ENSURING ENERGY SECURITY THROUGH HYDROELECTRIC POWER PLANT WITH PUMP ACCUMULATION

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ABSTRACT: *Energy security is a critical priority for modern power systems, especially as electricity demand grows and renewable energy sources become more widely integrated. Hydroelectric power plants with pumped storage, also known as pumped accumulation plants, provide an effective solution for balancing supply and demand, improving grid stability, and ensuring reliable energy availability. These plants store surplus electricity by pumping water to an upper reservoir during periods of low demand or excess generation, then release it through turbines to produce electricity during peak demand. This technology supports the integration of intermittent renewable sources such as wind and solar power, reduces dependence on fossil fuels, and strengthens national energy resilience. By offering large-scale energy storage, fast response capability, and long operational life, pumped-storage hydropower plays a strategic role in ensuring energy security and sustainable electricity supply.*

Keywords: energy security through hydroelectric power plant, pump accumulation

1. INTRODUCTION

Energy security is a major priority for modern power systems, especially as electricity demand grows and renewable energy sources become more widespread. Hydroelectric power plants with pumped accumulation, also known as pumped-storage hydropower plants, play a key role in ensuring a stable, reliable, and flexible energy supply. These plants store energy by pumping water from a lower reservoir to an upper reservoir when electricity demand is low or when surplus renewable energy is available. When demand increases, the stored water is released back through turbines to generate electricity. This process allows pumped-storage plants to act as large-scale energy storage systems.

By balancing electricity supply and demand, supporting grid stability, and providing backup power during peak consumption or emergencies, pumped-storage hydropower strengthens national energy security. It also supports the integration of intermittent renewable sources such as wind and solar power, reducing dependence on fossil fuels and improving the resilience of the energy system. Therefore, hydroelectric power plants with pumped accumulation represent an important solution for achieving a secure, sustainable, and efficient energy future. [1-3]

2. ESSENTIAL INFORMATIONS

Power plants with pumping accumulation (or hydro power plants with pumping accumulation) operate on the basis of a simple principle of energy storage by using the altitude difference between two water tanks.

The system uses the electricity available during periods of low consumption to pump water from a lower tank into an upper tank.

During periods of high energy demand, the water accumulated in the upper tank is released back into the lower one, passing through turbines that generate electricity.

This cycle allows the regulation of energy production and provides a reserve quickly accessible in the electrical system, according to *figures 1,2 and 3.*

2.1. The operating principle

The operation of a system of hydroelectric storage with pumping accumulation is based on three main cycles:

- *Pumping water into the upper tank:*
  - during the night or other periods of low consumption, the plant uses the surplus electricity from the grid to pump the water from a lower tank (lake, basin) into a upper tank placed at a higher altitude;
  - at this stage, the plant consumes energy to "climb" the water, turning electricity into potential energy of water stored at height.
- *Energy storage:*
  - water stored in the upper tank is a reserve of energy in the form of gravitational potential energy;
  - this reserve can be kept secure and without significant losses for a longer period.

Fig. 1. Hydro power plant with pumping accumulation – the operating principle

- *Electricity production:*
  - ➢ in peak consumption periods, when the demand for electricity is high, the water in the upper tank is released and flows back to the lower tank;
  - ➢ during this descent, water passes through hydraulic turbines, generating electricity as its potential energy is converted into kinetic energy and then into electricity through the rotation of generators connected to turbines. [4-6]

Fig. 2. Hydro power plant with pumping accumulation – top view

Fig. 3. Hydro power plant with pumping accumulation – top view

2.2. The advantages of the hydroelectric storage with pumping accumulation

Advantages:

- *High efficiency:* the yield of such a plant can reach up to 70-85%, which is quite high compared to other storage methods;

- *High storage capacity:* it is one of the few methods that allows storing a large amount of energy for long periods, from hours to days;
- *Grid stabilization:* is extremely useful in providing an energy reserve at times of maximum demand, stabilizing the power grid;
- *Integration of renewable sources:* helps manage the variability of renewable energy production, balancing the grid when there are fluctuations in production due to weather. [7]

2.3. Disadvantages and challenges

Disadvantages:

- *Requires a specific location:* it is only efficient in areas with significant altitude differences and access to water, limiting the potential for implementation;
- *High initial costs:* the construction of such infrastructure involves large investments, both for the construction of tanks and for the necessary equipment;
- *Ecological impact:* it may have a negative impact on local ecosystems by affecting water flows and natural habitats in mountain or river areas.

2.4. Examples and global usage

Hydroelectric storage systems with pumping accumulation are widely used worldwide.

In Europe, for example, countries such as Switzerland and Austria use these systems to optimise their energy production.

Also, in USA and China, they are a key part of energy infrastructure, being integrated with grids that use renewable sources on a large scale.

2.5. The future of the hydroelectric storage with pumping accumulation

As renewable energy sources grow as a percentage in the global energy mix, hydroelectric storage with pumping accumulation is expected to play an increasingly important role.

The emergence of more efficient technologies and investments in research and development, are intended to increase the efficiency of these systems and reduce their impact on the environment. [8]

3. CONCLUSIONS

Ensuring energy security through a hydroelectric power plant with pumped accumulation is a strategic solution for balancing electricity supply and demand, especially in systems with a growing share of renewable energy sources.

Pumped-storage hydropower contributes to energy security by storing surplus electricity during periods of low demand and releasing it during peak consumption. This improves grid stability, reduces dependence on fossil fuels, and supports the integration of intermittent sources such as wind and solar power.

In addition, such plants provide rapid response capacity, frequency regulation, emergency reserve, and long-term operational flexibility. Although construction requires significant investment and careful environmental assessment, the long service life, high efficiency, and reliability of pumped-storage systems make them valuable infrastructure for modern energy systems.

Therefore, hydroelectric power plants with pumped accumulation represent an important tool for achieving a secure, sustainable, and resilient energy supply.

4. REFERENCES

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