The Influence of the Solar Flywheel Energy Storage Control System Based on the Improved Disturbance Observation Method on the Improvement of New Energy Efficiency

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Abstract. The purpose of this study was to improve the utilization efficiency of solar energy, and accelerate the innovation and development of solar flywheel energy storage control system, so as to enhance the utilization value of new energy. Firstly, the definition and working method of flywheel energy storage control system were described, and the characteristics of flywheel energy storage control system were introduced in detail. Secondly, the concept and working principle of solar flywheel energy storage control system were introduced, and the principle and calculation method of perturbation and observation method (P&O) were described in detail. Finally, the improved P&O based on particle swarm optimization (PSO) algorithm was described in detail, and its principle and operation methods were explained. The research results show that the biggest characteristic of flywheel energy storage device is that it has no pollution to the environment, the energy stored per unit area is large, and the efficiency of converting it into electric energy is very high, which can be used for a long time. The working property of solar energy storage system is the introduction, maintenance, and output of electric energy. In order to obtain the best tracking data, the flywheel energy storage control system must control the disturbance amplitude and time accurately and make a comprehensive choice. The P&O improved by PSO algorithm is applied to the flywheel energy storage control system, and the experience time to reach the maximum efficiency position is relatively shortened. When the system's derived power reaches the balance, the variation of wave shape in the improved dynamic observation method is also relatively reduced.

Keywords: Solar flywheel energy storage control system; particle swarm optimization algorithm; disturbance observation method; new energy

1. Introduction
With the development of science and technology, the demand for energy is increasing in China and foreign countries in the new era. However, the traditional non-renewable and combustible energy will pollute the living environment to a great extent and in a large range [1], which is contrary to the sustainable development advocated by the human world. Therefore, the research on extraction technology of new energy in China and many other countries is imperative.
At present, the world's recognized fields of secondary energy include water, wind, sun, biology, and land thermal energy [2]. From the research data of scientists, it can be seen that the trend of using new energy to replace renewable energy is becoming more and more obvious in China, and the trend of using solar energy to generate electricity is growing fastest. It suggests that China has paid great attention to the use of solar energy, and also as the core goal of energy research in China in the future. Photovoltaic power generation in solar power generation has been widely used all over the world, but the electric energy output by using solar energy is greatly affected by the surrounding environment, resulting in great fluctuation of its output power. Thus, a new type of energy storage device is needed to store the electric energy generated by using solar energy into the system. The flywheel energy storage device will appear as a new energy and pollution-free model [3].

The principle and working method of flywheel energy storage device are mainly described, and the calculation method of maximum utilization rate in maximum power point tracking algorithm, namely disturbance observation method (P&O), is analyzed. Furthermore, the content and calculation principle of the improved P&O based on particle swarm optimization (PSO) algorithm are introduced in detail. It improves the energy storage efficiency of the solar flywheel energy storage control system, and provides a concrete and effective practical basis for enhancing the utilization efficiency of new energy.

2. Principle and working method of flywheel energy storage device

2.1. Principle of flywheel energy storage device
Flywheel energy storage device is a newly-developed machine energy storage system. Its greatest characteristic is that it has no pollution to the environment, the energy stored in unit area is large, and the efficiency of converting it into electric energy is very high, so it can be used for a long time. The performance of flywheel energy storage device is mainly the filling of electric quantity, the output of electric quantity, and the maintenance of working mode [4]. If the device is in the state of electric charge filling, the motor will be in the state of power, which can only provide power to the flywheel. At this time, the components in the flywheel will run at high speed. Therefore, the electrical energy in the photovoltaic cell can be converted into the mechanical energy in the flywheel component. If the flywheel energy storage device is in the state of electricity output, the motor will change into electricity output state. At this time, the operation efficiency of the flywheel component will reach the highest, and the motor will start to rotate. At the same time, it will change into braking mode. The mechanical energy in the flywheel will change into electricity output. If the flywheel rotation reaches the corresponding area, the entire wind turbine energy storage device will maintain the current work pattern. The schematic diagram of flywheel energy storage device is shown in Figure 1.

![Flywheel energy storage system (FESS)](image-url)
In the modern flywheel energy storage device, the motor is the central component. In reality, the most commonly used motor is the permanent magnet motor [5], but this kind of motor is expensive and hard to start. On this basis, the three-phase asynchronous motor is popular in the flywheel energy storage device because of its easy start and low price.

2.2. Working method of flywheel energy storage device
Flywheel is actually a kind of rotatable machine driven by an immutable central shaft, and the capacity of flywheel energy storage device determines the rotation speed of flywheel. The energy contained in the flywheel during rapid rotation is as follows:

$$E = \frac{1}{2} R \theta$$  \hspace{1cm} (1)

$E$ is the energy, $R$ is the inertia force when the flywheel is running, and $\theta$ is the speed of the flywheel.

The inertia force of the flywheel depends on its appearance and weight [6].

If there is an unstable external force moment, the speed of the flywheel will increase, which can transform the electric energy into kinetic energy and contain it in the system. But if the speed of the flywheel decreases, the kinetic energy of the flywheel will be converted into electrical energy and released to the outside. It can be seen that the unstable external torque is the essential factor for the change of flywheel running speed. If the relationship between the two is expressed in $N$, then:

$$N = R \frac{X_\theta}{X_T}$$  \hspace{1cm} (2)

In equation (2), the numerator represents the moment of inertia force of the flywheel, and the denominator represents the external moment at that moment.

The energy difference between the flywheel running at the maximum speed and the flywheel running at the minimum speed can be expressed as follows:

$$\Delta N = \frac{1}{2} R \left( \theta^2_{\text{max}} - \theta^2_{\text{min}} \right)$$  \hspace{1cm} (3)

If $\Delta N > 0$, the flywheel's running speed will increase, and the energy storage system can convert the electric energy into kinetic energy to complete the energy input work.

If $\Delta N < 0$, the flywheel's running speed will be reduced, and the energy storage system can convert kinetic energy into electrical energy to complete the electrical energy output.

According to the above analysis, if the rotating speed of the flywheel increases, the flywheel energy storage system can input the electric quantity. The driving part of flywheel is motor. The flywheel can maintain high-speed rotation only when the rotating torque of the motor is greater than the friction force of the device, which fully shows the central role of the motor in the flywheel energy storage device.

2.3. Solar FESS
First of all, the intensity of sunlight in a day varies with time. In the case of strong sunlight, a lot of solar energy will cause waste, and the FESS can store the excess solar energy. The structure diagram of solar FESS is as follows:
Figure 2. Structure of solar FESS

The solar cell device in the above structure will input and export energy when there is sunlight. In the day alternation, in the day time period, because the sun's light intensity is different in different time periods, the energy derived from the battery equipment is also different because of the change of time. When there is no sun's light at night, the electricity will not be synthesized. When the light intensity of the sun is the largest in the daytime, especially at noon, the electric energy output of the battery equipment is higher than the applied energy of the equipment. At this time, the remaining electric energy can be transformed from a special converter, so that the engine can drive the flywheel to run quickly and convert the excess electric energy into kinetic energy. If the light intensity of the sun is relatively weak, or if there is no sun at night, the electric energy output of the battery equipment is lower than the applied energy of the equipment. The required electric energy can be output by the FESS, and then the kinetic energy can be converted into electric energy for use by the equipment through a special converter. Then, the import, storage, and export of electric energy are formed.

Secondly, the working process of solar energy storage system includes electric energy import, maintenance, and electric energy output [7]. Electric energy import refers to that when the energy required by the external equipment is less than that of the solar cell equipment, the excess electric energy output by the battery equipment can be saved by the FESS. At this time, the whole system works in the environment of electric energy introduction. The FESS can make use of the electric energy output by the solar cell equipment, so that the engine works, and then the operation speed of the flywheel is greatly improved. The electric energy is quickly converted into kinetic energy and stored in the flywheel. Maintenance refers to that if the energy required by the external equipment is the same as that of the solar cell equipment, the system is in the maintenance atmosphere without the introduction of electric energy or the output of electric energy. There is no forward movement of energy and no reverse movement of energy. At this time, the internal work of the system consumes little and the energy has not changed. Moreover, the atmosphere can work with a smaller voltage, and the flywheel can store the energy continuously. Electric energy output refers to that when the energy required by the external equipment is larger than that of the solar cell equipment, the kinetic energy stored in the flywheel will be converted into kinetic energy through the converter for use by the external equipment, and the system will output the electric energy. The flow of energy is opposite to that of the electric energy import stage,
which is from the flywheel to the external equipment. And the engine needs to use the power to transfer the electric energy to the external equipment and convert kinetic energy into electrical energy.

3. Application of improved P&O based on PSO algorithm in solar flywheel energy storage device

3.1. P&O
P&O [8] is that the converter interferes with and fluctuates the FESS, i.e. changes the tail voltage of the photovoltaic source, so as to change the acting part of the photovoltaic. After the disturbance, the specific calculation method will compare the power changes of the photovoltaic leading part before and after the disturbance for comparative analysis. If the leading power after the disturbance is larger than that before the disturbance, it means that the direction of system operation is toward the highest part of power, and the later power interference will move towards the former direction. If the derived power after the disturbance is smaller than that before the disturbance, it means that the operation direction of the system is away from the highest part of the power, and the power interference in the later period will also be away from the previous direction.

With the updating of scientific research methods, P&O has been improved continuously, although the basic application criteria of this method have not changed. There are two types of P&O: one is basic, and the other is innovative. The basic P&O includes voltage disturbance and space proportion disturbance. The disadvantage of this method is that when the system is running, it needs to detect the battery equipment from the beginning to see whether it has reached the maximum working efficiency, and know the end of the system operation. On this basis, the detected information is disturbed by voltage. After the voltage interference is added, the voltage in the actual operation of the system will fluctuate in an indefinite range, which will result in a waste of the working efficiency of the system. The function of the whole FESS is determined by the magnitude of interference and the time of control. These two factors work interactively, but they cannot guarantee the speed and accuracy of detection at the same time. If the interference amplitude is too large, the energy storage system can find the maximum working efficiency position in less time, and can respond to external changes quickly, but there will be great efficiency fluctuation in the maximum working efficiency position. On the contrary, if the interference amplitude is too small, it can prevent the efficiency fluctuation of the maximum work efficiency part, but the time period of finding the maximum work efficiency part will be very long, and the whole system cannot respond to the changes of the outside world quickly. Therefore, to obtain the best tracking data, it is supposed to control the disturbance amplitude and time accurately and make a comprehensive selection.

3.2. PSO algorithm
In view of the comprehensive selection requirements of disturbance amplitude and control time, the P&O is optimized, that is, the PSO algorithm [9] is added to the space proportional disturbance method. The creation prototype of PSO algorithm is based on the mass life process of birds. It uses the objective function of particles to calculate. The special feature of the algorithm is that it regards other things as particles without mass and size in several dimensions [10]. At the same time, particles use their own specific speed to carry out activities, and the activity rate of particles will be compared with the particle's passing activity experience, and move to the best position in the past and the best part in the dimension. This algorithm uses less factors, so it is easy to code. Supposing that in the calculation space of N dimension, the constituent particles of each group are W, and the m-th particle in this range can be represented by the vector of N dimension, as shown in the following equation:

\[ X_m = (x_{m1}, x_{m2}, \ldots, x_{mN}), m = 1, 2, \ldots, W \]  

The activity rate of the m-th particle can be represented by n-dimension vector:

\[ V_m = (v_{m1}, v_{m2}, \ldots, v_{mN}), m = 1, 2, \ldots, W \]
The best location of the m-th particle in the dimension during this period can be represented by the following equation:

\[ L_{\text{best}} = (L_{m1}, L_{m2}, \cdots, L_{mN}), M = 1, 2, \cdots, W \] (6)

The best location that all particles in the dimension can find in the dimension during this period can be represented by the following equation:

\[ A_{\text{best}} = (A_1, A_2, \cdots, A_N) \] (7)

Next, particles in the dimension can change their own speed and location by using a specific calculation method. In PSO algorithm, the above specific calculation method is actually to guide particles' characteristics, cognitive materials, and external information. If the characteristics of particles have a good trend with cognitive materials, the PSO algorithm will reach the best environment. Therefore, the best answer of the whole region cannot be shortened.

3.3. Simulation application of PSO algorithm

In this paper, Matlab matrix algorithm is used to simulate the FESS. The coefficient of photovoltaic (PV) cell equipment used in this paper is as follows:

| Coefficient representation     | Representative value |
|--------------------------------|----------------------|
| Operating voltage U_{AB}      | 8.95V                |
| Fault current I_{f0}          | 8.99A                |
| Maximum power voltage U_{mpp} | 6.80V                |
| Maximum power current I_{mpp} | 6.99A                |

At the beginning, the PSO algorithm is: the total number of particles is 19, the maximum value of replacement stack is 99, the search area of particles is (1,99), the learning parameters are 0.79 and 1.19, the maximum weight parameter is 0.89 and the minimum value is 0.39, and the disturbance value of power is 0.49W. In the simulation model, the battery equipment is powered by a special converter to the external equipment, and the special wave of the transistor changes to complete the configuration with the external equipment, so as to achieve the maximum power derived from the energy. The simulation time of the system is 14 seconds. The comparison between the common P&O and the improved P&O based on the PSO algorithm is as follows:

![Figure 3. General P&O pattern](image-url)
Comparing Figure 3 and Figure 4, it is seen that, with the change of light intensity, the wave shape of common P&O changes much more than that of P&O based on PSO, and the time of reaching the maximum efficiency position of the FESS after improvement is much shorter than that after improvement. When the derived power of the system reaches the balance, the variation of the waveform in the P&O after improvement is relatively small, which is basically 1.8W and in line with the simulation value, i.e. the power difference is 0.49 W.

4. Conclusion
The principle and working method of the solar energy flywheel energy storage device are mainly introduced, and the P&O method which changes the working efficiency of the system in the FESS is expounded. Then, the basic P&O is improved by using the PSO calculation method, so that the experience time for the FESS can reach the maximum efficiency position, which is much shorter than before. After the balance of the derived power is achieved, the waveform changes in the improved P&O are also reduced, so that the system can obtain the best tracking data, which provides a practical basis for improving the utilization rate of new energy.

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