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Smart Controller Fed Non Conventional Microgrid for Optimal Power Distribution*

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Abstract

This Paper proposes the smart controller SUG to achieve system reliability and optimal power distribution. Control targets were acquired by mixed application of various strategies, such as Micro-grid peak load shifting be used to reduce State Utility Grid (SUG) supply pressure, SUG connection be controlled flexibly to maintain Micro-grid load working reliably, Micro-grid power production and load supply demands of SUG and Micro-grid be predicted to plan battery energy storage in advance, actual monitoring date be used to control overcharge and over-discharge, State of Charge (SOC) be managed to realize battery efficient storage and full life cycle as far as possible. All designs were integrated with forecasting and monitoring data from different locations of Micro-grid supply side and demand side, the SOC of storage system.

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Keywords: Wind photovaltic storage, Microgrid, Information Fusion, Peak Load Shifting, State Utility Grid.

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1. Introduction

As a new alternative energy, small wind and solar complementary generation system is always operated in Micro-grid island mode, also as a distributed generation technology used in group buildings [1]. The use of wind and solar complementary power can solve problems to a certain extent of environmental pollution and energy exhaust caused by the use of traditional energy sources, but the unique uncertainty and randomness of wind and solar generation power create major obstacles to the power generation and supply demand management[2], which show inherent shortages of centralized control or distributed control, wind and photovoltaic Micro-grid system is difficult to provide continuous and stable energy output [3]. There are hybrid systems appeared in existing literatures integrated with energy storage device. However, due to the battery own characteristics, such as capacity and life, system cost and efficiency of wind and solar power generation are affected [4].To improve the efficiency of the system, mixed control structure is used under reliability constraints [5]. By predicting the wind speed and solar radiation per-hour, thus the rational capacity allocation of hybrid power system is done, so improving reliability and reducing cost [6]. The energy storage system is undoubted the preferred mode of distributed generation of energy regulation, the key technology related battery life closely is the battery charge and discharge methods and strategies [7]. Charge and discharge management of battery is essential for reliable and stable operation of wind and solar Micro-grid system. Literature [8] proposes a hybrid energy storage structure consisted of ultra-capacitor and battery, which can prevent battery from too large charge and discharge current resulting from power fluctuations and keep battery in an effective service life. To meet user more needs and improve the efficiency of the system, a more reliable charge and discharge control system must be used as a support [9].

In general, Wind/ Photovoltaic Micro-grid storage technology appeared in literatures are mostly focused on single function of maximum power tracking or analysis of battery capacity or operation method. Few are focused on proactive energy storage planning from the angle of the multi-objective control, such as battery charge and discharge protection, reliable power supply of Micro-grid load and peak load shifting, so as to achieve flexible and efficient control. In this context, the subject of intelligent control research is expanded on Wind/ Photovoltaic Micro-grid storage systems. According to SUG (State Utility Grid) load forecasting and Micro-grid power generation and load demand prediction as well, multi-information fusion concept of intelligent control is introduced. Stage planning is done for battery charge and discharge within the next 24 hours, solving the shortage problem of power generation of Micro-grid that may be happened during the future peak time of SUG load. So peak load shifting to valley and stagger supply power away from SUG peak is achieved under SUG connection, relieving the SUG supply pressure. At the same time, according to the Micro-grid power production forecast, a further SOC is predicted effectively to prevent battery from overcharge or over-discharge, thereby extending battery life.

2. Wind/ Photovoltaic Storage System Topology

Wind/ Photovoltaic storage power generation system consists of five functional blocks in Fig. 1. From the point of view of energy flows, there are multiple path divisions. The first is complete energy transmission from Wind/ Photovoltaic complementary power generation to Micro-grid load. The second is from Wind/ Photovoltaic complement power generation to battery energy storage system. The third is from the SUG to Micro-grid load. The fourth is two-way bi-direction power transmission from SUG to battery storage. The fifth is from Wind/ Photovoltaic complementary power generation to the SUG. According to the system function module structure analysis, the topology diagram designed is as shown in Fig. 1, Wind/ Photovoltaic complementary power generation supplies local Micro-grid load through the DC/AC converter. Battery is given an access to DC bus by DC-DC converter. As can be seen from the figure, to achieve energy management and intelligent control, monitor equipment must be placed firstly at the different locations, such as output port of DC-DC converter of Wind/ Photovoltaic power, the output port of storage system, the port of Micro-grid load, the port of SUG. So Wind/ Photovoltaic power generation production, SOC of battery, load supply demand and SUG parameters are monitored. Then based on the each monitoring parameter, combined with relevant forecasting data, information fusion is used to control battery charge and discharge and SUG connection flexibly by the intelligent controller in Fig. 2..

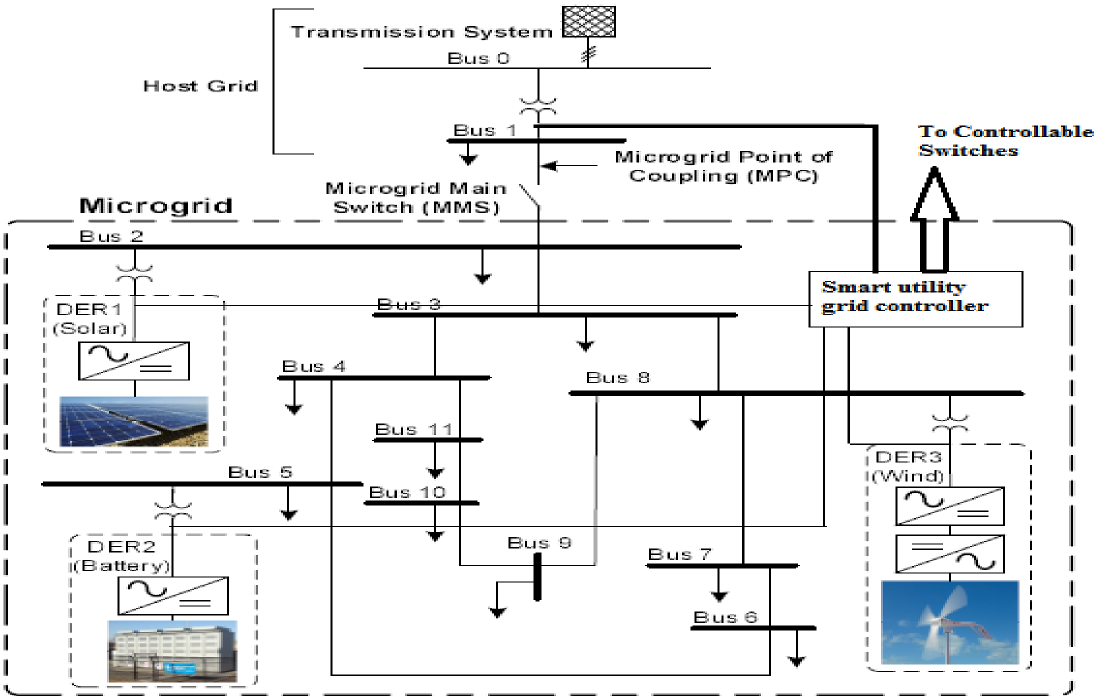

Fig. 1. Hybrid systems of wind/photovoltaic/Battery topology schematic

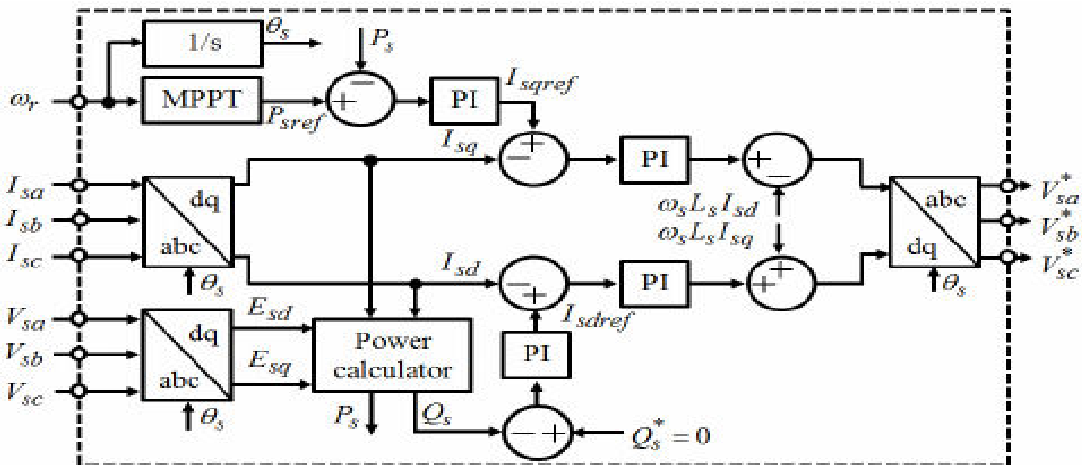

Fig.2. Simulation Model of WECS

3. Statistical Formulation of Wind Turbine representation

The mechanical power output from wind turbine is given as in Eq. 1.

$$P_m = \omega_r[J.d\omega/dt] + P_e \quad (1)$$

The Wind Turbine drive train based on 2 mass models is utilized in shaft modelling analysis. Driving by the dynamic torque T_d, the wind turbine rotor rotates at ω_r and the braking torque is represented as T_{lb}. The dynamics of rotor is characterized by the state equation in first order differential equation representation in Eq. 2.

$$J_r\, d\omega_t/dt = T_d - T_{lb} - k_r\omega_t \tag{2}$$

The low speed shaft results T_{lb} from the torsion and friction effects due to the difference between x_t and the low-shaft speed x_{lb}. This torque act as a breaking torque on the rotor in Eq. 3.

$$T_{lb} = B_{lb}\,(\theta_t - \theta_{lb}) + K_{lb}\,(\omega_t - \omega_{lb}) \tag{3}$$

The torque on high shaft is generated by torque on low shaft using gear box in Eq. 4.

$$T_{hs} = T_{ls}/ G \tag{4}$$

Pitch angle and pitch speed of the gear box is given as Eq. 5.

$$\begin{aligned} \theta_a &= G.\theta_{ls} \\ \omega_a &= G.\omega_{ls} \end{aligned} \tag{5}$$

The low shaft speed ω_{ls} is enlarged by the changing the gearbox ratio so as to obtain the generator speed ω_g, while the low-speed shaft torque T_{ls} is increased. If we presume an ideal gearbox the gear ratio can be written as Equ. 6.

$$G = T_{ls} / T_{hs} = \omega_g / \omega_{ls} \tag{6}$$

The generator is driven by the high-speed shaft Torque T_{hs} and braked by the generator electromagnetic torque T_{em}

$$J_g\dot{\omega}_g = T_{hs} - K_g\omega_g - T_{em} \tag{7}$$

The electromagnetic torque is represented as T_{em} and is given by Eq. 7, and Eq. 8.

$$T_{em} = \frac{1}{[illegible]}\left[E_R i_R + E_\nu i_\nu + E_B i_B\right] \tag{8}$$

In an Linear model the voltage and flux equation with respect to stationary reference frame is given as in Equ. 9.

$$\begin{aligned} V_{ds} &= I_{ds}R_{ds} + {}^{d\varphi_{ds}}\!/_{dt} \\ V_{qs} &= I_{qs}R_{qs} + {}^{d\varphi_{qs}}\!/_{dt} \end{aligned} \tag{9}$$

4. SUG connection controller design under load reliable operation

Scientific and rational intelligent algorithm of energy storage device is necessary for a good performance Micro-grid system. Not only the dynamic relationship between power production and load demand must be considered, but also the energy storage SOC itself, Micro-grid power supply and load forecasting, SUG load forecasting within next 24 hours as well, and thereby scientific and reasonable control to the battery storage and SUG connection device is given out. The overall design schematic diagram of intelligent control strategy is as shown in Fig. 3. Prediction error at each moment is adjusted according to pre-period prediction and monitor.

Actual value of the Wind/ Photovoltaic power production and load demand, and Wind/ Photovoltaic power output and load power demand are forecasted for the next period. Then take Wind/ Photovoltaic power production and load demand prediction value as a control basis, combined with the current battery SOC, the SUG connection control signal is given out. Meanwhile, according to the SUG load distribution and quantity of Micro-grid load demand and power production during SUG load peak period within the future 24 hours, the amount of energy needed to be stored in advance is planned during SUG valley load period.

5. THD ANALYSIS

The Total Harmonic Distortion is analyzed in MATLAB/SIMULINK either by using two Discrete Fourier blocks allow computation of the fundamental component of voltage and current while simulation is running or by using FFT tool of Powergui to display the frequency spectrum of voltage and current waveforms. Analyzing THD by Discrete Fourier blocks is not an Convenient method. Therefore FFT tool of Powergui is used for the analysis of THD.

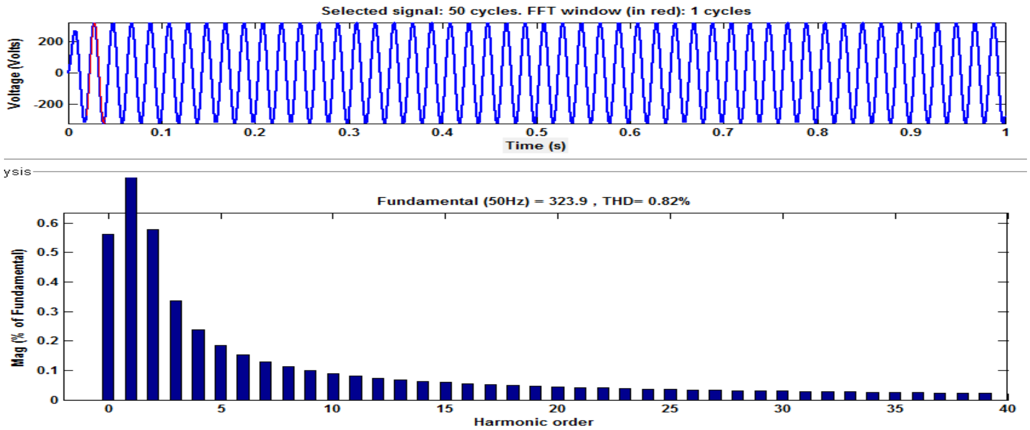

Fig. 3. THD Analysis on Converter Section without ideal Controller

The Fig. 3. Shows the Simulation result of THD analysis over the Converter Section with an SVPWM controller and it is found that the converter output is 323.9V at fundamental frequency with a Total Harmonic Distortion of 0.82%.

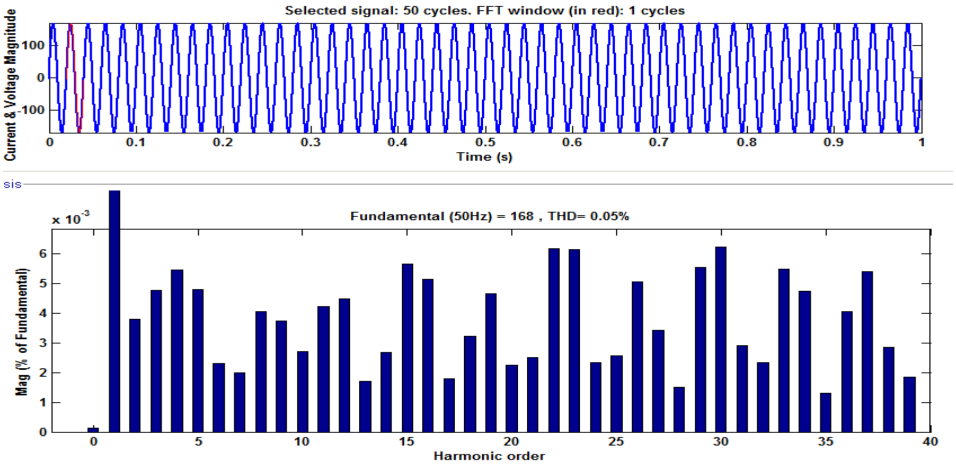

Fig. 4. THD Analysis on Grid Side with SUG Controller

The Fig.4. shows the Simulation result of THD analysis over the Grid Section with SUG Controller and the total Harmonic Distortion of 0.05%. The Fig. 3. & fig.4. Shows the Simulation test results of THD analysis on per phase current on islanded Grid system with SUG controller. The Current output is 18Amps with a THD of 0.71% and voltage of 325 Volts at fundamental frequency with a THD of 0.73%The Fig. 4. Shows the Simulation test results of THD analysis on per phase Voltage on islanded Grid system. The Simulation is done by FFT tool of Powergui and by looking at the result it is clear that the frequency spectrum of voltage and current waveforms are present. The Current output is 325 Volts at fundamental frequency with a Total Harmonic Distortion of 0.73%.

Conclusion

It has been analyzed that the controller can perform several functions, such as trigger SUG connection flexibly according to Micro-grid actual power production and load supply demand, integrate with SOC to ensure reliable operation of the Micro-grid load. Local peak load are moved to valley segment to achieve peak shifting to ease the supply pressure of SUG peak power demand, reducing the running costs of Micro-grid. At the same time, bi-directional DC/DC converter is introduced to Wind/ Photovoltaic/Storage power system, reducing the number of electronic converter components and the volume of equipment. The Power reliability and optimum power solution is obtained by simulating the circuit in MATLAB/SIMULINK.

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