energy System. This proposed system is tested under three different cases.

Table 1. System Parameters for PV System

Parameter Variable	Value
Maximum Power	1800W
Maximum Voltage	140V
Current at max Power	11.8A
Open Circuit Voltage	148V
Short Circuit Current	12.74A
Boost inductor	Lb=2.0 mH
Input filter capacitor	Cs=940 μF/500 Vdc
DC capacitor	C_{BUS}=5640 μF/500 Vdc
Reference voltage of the boost function	VBUS=400 Vdc
Boost switching frequency	fSb=24 kHz

Table 2. System Parameters for Wind System

Parameter Variable	Value
Nominal Wind Speed	12 m/s
Nominal Power	0.855MW
Wind Turbine Bus Voltage	575V
Generator Specifications	
Stator Resistance	0.0048 p.u
Stator Leakage Inductance	0.1248 p.u
Rotor Resistance	0.0044 p.u
Rotor Leakage Inductance	0.1791 p.u
Mutual Inductance	6.77 p.u

In this the solar system and wind system is designed as per the modelling expressions presented in the previous sections. The solar plant is designed to generate 16kw and Wind energy system is designed to generate 20kw. The power management strategy for different load conditions is shown.

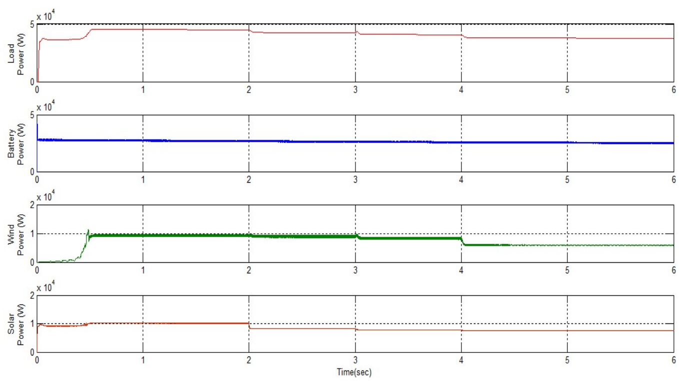

Figure 8: Simulation Result for (a) Load Demand, (b) Solar Power, (c) Grid Power and (d) Battery Power

Figure 8 shows the simulation result for the proposed system to show the power management strategies.

Here, the load sharing is chosen between PV, battery and wind system according to their generations. The solar system generates 10kW during 0s to 2s and 8kw between 2s to 6s. And the wind system generates 9.8kW between 0s to 4s and 6kW during 4s to 6s. The demand for load to this system is approximately 47kW and it is changed to 38kW during the period 3s to 6s.

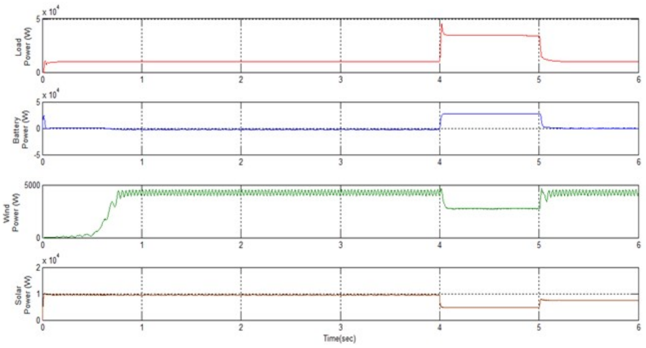

Figure 9. Simulation Result for (a) Load Demand, (b) Solar Power, (c) Wind Power and (d) Battery Power using Fuzzy Controller

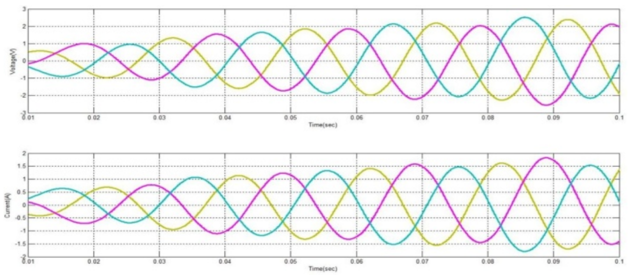

Figure 10. Simulation waveform for Inverter Voltage and current using Fuzzy

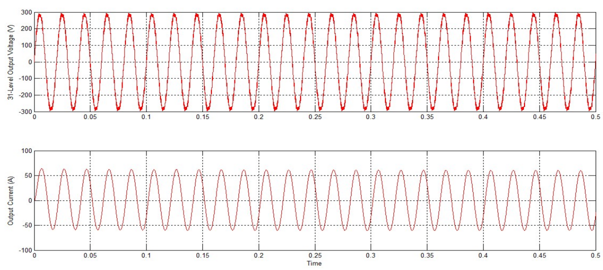

Figure 11. Simulation Result of Output voltage and Current

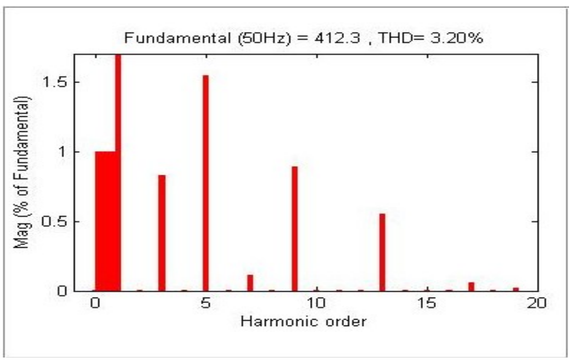

Figure 12. Harmonic analysis for Inverter Voltage with conventional PI technique

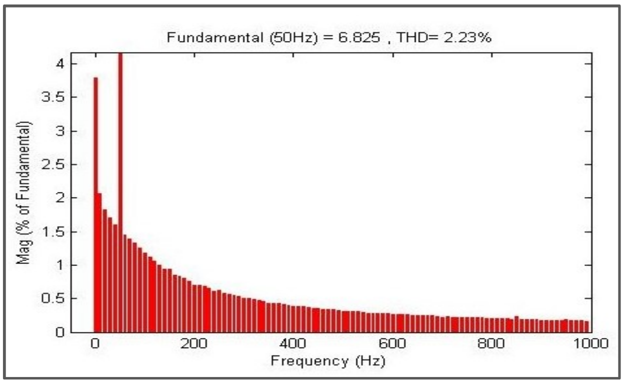

Figure 13. Harmonic analysis for Inverter Voltage with Fuzzy technique

Table 3. Comparison of THD Values (with and without Fuzzy controller)

S NO	Parameters	Without Fuzzy ControllerThd in (%)	With Fuzzy Controllerthd in (%)
1	LOAD VOLTAGE	7.83	4.30
2	LOAD CURRENT	8.49	4.23
3	INVERTERVOLTAGE	8.49	4.30
4	INVERTERCURRENT	7.78	4.22

Figure 9 shows the simulation result for the proposed system to show the power management strategies implemented with PO and anfis controller. Here, the load sharing is chosen between PV, battery and grid system according to their generations. The irradiance to solar system is considered in variable mode i.e during 0s to 4s the irradiance is 1000w/m2, 800 w/m2 applied during 4s to 5s and later it changed to 900 w/m2. Based on these conditions, the output from the solar system like 10kW during 0s to 4s and 8.2kw between 4s to 5s and again it raised to 9kW after 5s. The wind energy system generates 4.8kW between 0s to 4s with wind speed of 9m/s, it generates 3.6kW during 4s to 5s with wind speed of 7m/s again after 5s the wind speed is changed to 9m/s and generates 4.8kW. The demand for load to this system is approximately 14kW and it is changed to 45kW during the period 4s to 5s. The PV and Wind system contributes their generation to meet the load requirement and the excess requirement is taken from battery system or gives to the battery if generation is more than demand.

CONCLUSION

A hybrid system with photovoltaic (PV) - wind and battery backup to meet reliable power supply demands was proposed in this study. The solar system is designed for 16 kW of power, and the wind energy system is designed for a rating of 20 kW and has the capability to maintain power management to share the load demand under various variable conditions. Both the PV and wind systems were implemented using MPPT-based DC-DC converters to improve the efficiency and reliability of the proposed system. It proposes PO MPPT techniques. To improve the performance of PV-Hybrid and improve the power quality problems a Fuzzy controller is implemented. The proposed MPPT-based hybrid system was tested and verified using the MATLAB/Simulink software.

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