Research on compressed air energy storage technology based on photovoltaic power generation system

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Abstract: At the present time of rapid development of social economy, the upsurge of “energy revolution” has come. Clean, low-carbon, safe and efficient modern energy system is undoubtedly the current research hotspot. Micro-grid with photovoltaic power supply has become an important way for renewable energy utilization. However, there are still some problems in the operation of micro-grid with photovoltaic power supply in terms of power supply reliability and power quality. By adopting energy storage control technology to control the operation of the micro-grid with photovoltaic power supply, the reliability of the micro-grid operation can be effectively improved, so that the renewable energy utilization form can be effectively applied.

1. Introduction

Electric energy is an indispensable application energy in today’s society. Its influence range is very wide. At the same time of technology development, the field of electric energy production has also made innovative adjustments to its process projects. Only by fundamentally optimizing the structure of electric energy production can we meet increasingly. The increased demand for electrical energy, and the power industry has gradually developed into a basic industry for the operation of the national economy. In the past, the grid operation system has certain defects, which has a lag effect on the supply of electric energy to a certain extent. The emergence and application of energy storage technology can effectively improve the flexibility of power production and provide economic construction. It is of great significance to promote the application and development of energy storage technology.

2. The role and mode of energy storage technology in the power system

2.1. The role of energy storage technology in the power system

Energy storage technology can help increase the penetration rate of renewable energy, promote the development of distributed generation; improve the stability of power systems and achieve adequate peak shaving, reduce peak load and corresponding power system investment and power investment; Promote the liberalization of the electricity market.

2.2. Pumped energy storage technology

The pumped storage power station is constructed according to the relevant capacity. Under normal circumstances, the stored energy can be released for a few hours, several days, and the efficiency can be maintained at about 75%. This approach is commonly used in the areas of energy management and...
frequency control. One of the biggest characteristics of pumped energy storage is that the stored energy is very large, and because of this feature, it is very compatible with the development of the power system.

2.3. Battery energy storage technology
The NaS battery used for energy storage can output pulse power, and because of the high power, the power output is usually six times the rated power, but the whole work usually does not exceed 30s. This feature allows us to better adjust and improve the electrical energy, and effectively improve and develop the overall equipment economy.

2.4. Super capacitor energy storage technology
In general, super capacitors have more permittivity, pressure resistance and larger surface area than conventional capacitors. For example, the insulation ability of ceramic super capacitor is relatively strong, and the withstand voltage level of ceramic super capacitor is relatively high, so this technology also provides a good foundation for the application and development of energy storage in the future.

2.5. Compressed air energy storage
Compressed air storage energy is often used for peaking gas turbine power plants. For the same power output, CAES units consume 40 less gas than conventional gas turbines. This is because conventional gas turbines need to consume about two-thirds of the input fuel for air compression when generating electricity, while CAES can pre-compress air using cheap electricity at the bottom of the grid load, and then release stored energy as needed. Add some gas to generate electricity.

3. Brief introduction and development of compressed air energy
Compressed air energy storage is the use of high-pressure air for power storage. The basic compressed air energy storage system shall include compressor, air storage room, generator and expander, etc. It takes the air storage room as the energy pool, and the compressor, expander and generator as the equipment for energy conversion. In the process of energy storage, electric compressor (or directly driven by mechanical energy) is used to compress air and store it in the gas storage chamber; in the process of energy release, the work is done by the expansion of released high-pressure air, which drives the generator to output electric power. In this system, the maximum storage capacity is determined by the maximum storage capacity of the gas chamber and the circulating pressure difference, and the response time is also related to the start-up characteristics of the power equipment. As a large-scale energy storage technology, compressed air energy storage has unique system advantages. Its use of air as energy storage medium determines that it is extremely insensitive to climate and temperature, and has stronger geographical adaptability, even in areas with poor conditions, it still has great potential.

4. Operating principle of CAES
CAES is a kind of energy storage method that compresses the air by using low valley power, wind power, photo electricity and so on, and seals the high-pressure air in the underground salt cavern, underground mine hole, expired oil and gas well or new gas storage room, and releases the compressed air to promote the turbine power generation during the peak load period of power grid. According to the operation principle, it can be divided into two types: supplementary combustion type and non supplementary combustion type. In order to realize the cycle operation of the system, the supplementary combustion of fuel is needed for the supplementary combustion of CAES. During energy storage, the motor drives the compressor to compress the air to a high pressure and store it in the gas storage chamber; during energy release, the high pressure air in the gas storage chamber enters the gas turbine and burns with the fuel in the combustion chamber to drive the gas turbine to do work, so as to drive the generator to output electric energy. Due to the use of fuel for supplementary combustion, there is a problem of pollution emission, and there is a dependence on natural gas and...
other fuels, which to some extent limits its application. Based on the development of conventional supplementary combustion CAES, non supplementary combustion CAES collects and stores the compressed heat generated in the compression process during energy storage by adopting regenerative technology, and heats the high-pressure air entering the turbine when the system releases energy. Non supplementary combustion CAES can not only eliminate the dependence on fuel and achieve zero emission of harmful gases, but also use the compressed heat and low-temperature exhaust of the turbine for external supply. Heating and cooling, and then realize the combined cooling, heat and power supply, realize the comprehensive utilization of energy, and improve the system efficiency.

![Compressed air energy storage schematic diagram of photovoltaic power generation system](image)

In the compression process, the compressor absorbs the electric energy of the power grid, converts the outside air into high temperature and pressure air, and then stores part of the compressed energy in the heat storage system in the form of heat energy (such as high temperature hot water), while the other part mainly stores the energy in the gas storage tank in the form of molecular potential energy (high pressure air). The process of energy conversion is very complex, but when the parameters of the system are given, the relationship between the electric energy absorbed by the system from the grid and the technical functions of the outside world to the compressed air can be constructed. To this end, this section first gives the definition of compression efficiency as follows:

**Compression link efficiency:** in the process of compression and energy storage, the ratio between the technical function amount of compressed air by the outside world and the electric energy provided by the grid to the system, expressed in $\eta_c$. The efficiency of the compression link is determined by the conversion efficiency of electrical energy to mechanical energy and the adiabatic efficiency of the compressor. In engineering, the conversion efficiency of electric and mechanical energy of compressor can be approximated as a constant, expressed in $\eta_{cm}$. The adiabatic efficiency of compressor can also be regarded as a constant, expressed in $\eta_{ad}$. Therefore, if we know the technical functions of the outside world on the compressed air at all levels of the compressor, we can calculate the electric energy absorbed by the system from the grid.

5. **High speed air turbine expander model**

The working process of high-speed air turbine expander includes three parts: gas suction, expansion and discharge. The simulation model of turbine expansion is shown in the figure below.
6. Simulation model of gas storage device
The simulation model of gas storage device is shown in the figure below.
7. Multi-stage compression process simulation model

![Diagram of a multi-stage compression process simulation model](image)

Fig. 4 Compression process simulation

8. Simulation results analysis

Simulation of compressed air energy storage expansion power generation control system

![Time-output power curve](image)

Fig. 5 Time-output power curve

Figure 5 shows the output power simulation results. When the demand changes, the output power can quickly track the demand set value and meet the load side power command requirements.
Fig. 6 time-speed curve

Fig. 6 is the simulation result of the speed. The blue line is the change of the speed reference value. The value changes at 0.3 S and 0.6 S. This is related to the flow change. The goal is to make the expansion machine operate with the highest efficiency. The real line is the actual speed value. It can be seen that the system speed coincides with the speed reference value, and when the grid demand changes, the system speed can quickly and accurately track the speed reference value change within 0.1 S, and can achieve the highest efficiency point tracking of the expansion power generation system. Make the system work best.

9. Conclusion
As one of the most promising large-scale power storage technologies, compressed air has a very broad development prospect. It is considered to be the most promising large-scale energy storage technology because of its advantages such as large storage capacity, long storage period and little influence by geographical conditions. However, compressed air energy storage still faces many problems. For example, how to effectively improve the efficiency of energy storage system, capacity efficiency, environmental protection efficiency and energy conversion efficiency and so on. Therefore, it is of great significance to study the mathematical model of compressed air energy storage system to provide guidance on the control level for the industrialization of compressed air energy storage technology. At present, as a new energy storage technology, compressed air energy storage has significant comparative advantages and market prospects. And its key subsystem also has a good prospect.

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