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# Flywheel Energy Storage System in the Grid with the Renewable Energy Sources

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**ABSTRACT**: Recently, the need to exploit and use renewable energy sources to replace fossil energy sources which are running out and polluting the environment has become an urgent issue for many countries in the world. However, wind and solar power always fluctuate due to weather and environmental conditions, so when they merge into the local grid (microgrid), it is easy to destabilize the grid, sometimes causing errors grid, or grid collapse. This article presents the structure of the Flywheel Energy Storage System (FESS) and proposes a plan to use them in the grid system as an energy "regulating" element. The analytical results show the role of FESS and the principle of controlling their operations in the microgrid.

**KEYWORDS:**FESS, Flywheel Energy storage system, Micro mesh, Renewable energy, Wind power

## I. INTRODUCTION

Renewable energy is a clean and endless energy source that nature bestows upon people. Renewable energy sources include solar energy, wind energy, biomass energy, ocean wave energy, geothermal energy, etc., among which the most popular is solar energy and wind energy. Since ancient times people have taken advantage of these energy sources to serve themselves from windmills, water pumps, rice pounders with waterpower, solar cookers, solar water heaters, etc. So far, there are many wind farms, solar power fields, solar power plants, buildings using wind and solar power. Renewable energy with outstanding advantages such as infinite reserves, does not cause climate change and does not affect adverse impacts on the environment, is attracting the attention of many countries around the world. Currently, many countries in the world have taken specific steps to gradually replace traditional fossil energy sources with renewable energy sources. The main direction for exploiting and using renewable energy is to turn them into electricity and merge into the national grid or cooperate with each other to form a local grid (microgrid) [1], [3], [4], [5].

The characteristics of electrical energy produced from renewable energy sources are:

- Like electrical energy, electrical energy from renewable energy sources when produced without use is not "savable".
- Renewable energy changes continuously by hour and by day, night, and season, for example solar and wind energy at each time will be different, at night, there is no solar energy, in winter, solar energy is significantly reduced, resulting in the amount of electricity they produce, which also changes intermittently beyond human control. This second feature affects the quality of the grid and the continuity of power supply. Especially for micro-grid, the abnormal fluctuation of electricity from renewable energy can lead to grid failure or grid collapse.

The problem is that elements such as storage and regulation warehouses need to be ensured to ensure continuity of renewable energy. To do this, people are now using common batteries, they have the disadvantage that their capacity is not large (to have a large capacity, it is very cumbersome), short life span, expensive maintenance costs.

A proposed and developed option over the last twenty years is to use flywheels to store and regulate electrical energy. This is an interesting solution and has many development prospects that have attracted the attention of many scientists in the world. However, to use flywheels to store and regulate energy, two major technical problems need to be addressed: first, the problem of friction loss, and second issue is the energy transformation mechanism of the flywheel into electrical power.

In this paper, we are interested in researching the second issue and proposing a power electronic converter in combination with flywheel to regulate the continuous operation of wind and solar power systems. grid connection.

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The next part of the paper presents the structure of flywheel system to store renewable electrical energy, power electronic circuit calculation, modeling results and system simulation.

## II. FUNCTION DIAGRAM

Renewable energy is a clean and endless energy source that nature bestows upon people.The block diagram of the grid using renewable energy with the participation of the energy storage element, is shown in Figure 1, including the following blocks:

- Energy generating units are renewable energy sources such as photovoltaic batteries, wind turbines, etc.
- Energy transceiver / receiver is responsible for charging and storing energy when there is an excess and discharge of energy when there are abnormal fluctuations of the grid. For this purpose, batteries, batteries, supercapacitors, or flywheels can be used
- Block of grid and load
- Power electronic block is a versatile, flexible grid connection. For this energy source, it is the task of converting the renewable energy into electricity with the right voltage, frequency, and phase angle to connect to the grid. For power electron storage element, it is possible to work in two directions, when the grid works stably, the energy from the grid is brought to storage in the storage element, when there is a sudden change in electricity, energy from storage element will be returned to overcome fluctuations and stabilize the grid. The problem of fixing grid errors and grid stability is not mentioned in this article.
- Control unit has the function of operating the whole system such as power source control, power electronics converter, grid connection control, charging / discharging process of storage system energy.

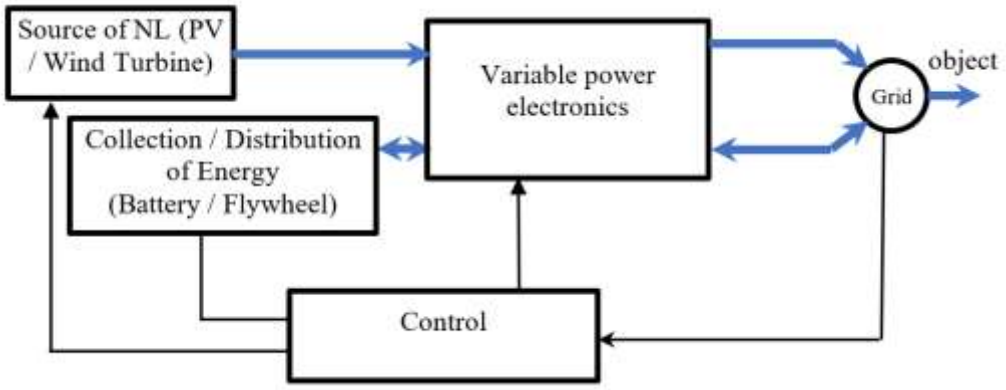


**Figure 1.**Diagram of grid connected renewable energy system with energy storage elemen

## III. FLYWHEEL ENERGY STORAGE SYSTEM

Flywheel energy storage system (FESS) is an efficient energy saving, storage, and regulation technology. In the FESS system, energy is stored in the flywheel in the form of kinetic energy of the rotating and emitted blocks as required by the system [6], [8]. The structure of the energy storage flywheel is shown in Figure 2.

Energy storage flywheels are often designed to operate at high speeds to achieve the highest energy storage density. The first-generation flywheels are made of steel with mechanical bearings, so the speed is not high (only about 6000 rpm). Thanks to the improvements of materials and AMB: active magnetic bearing, it has made important advances in energy flywheel technology, the current flywheel speed has reached up to 60,000 revolution per minute (10 times larger than the first-generation flywheel). In the FESS system, not only the rotors rotate at high speed but also the position of the rotor must be precisely controlled in the middle and not in contact with the stator, so the rotor's vibration is as small as possible. Magnetic bearing is a device that supports high-speed use with features such as frictionless operation, grease-free lubrication, no noise, no environmental pollution, longevity .... Figure 2 shows the structure of the energy storage flywheel.

The energy stored in flywheel in kinetic form is calculated according to the formula [9], [10]:

$$W = \frac{1}{2} J\omega^2 \text{ (Jul)} \qquad (1)$$

Where W is the energy stored in the flywheel in the kinetic form (Jul), J is the inertial moment (kgm2) J = kMR2 with M being the mass (kg), R radius (m),

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k: constant inertia depends on the shape and physical structure of the flywheel.

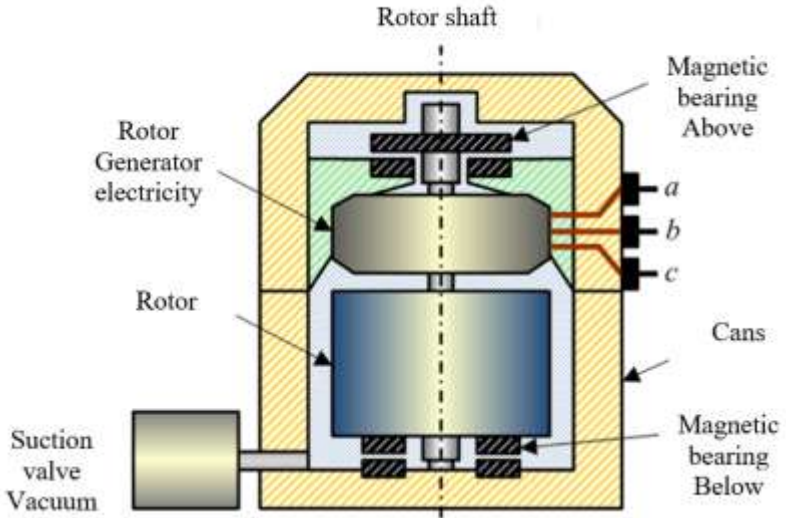


**Figure** 2. Structure of energy storage flywheel

In flywheels, the integrated rotor of an electric machine can work in transmitter mode or engine mode to convert energy from mechanical to electrical and vice versa. There are many types of generators used for flywheel systems, such as permanent magnet generators, induction machines, etc.

The operation of the flywheel can be summarized as follows: when there is an excess of energy, the flywheel performs energy storage, it works as an electric motor, different from the conventional electric motor, the motor used in flywheels has a very large moment of inertia and a very high rotation speed. On the other hand, when there is an abnormal oscillation at the source or load, the flywheel acts as a generator that provides the additional energy needed to stabilize the system. During the discharge process the speed of the flywheel decreases gradually, leading to the frequency of voltage constantly changing. To maintain the voltage frequency generated by the flywheel generator, it is necessary to use a power electronic converter in the rectifier mode so that the power frequency of the frequency changes to DC and one power electronic converter works in inverter mode to convert DC electric energy into sinusoidal AC voltage connected to the grid.

## IV. ELECTRIC STRUCTURE OF FESS

In flywheel solar and wind power systems, it acts as a battery to store excess energy and as a backup generator to supply energy when there is an abnormal change in the grid. To do this, the main electrical components of a flywheel energy storage system are a power electronic module and a control module to control the operation of a power electronic module in the charging, discharging mode or preventive.

The most common configuration of the energy storage flywheel system is shown in Figure 3 and Figure 4. In Figure 3, converters 1 and 2 are 2-way converters. In discharge mode, converter 1 works as a rectifier, converter 2 works as an inverter. In transducer mode, converter 1 works in inverter mode and converter 2 in rectifier mode. Figure 4 has the working principle as shown in Figure 3 but using multi-step flywheels, they are connected via DC bus. The multi-step flywheel system can provide higher power reserve capacity than a flywheel system.

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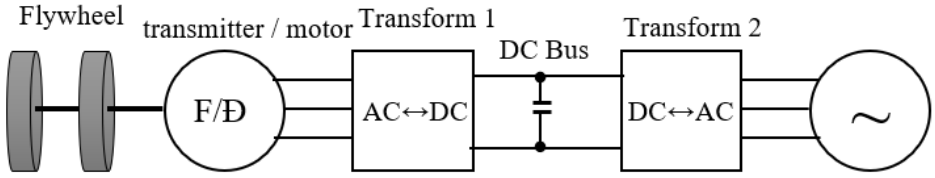


**Figure 3.**Structure of a 1-level grid connected energy storage flywheel

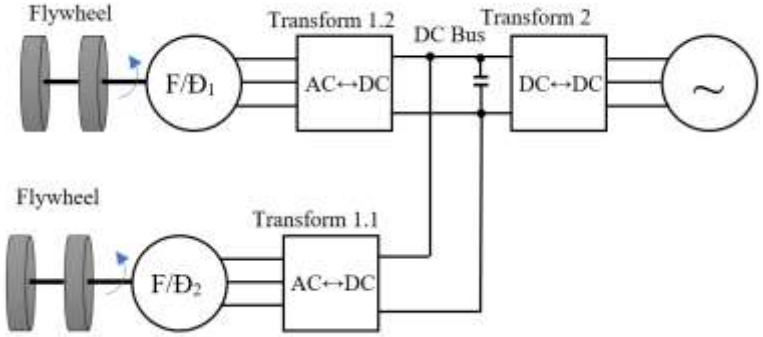


**Figure 4.** Structure of 2-level grid connected flywheel system

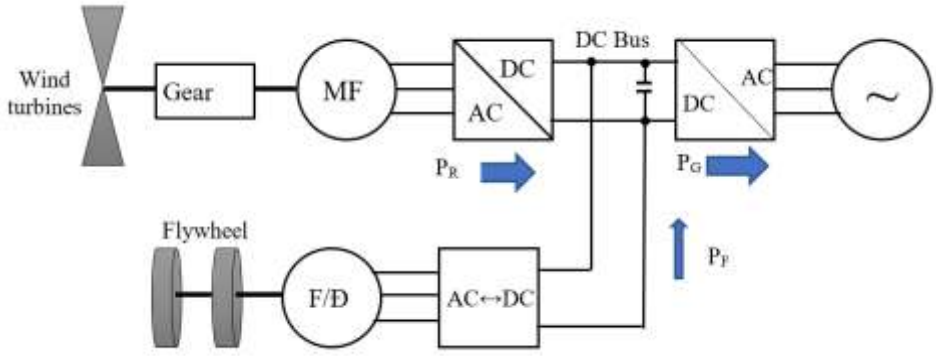


**Figure 5.**Grid-connected wind power system with energy storage flywheel

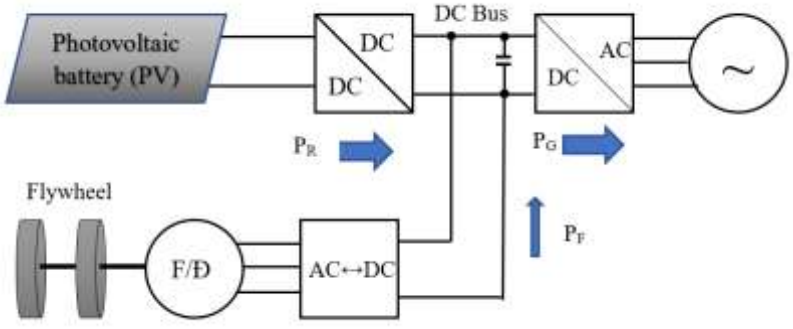


**Figure 6.**Grid-connected solar power system integrated with energy storage flywheel

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The flywheel system can be combined with other primary sources such as wind power, solar power, etc., to form a hybrid system. There are many hybrid systems depending on the primary energy source and the FESS system integrated into the system. Figure 5 shows a grid-connected wind power system with integrated energy storage flywheel system. The flywheel system's power is integrated into the DC bus of the wind power system using a two-way DC-AC converter.
Figure 6 shows the structure of the grid connected solar power system integrated with flywheel system

In order to analyze the activity and illustrate the effect of energy storage flywheel for the hybrid system as shown in Figure 5 and Figure 6, we assume that $P_R$ is the capacity from renewable energy source (wind power, solar power) supplied to the grid, this capacity often changes constantly according to environmental conditions [1], [2], [7]; $P_F$ is the system capacity of flywheel system; $P_G$ is the pump power to the grid, so that the grid is stable, this capacity needs to be fixed ( $P_G = \text{const}$ )

We have: $$P_F = P_G - P_R \quad (2)$$

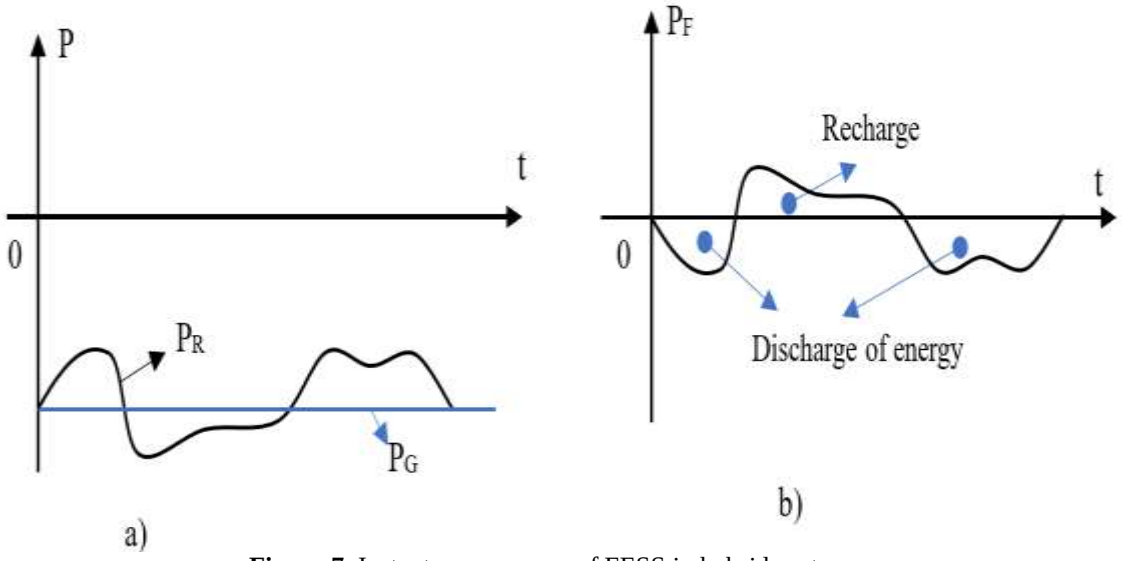


**Figure 7.** Instant power curve of FESS in hybrid system

The power type curve is shown in Figure 7. From the expression (2) and Figure 7 we see that the power of the FESS varies according to the fluctuation of the power of the renewable energy source. FESS will perform energy charging when $P_F > 0$ and discharge energy to replenish the system energy when $P_F < 0$. The $P_F$ curve is used to control the operation of FESS (this issue describes in detail in the following article).

## V. CONCLUSION

Flywheel Energy Storage System is an energy storage system with many outstanding advantages compared to traditional energy storage elements (batteries, batteries, microcapacitors). They have a very long life, storage capacity can be very large, no maintenance during operation. However, FESS system has some disadvantages: high cost, short discharge time. The above analysis shows the structure and role of the FESS system in the participating grid of renewable energy sources. This article just stops at describing the structure and principles of controlling the FESS system in hybrid systems. In subsequent publications we will describe in detail the FESS control strategies to ensure stable work of the grid.

## ACKNOWLEDGMENTS

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