Research on Smooth Control of Wind Power Fluctuation with Hybrid Energy Storage

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Abstract

The output fluctuation of wind power system has brought huge hidden dangers to the grid. In recent years, the application of energy storage devices to stabilize the fluctuation has been greatly developed. In this paper, a control strategy for wind power fluctuation based on hybrid energy storage of battery and super-capacitor is proposed. Due to the performance characteristics of battery and super capacitor, a low-pass filter is designed to separate the output into low frequency for battery, and high frequency for super-capacitor. A voltage and current double closed-loop coordination controller is further designed to realize the frequency division mixed energy throughput of the battery and the super capacitor. The simulation results show that the proposed hybrid energy storage system effectively suppresses the power fluctuation of wind power system and prolongs the service life of the battery.

Index terms— wind power generation, hybrid energy storage, power fluctuation, smooth control

1 Introduction

n order to alleviate energy crisis and improve ecological environment, the development and utilization of new energy has been worldwide concerned, among which the wind power generation technology has been rapidly developed. However, wind energy, as a natural clean energy, has great volatility and randomness under the influence of weather. Largescale wind power grid connection has a certain impact on the safe and stable operation of the power system. At present, matching corresponding energy storage devices is usually adopted in the wind power generation system to effectively smooth the power fluctuation of wind energy [1][2][3] .

At present, the energy storage system based on battery and super capacitor is mainly used to smooth the wind power fluctuation. Literature [4] proposed an energy storage structure of dual battery pack that separated charging and discharging processes, and designed a control strategy for power fluctuation to keep the battery running within the optimum discharge depth, thus prolonging the service life of the battery. Sun G W [5] utilized storage battery to suppress the power fluctuation of the wind farm, and realized real-time system adjustment by studying the space vector modulation algorithm of PWM converter. However, a single energy storage device cannot fully meet the comprehensive performance requirements of the system, and the combination of super capacitors and battery can improve the power regulation capacity of the energy storage system [6] . In literature [7] , super capacitor voltage low-frequency suppression method is adopted to distribute the smoothing power required by supercapacitor and battery respectively. The battery set is divided into three independent units to alleviate the current imbalance and reduce the loop current ripple. In literature [8] , the sliding average filtering algorithm is adopted to separate the power required by the flat suppression of the battery, which effectively reduces The Times of charging and discharging of the battery and improves the operation economy of the energy storage system. Literature [9] proposed an energy storage technology based on wavelet packet decomposition to smooth power fluctuations. Power fluctuation signals are decomposed at multiple scales by wavelet packet decomposition theory. Low-frequency fluctuations are directly connected to the grid, while high-frequency fluctuations are further decomposed to different energy storage devices through wavelet packet decomposition for smoothing.

In this paper, for the combined wind storage system, a control strategy based on hybrid energy storage to smooth out wind power fluctuations is studied. Through a low-pass filter the fluctuation of power is separated into high frequency and low frequency, complying with the super capacitor and battery characteristics respectively, to enhance the control capacity and the service life of the battery energy storage system, proposing a voltage and current double closed-loop coordination controller where two kinds of energy storage devices share the voltage outer loop. Finally the validity of the proposed control strategy is validated by computer simulation.

2 II.

3 Structure of the Wind Storage System

The energy storage system can cut the peak load, fill the valley load and reduce the power fluctuation when wind power is connected to the power system, which is conducive to large-scale access of wind power, improving the stability of the grid, and carrying out planned dispatching of wind power generation [10] . For The energy storage devices are all connected to the dc bus of the energy storage converter through bidirectional DC-DC Converter, as shown in figure **??**.The circuit has a Boost state and a Buck state. When the wind energy is insufficient, the energy storage device is required to provide energy. Energy flows from the energy storage device to the dc bus. When there is surplus of wind energy, the energy storage device is required to absorb energy. Energy flows from the dc bus to the energy storage device. Meanwhile T1 tube is turned on and T2 tube is turned off, the converter works in Buck state, and the energy storage device is charged.C R T1 T2 L ? ? ? + Udc - ? ? ? ? ?

4 Fig. 2: Bidirectional DC-DC convertor

The energy storage converter is connected between the dc bus and the common ac bus, and PQ control is adopted to obtain the active power and reactive power required by the system (where the reference value of reactive power is set as 0). When there is surplus of wind energy, the energy storage system absorbs energy, and the energy storage converter is in the rectifying state. When there is short of wind energy, the energy storage system releases energy, and the energy storage converter is in the state of inverter. Its circuit structure diagram is shown in figure **??**.? ? ? ? + U dc _C L i C i dc i V 1 V 2 V 3 V 4 V 5 V 6 a u b u c u L R sa E sb E sc E a i b i c i

5 Equivalent circuit model energy storage convertor

The expressions of active power and reactive power of the energy storage converter are as follows [11] sd d sd qP E i Q E i ? ? ? Where d i ? q

i is the component of the three-phase current on the ac side in the d and q axis, and is the component of the three-phase voltage on the ac side in the d axis. Active power and reactive power can be The main output power of the wind storage system comes from the power generated by the draught fan, so the main factor affecting the wind storage system is wind speed. The power balance relationship of wind storage system is as follows P is the grid-connected power of the whole system. When the wind speed is relatively high, the energy storage system needs to absorb power to smooth the fluctuating power, while the wind speed is relatively low, the energy storage system emits power to stabilize the power fluctuation.

6 b) Low pass filter for frequency division

The first order low-pass filter is designed to separate the power frequency of the energy storage system into low frequency for battery and high frequency for super-capacitor. The circuit schematic diagram is shown in figure **??**, where 1 U is the input signal, 2 U is the output signal, R is the filter resistance, and C is the filter capacitor.

7 RC U U dt ? ?

The transfer function is1 ( ) 1 H s s ? ? ?

Where s is the filter operator, ? is the filter time constant, **??**nd c f is the filter cut-off frequency.1/ 2 c f ? ? ? ,

When the filter is applied to the power distribution of the energy storage system, the input signal 1

In the expression,* c

P is the reference value of the power suppressed by super-capacitor. According to the characteristics of each energy storage device, the battery response time is the key factor. The power with a frequency higher than 0.1Hz and the power with a frequency lower than 0.1Hz is designed to be absorbed by a super-capacitor and a battery respectively, so take tube is working, the state equation can be obtained as follows:1(1) 1 0 1 1 0 bar dc dc D d I I L U L D dt U U C RC ?

Thus, the circuit's current loop control equation and duty cycle adjustment equation under Boost state are:

(1)bar dc dI L U D U dt ? ? ? (/)( ) p i ref bar dc dc K K s I I U U D U ? ? ? ? ?

Where p K and i K are the proportional and integral current loop parameters of the PI controller.

Similarly, when the circuit is in Buck state, the current loop control equation and duty cycle expression are:bar dc dI L U D U dt ? ? ? ?**(10)**

(/)( )p i ref bar dc K K s I I U D U ? ? ? ? IV.

8 Simulation Results

Based on Matlab / Simulink, an integrated wind and energy storage grid-connected system is established. The external system uses a single-machine infinite system. The main parameters of the fan are 100kW fan capacity and 690V rated voltage, and the main parameters of the energy storage system are 300Ah battery capacity, 0.5R battery internal resistance, 70F super-capacitor capacity and 800V DC bus reference voltage.

Assume that the active power output expectation of the system, namely the grid dispatch value, is constant within a second time scale, the reactive power is zero, and the wind speed is variable. The output power of the wind turbine and the power to and discharge for many times, and the charge and discharge depth is also larger than that of the battery. Therefore, the effectiveness of the hybrid energy storage control strategy is verified, which can effectively reduce the charging and discharging times of the battery and prolong its service life.

9 Conclusion

In this paper, a wind power grid-connected system based on hybrid storage of battery and supercapacitor is established, and a power fluctuation smoothing strategy based on voltage and current double closed-loop frequency division coordinated control is proposed. The actual power characteristics and SOC change curve of the battery and supercapacitor are observed in the simulation under the conditions of constant wind speed and variable wind speed. The results verify that the control strategy can effectively smooth the fluctuation of wind power, reduce charging and discharging times of the battery, and prolong its service life. [1]

Figure 1: IFig. 1 :

Figure 2:

Figure 3: 2 UFig. 4 :

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Figure 4: Fig. 5 :

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Figure 5: GlobalF©

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Figure 6: Fig. 6 :

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Figure 7: Fig. 7 : 8 :

9t/s

Figure 8: Fig. 9 :

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Fig. 3:
(1)

Figure 9: Table 1 :

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