Paper-343-22

20th International Conference on Renewable Energies and Power Quality (ICREPQ'22)
Vigo (Spain), 27th to 29th July 2022
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.20, September 2022

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

Lv. Huixiang, Chen. Caixue and Xiong. Zhigang

Department of Automation and Electronic Information, Xiangtan University,Xiangtan, China,
Phone/Fax number: +0086 17673911062, e-mail: mia05010104@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-double 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:

$$\begin{Bmatrix} P(t) = P_{grid}(t) + P_b(t) + P_c(t) \\ P_{grid}(t) = P_0(T) \\ P_b(t) = P_1(t) + P_2(t) + P_3(t) \\ P_c(t) = P_4(t) + P_5(t) + \cdots + P_{63}(t) \end{Bmatrix} \quad (1)$$

3. Energy Storage Model

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

$$\begin{Bmatrix} E_c(t) = E_c(t-1) + \int_0^T P_c(t)\,dt \\ E_b(t) = E_b(t-1) + \int_0^T P_b(t)\,dt \end{Bmatrix} \quad (2)$$

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

$$\begin{Bmatrix} SOC_c(t) = SOC_{c0} + \dfrac{E_c(t)}{E_{mc}} \\ SOC_b(t) = SOC_{b0} + \dfrac{E_b(t)}{E_{mb}} \end{Bmatrix} \quad (3)$$

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:

$$\begin{Bmatrix} E_{mc} = \dfrac{2 * max\{\max(E_c), -\min(E_c)\}}{\eta_{c*}(SOC_{cmax} - SOC_{cmin})} \\ E_{mb} = \dfrac{2 * max\{\max(E_b), -\min(E_b)\}}{\eta_{b*}(SOC_{bmax} - SOC_{bmin})} \end{Bmatrix} \quad (4)$$

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 double fuzzy control algorithm to optimise the hybrid energy storage SOC and e-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 effect of optimising the hybrid energy storage output. The control strategy is shown in the Fig.1 shown.

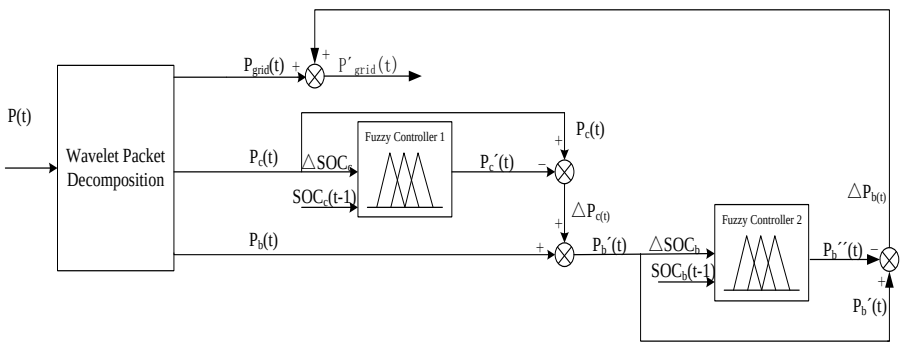


Fig. 1 Control strategy

B. Fuzzy Controller 1

Supercapacitor state-of-charge change ΔSOC_c at time t and the state of charge $SOC_c(t-1)$ 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:

$$\begin{matrix} P_c'(t) = k1 * P_c(t) \\ P_b'(t) = P_b(t) + (1-k1) * P_c(t) \end{matrix} \quad (5)$$

C. Fuzzy Controller 2

ΔSOC_b snd $SOC_b(t-1)$ 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:

$$\begin{Bmatrix} P_b''(t) = k2 * P_b'(t) \\ P_{grid}'(t) = P_{grid}(t) + (1-k2) * P_b'(t) \end{Bmatrix} \quad (6)$$

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.

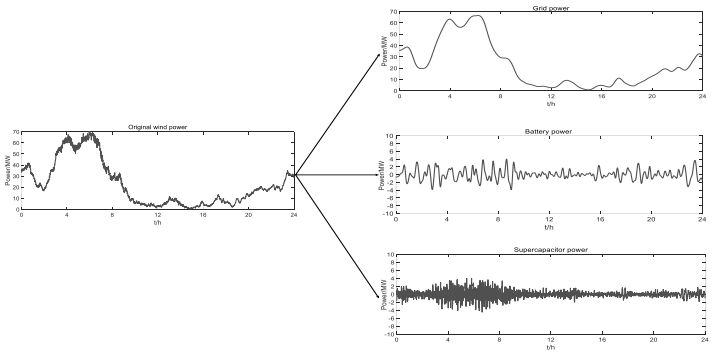
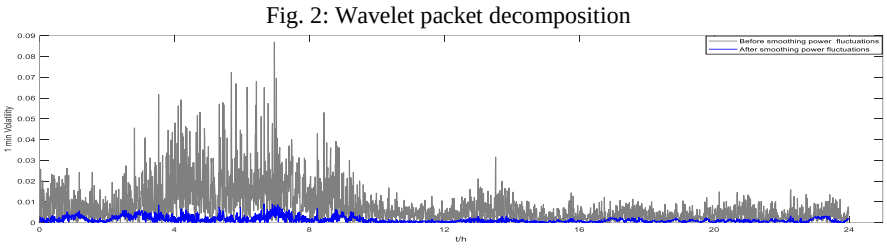
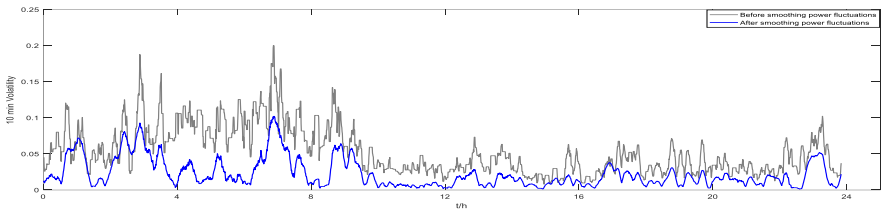


Fig. 2: Wavelet packet decomposition



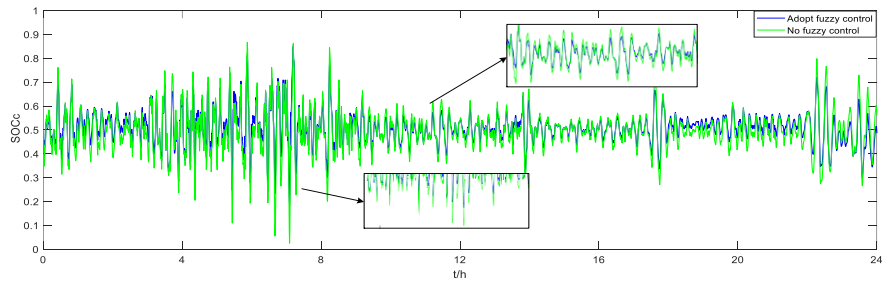
(a).1 min volatility



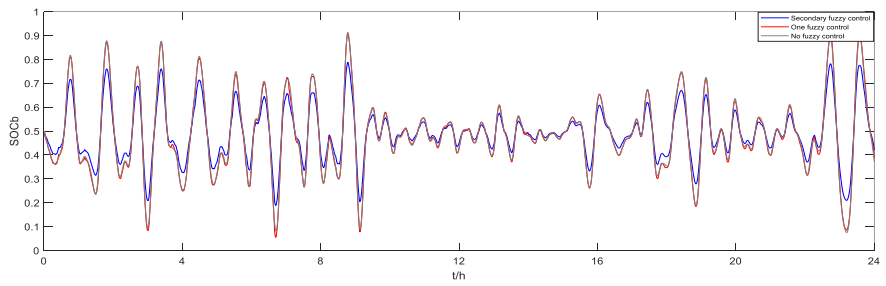
(b) .10 min volatility

Fig. 3. Comparison of 1 min and 10 min fluctuations before and after wind power leveling

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.



(a). Supercapacitor



(b).Lithium battery

Fig. 4. Comparison of SOC variation trend of hybrid energy storage before and after fuzzy control

As can be seen in Fig.4, When Li-ion battery SOC_b and supercapacitor SOC_c are optimised using the fuzzy control algorithm, the trend is within a reasonable range and stays between 0.2 and 0.8 most of the time, keeping the Li-ion battery and supercapacitor.

6. Conclusion

In this paper, a method based on wavelet packet-double fuzzy control for hybrid energy storage to smooth out 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 optimize 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.