A wavelet packet-dual fuzzy control method for hybrid energy storage to suppress wind power fluctuations

L.v. Huixiang, Chen. Caixue and Xiong. Zhigang

Department of Automation and Electronic Information, Xiangtan University, Xiangtan, China,
Phone/Fax number: +0086 17673911062, e-mail: mai5010104@outlook.com

1. Introduction

its fluctuating, intermittent and random characteristics have a more and more significant impact on the stability and reliability of the power system, a factor that largely limits the development of wind power. In this paper, a wavelet packet-dual fuzzy control hybrid energy storage method is proposed to suppress the fluctuation of wind power. First, the wavelet packet decomposition is used to obtain the wind power grid-connected power and the hybrid energy storage power; finally, the SOC of the hybrid energy storage is optimised by means of a fuzzy control algorithm to keep it within a reasonable range and to correct the charging and discharging power of the hybrid energy storage twice. The analysis results of the example verify the effectiveness of the method proposed in this paper.

2. Wavelet Packet Decomposition for Power Allocation

DB8 wavelet basis function is better in non-smooth vibration signal analysis, so DB8 wavelet is used to decompose 6-layer wavelet packets for wind farm output power signal. The power distribution expressions for grid-connected power, supercapacitor and lithium battery are obtained by fast Fourier transform and analysis of the wind farm output power data as follows:

\[
P(t) = P_{grid}(t) + P_b(t) + P_c(t)
\]

(1)

3. Energy Storage Model

The change in capacity of supercapacitors and lithium batteries can be expressed as:

\[
E_b(t) = E_b(t - 1) + \int P_b(t) \, dt
\]

(2)

The real-time SOC of supercapacitor and lithium battery is expressed as follows:

\[
SOC_b(t) = SOC_{b0} + \frac{E_b(t)}{E_{bmax} - E_{bmin}}\]

(3)

The state of charge SOC of the supercapacitor and lithium battery during operation cannot exceed the limit, so the rated capacity of the supercapacitor and lithium battery must satisfy the equation:

\[
E_{bmax} = \frac{2 \times \max(U_{k1}(E_b) - \min(U_{k1}(E_b)))}{\eta_{b} \times SOC_{bmax} - SOC_{bmin}}
\]

(4)

\[
E_{bmin} = \frac{2 \times \max(U_{k1}(E_b) - \min(U_{k1}(E_b)))}{\eta_{b} \times SOC_{bmax} - SOC_{bmin}}
\]

(4)

4. Fuzzy Control of Energy Storage SOC

A. System Control Strategy

However, the hybrid energy storage power allocation based on wavelet packet decomposition theory alone may cause overcharging and discharging of energy storage in actual operation. Based on this, this paper adopts a dual fuzzy control algorithm to optimise the hybrid energy storage SOC and correct the allocated hybrid energy storage charging and discharging power to maintain the SOC of supercapacitor and lithium battery within a reasonable range, so as to achieve the hybrid energy storage output power control. The control strategy is shown in the Fig.1 shown.

B. Fuzzy Controller 1

Supercapacitor state-of-charge change ΔSOCb at time t and the state of charge SOCb(t – 1) of the supercapacitor at time t-1 are used as the input of the fuzzy control, and the output is the power adjustment coefficient k1 of the supercapacitor. The corrected charge-discharge power of the supercapacitor and lithium battery is:

\[
P_b(t) = k1 \times P_b(t)
\]

(5)

C. Fuzzy Controller 2

ΔSOCc and SOCc(t – 1) are used as the input of the fuzzy control, and the output is the power adjustment coefficient k2 of the battery. The corrected lithium battery charging and discharging power and grid-connected power are:

\[
P_{grid}(t) = P_{grid}(t) + (1 - k2) \times P_b(t)
\]

(6)

5. Simulation Analysis

The simulation example in this paper uses the 24-hour actual output power data of a 70 MW wind farm, and the sampling time is 30 s. The grid-connected power, supercapacitor and lithium battery power obtained by decomposing the wind power raw power signal into wavelet packets are shown in Figure 2.

As can be seen from Fig. 3, it can be seen that the fluctuation rate of grid-connected power after the introduction of hybrid energy storage wavelet packet-double fuzzy control smoothing is significantly lower than the fluctuation rate of grid-connected power of the original wind power output power on the time scale of 1min and 10 min, which makes the grid-connected power of wind power smoother.

6. Conclusion

In this paper, a method based on wavelet packet-dual fuzzy control for hybrid energy storage to smooth wind power fluctuations is proposed. Combining the advantages of hybrid energy storage, the original output power of wind power is firstly decomposed by wavelet packet decomposition method to obtain the grid-connected power and the power allocated by hybrid energy storage; then the double fuzzy control algorithm is used to optimise the state of charge of supercapacitor and lithium battery, and the power allocated by hybrid energy storage is secondly modified to keep the state of charge of hybrid energy storage within a reasonable range. It not only achieves the smoothing of wind power fluctuations, but also improves the safety and reliability of the operation of energy storage devices, providing a theoretical reference for the application of hybrid energy storage to smooth wind power fluctuations. wind power fluctuations.