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## Water pumping and compressed air energy storage system

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### Abstract of CN102797613 (A)

The invention discloses a water pumping and compressed air energy storage system and relates to an electric power storage technology. By the system, water is pumped from a reservoir to a pressure tank through a water pump, and air in the pressure tank is compressed, so that electric energy is converted into internal energy of air to be stored in a valley period; and water is pumped out by high pressure air in the pressure tank, drives a water turbine through a water pipeline and drives a generator to generate electricity in a peak period. According to the system, work characteristics of the pressure tank are utilized, and the water pumping energy storage and compressed air energy storage system is miniaturized, so that the problem that a large scale water pumping energy storage system and the traditional compressed air energy storage system depend on geographical conditions is solved. Meanwhile, the water pumping and compressed air energy storage system has the characteristics of low manufacturing cost, no limitation to energy storage period, suitability for different power sources, environment friendliness and the like, and has a wide application prospect.

DESCRIPTION CN102797613A
A pumped compressed air energy storage system
[0001]

Technical Field
[0002]

The invention relates to the technical field of power storage, in particular to a water-pumped compressed air energy storage system.
[0003]

Background Art
[0004]

For a long time, in order to meet the ever-increasing power load requirements, the power sector has had to build power generation capacity based on maximum load requirements.
On the one hand, this has resulted in a large amount of excess and waste of power generation capacity; on the other hand, the power sector has been forced to limit electricity consumption during peak hours.
Therefore, there is an urgent need for an economical, stable, reliable and efficient power storage system to match it and improve the situation where the peak and valley differences in system load are too large.
Especially for power systems that can only operate at high levels, such as nuclear power plants, the demand for power storage systems is even more urgent. More importantly, the power storage system is an effective means to "splice" intermittent energy sources such as wind energy and solar energy to improve the utilization rate of renewable energy (which has intermittent characteristics).
At the same time, power storage system is also a key technology for distributed energy systems.
Distributed energy systems use a large number of small distributed power systems to replace conventional large-scale centralized power systems. They have the advantages of comprehensive energy utilization, high thermal efficiency, and low pollution. However, the system failure rate caused by lines, operations, and other reasons will be higher than that of conventional large-scale centralized power systems. Moreover, due to the small capacity of the system, the fluctuation of the system load will also increase significantly. Therefore, the use of power storage system as a load balancing device and backup power supply is a measure that must be considered in distributed energy systems.
[0005]

Currently available power storage technologies include pumped storage, compressed air storage, battery storage, superconducting storage, flywheel storage and capacitor storage. However, due to reasons such as capacity, storage cycle, energy density, charging and discharging efficiency, life, operating costs, and environmental protection, only pumped storage and compressed air storage are currently operating in large commercial systems.
[0006]

The pumped storage system uses a water pump to send water from a low-level reservoir to a high-level reservoir during low-power consumption periods, thereby converting electrical energy into water potential energy and storing it. During peak power consumption periods, water is discharged from the high-level reservoir to the low-level reservoir to drive turbines to generate electricity.
The pumped storage system has the advantages of mature technology, high efficiency, large energy storage capacity, and unlimited energy storage cycle. It is currently a widely used power energy storage system.

However, large-scale pumped storage systems require special geographical conditions to build two reservoirs and dams, with a long construction period and huge initial investment. What is more troublesome is that the construction of large reservoirs will flood vegetation and even cities over a large area, causing ecological and immigration problems. Therefore, the construction of large-scale pumped storage systems is increasingly restricted.
[0007]

The traditional compressed air energy storage system is an energy storage system developed based on gas turbine technology. During low electricity consumption, air is compressed into the air storage chamber, thereby converting electrical energy into air internal energy and storing it; during peak electricity consumption, the high-pressure air is released from the air storage chamber and enters the gas turbine combustion chamber to burn with the fuel, and then drives the turbine to generate electricity.
Traditional compressed air energy storage systems have the advantages of large energy storage capacity, long energy storage cycle, high efficiency and relatively small unit investment. However, compressed air energy storage systems still rely on the combustion of fossil fuels to provide heat sources. On the one hand, they face the threat of gradual depletion and price increases of fossil fuels. On the other hand, their combustion still produces nitrogen oxides, sulfides and carbon dioxide, which does not meet the requirements of green energy development. What is more fatal is that traditional compressed air energy storage systems also require specific geographical conditions to build large gas storage chambers, such as rock caves, salt caves, abandoned mines, etc., which greatly limits the application scope of traditional compressed air energy storage systems.
[0008]

At present, there is an urgent need to solve the main problem faced by large-scale pumped storage systems and traditional energy storage systems, namely the dependence on special geographical conditions.
[0009]

Summary of the invention
[0010]

The purpose of the present invention is to disclose a water-pumping compressed air energy storage system, which uses a water pump to press water from a water reservoir into a pressure tank during low electricity consumption, compressing the gas in the tank, thereby converting electrical energy into the internal energy of air and storing it; during peak electricity consumption, the high-pressure air in the pressure tank presses the water out, drives the turbine through a water pipeline, and drives the generator to generate electricity.
The system of the present invention makes full use of the working characteristics of the air pressure tank to miniaturize the pumped water energy storage and compressed air energy storage systems, thereby solving the problem of large-scale pumped water energy storage and traditional compressed air energy storage systems' dependence on geographical conditions.
[0011]

To achieve the above object, the technical solution of the present invention is:
[0012]

A pumped compressed air energy storage system, comprising a pumped energy storage unit, an air pressure tank, a water reservoir, a valve and a water pipeline; wherein:
[0013]

The pumped energy storage unit has at least one motor, one water pump, one turbine, and one generator. The water reservoir is connected to the water pump inlet of the pumped energy storage unit through a water pipeline and a first valve, and the water pump outlet is connected to the inner cavity through a water pipeline and an air pressure tank inlet.
[0014]

The outlet of the air pressure tank is connected to the water storage tank through a water pipeline, multiple valves, and the turbine of the pumped energy storage unit;
[0015]

The motor drive shaft is fixedly connected to the water pump shaft, and the turbine drive shaft is fixedly connected to the generator shaft;
[0016]

Its workflow is:
[0017]

When storing energy, the electric motor is started to drive the water pump to press water from the water reservoir through the water pipeline and valve into the compressed air in the pressure tank for storage; when releasing energy, the high-pressure air in the pressure tank presses the water out, drives the turbine through the water pipeline and valve, and the turbine drives the generator to generate electricity.
[0018]

In the pumped compressed air energy storage system, the plurality of valves are two, respectively disposed on both sides of the turbine of the pumped energy storage unit, the second valve is located upstream of the turbine, and the third valve is located downstream of the turbine.
[0019]

The pumped compressed air energy storage system, wherein the pumped energy storage unit is a four-unit or three-unit pumped energy storage unit. When storing energy, the first valve is opened, and the second valve, the third valve, the turbine, and the generator are closed; when releasing energy, the second valve and the third valve are opened, and the first valve, the motor, and the water pump are closed.
[0020]

A micro pumping compressed air energy storage system, comprising a pumping energy storage unit, an air pressure tank, a water reservoir, a valve and a water pipeline; wherein:
[0021]

The pumped energy storage unit is a reversible pumped energy storage unit, including a reversible motor-generator and a reversible water pump-turbine, and the transmission shafts of the reversible motor-generator and the reversible water pump-turbine are fixedly connected;
[0022]

The reversible pumped energy storage unit is connected to the inner cavity of the air pressure tank and the water storage tank through a water pipeline and multiple valves;
[0023]

Its workflow is:
[0024]

When storing energy, multiple valves are opened, and the reversible electric-generator is started to drive the water pump to press water from the reservoir through the water pipeline and multiple valves into the compressed air in the pressure tank for storage; when releasing energy, multiple valves are opened, and the high-pressure air in the pressure tank presses the water out, drives the reversible water pump-turbine through the water pipeline and multiple valves, and the turbine drives the generator to generate electricity.
[0025]

In the pumped compressed air energy storage system, the multiple valves are two, respectively arranged on both sides of the pumped energy storage unit, the second valve is located upstream of the pumped energy storage unit, and the third valve is located downstream of the pumped energy storage unit.
[0026]

In the pumped compressed air energy storage system, the power source of the starting motor is one or more of off-peak (low-price) electricity from conventional power stations, nuclear power, wind power, solar power, hydropower or tidal power.
[0027]

The pumped compressed air energy storage system is activated during power trough (low price) and when renewable energy generation is redundant; the energy release process is activated during power peak (high price), power accidents, and when renewable energy generation does not meet requirements.
[0028]

In the pumped compressed air energy storage system, when there are multiple water pumps, turbines or reversible pump-turbines, the multiple water pumps, turbines or reversible pump-turbines are in series or parallel form; in the parallel form, each branch shaft is dynamically connected to the main drive shaft.
[0029]

The air pressure tank of the water-pumping compressed air energy storage system is one of the vertical or horizontal air bag type, diaphragm type, and full displacement type.
[0030]

The water storage tank of the pumped compressed air energy storage system is installed above ground or underground.
[0031]

The water pumping compressed air energy storage system, wherein the water pump and the reversible water pump-turbine, wherein the water pump is an impeller pump or a positive displacement pump; and the water turbine is a reaction turbine or an impulse turbine.
[0032]

In the water-pumping compressed air energy storage system, the impeller pump is one of axial flow, mixed flow or centrifugal type; the positive displacement pump is one of gear pump, screw pump, Roots pump or vane pump.
[0033]

In the pumped compressed air energy storage system, the reaction turbine is one of axial flow, mixed flow, diagonal flow or cross-flow; the impulse turbine is one of Pelton, oblique impulse or double impulse.

[0034]

The pumped compressed air energy storage system adjusts the energy storage capacity by controlling the flow of the water pump and shutting down some of the water pumps when storing energy; and adjusts the power generation capacity by controlling the flow of the turbine and shutting down some of the turbines when releasing energy.
[0035]

The advantages of the present invention are: utilizing the working characteristics of the air pressure tank to miniaturize the pumped water energy storage and compressed air energy storage systems, thereby solving the problem of large-scale pumped water energy storage and traditional compressed air energy storage systems being dependent on geographical conditions.
At the same time, it has the characteristics of low cost, no restrictions on energy storage cycle, applicability to various types of power sources, and environmental friendliness, and has broad application prospects.
[0036]

BRIEF DESCRIPTION OF THE DRAWINGS
[0037]

FIG1 is a schematic structural diagram of Embodiment 1 of the pumped compressed air energy storage system of the present invention;
[0038]

FIG2 is a schematic structural diagram of Embodiment 2 of the pumped compressed air energy storage system of the present invention;
[0039]

FIG3 is a schematic structural diagram of Embodiment 3 of the pumped compressed air energy storage system of the present invention;
[0040]

FIG4 is a schematic structural diagram of a fourth embodiment of a pumped compressed air energy storage system according to the present invention;
[0041]

FIG5 is a schematic structural diagram of Embodiment 5 of the pumped compressed air energy storage system of the present invention;
[0042]

FIG6 is a schematic structural diagram of Embodiment 6 of the pumped compressed air energy storage system of the present invention;
[0043]

FIG7 is a schematic structural diagram of Embodiment 7 of the pumped compressed air energy storage system of the present invention;
[0044]

FIG8 is a schematic structural diagram of Embodiment 8 of the water-pumping compressed air energy storage system of the present invention.
[0045]

DETAILED DESCRIPTION
[0046]

The present invention discloses a pumped compressed air energy storage system, which uses a water pump to press water from a water reservoir into a pressure tank during low electricity consumption to compress the gas in the tank, thereby converting electrical energy into the internal energy of air and storing it; during peak electricity consumption, the high-pressure air in the pressure tank presses water out, drives a water turbine through a water pipeline, and drives a generator to generate electricity.
It utilizes the working characteristics of air pressure tanks to miniaturize pumped water energy storage and compressed air energy storage systems, thereby solving the problem of large-scale pumped water energy storage systems and traditional compressed air energy storage systems' dependence on geographical conditions.
At the same time, it has the characteristics of low cost, no restrictions on energy storage cycle, applicability to various types of power sources, and environmental friendliness, and has broad application prospects.
[0047]

Example:
[0048]

FIG. 1 is an embodiment 1 of the pumped compressed air energy storage system of the present invention.
The four-machine type water-pumping compressed air energy storage system of the present invention adopts a four-machine type water-pumping energy storage unit, and the air pressure tank is a vertical airbag type.
Among them, there are a water reservoir 1, water pipelines 2, 4, 6, 8, 10, 11, 13, a four-machine pumped storage unit 5, valves 3, 9, 12 and a pressure tank 7.
The four-machine pumped storage unit includes an electric motor, a water pump, a turbine and a generator; the transmission shafts of the electric motor and the water pump are fixedly connected, and the transmission shafts of the generator and the turbine are fixedly connected.
[0049]

The water reservoir 1 is connected to the four-machine pumped energy storage unit 5 via water pipelines 2, 4, 11, 13 and valves 3 and 12, and the four-machine pumped energy storage unit 5 is connected to the pressure tank 7 via water pipelines 6, 8, 10 and valve 9.
[0050]

When storing energy, valve 3 is opened, valves 9 and 12 are closed, and the low-valley (low-price) electricity drives the four-machine pumped energy storage unit 5 to press water into the pressure tank 7 through the water pipes 2, 4, and 6 to compress the gas in the tank.
The energy storage process ends and valve 3 is closed.
When releasing energy, valves 9 and 12 are opened, valve 3 is closed, and the high-pressure air in the pressure tank 7 delivers water to the reservoir 1 through the water pipes 8, 10, 11, 13 and valves 9 and 12, and drives the four-machine pumped energy storage unit 5 to generate electricity.
The energy release process is completed and valves 9 and 12 are closed.
[0051]

Generally, the energy storage and energy release processes do not run at the same time. When storing energy, the water pump and the motor of the four-machine pumped energy storage unit 5 work, and the turbine and the generator are turned off; when releasing energy, the opposite is true.

The turbine and the generator of the four-machine pumped energy storage unit 5 work, and the water pump and the motor are turned off.
[0052]

FIG. 2 is a diagram of Embodiment 2 of the pumped compressed air energy storage system of the present invention.
The three-machine pumped compressed air energy storage system of the present invention has the same main structure as that of Example 1, but uses a three-machine pumped energy storage unit to replace the four-machine pumped energy storage unit in Example 1.
Among them, there are a water reservoir 1, water pipelines 2, 4, 6, 8, 10, 11, 13, a three-machine pumped storage unit 5, valves 3, 9, 12 and a pressure tank 7.
The three-machine pumped storage unit includes a water turbine, a water pump and a reversible electric motor-generator; the water pump and the water turbine are fixedly connected to the transmission shaft of the reversible electric motor-generator.
[0053]

The water reservoir 1 is connected to the three-machine pumped energy storage unit 5 via water pipelines 2, 4, 11, 13 and valves 3, 12, and the three-machine pumped energy storage unit 5 is connected to the pressure tank 7 via water pipelines 6, 8, 10 and valve 9.
[0054]

When storing energy, valve 3 is opened, valves 9 and 12 are closed, and the low-valley (low-price) electricity drives the three-machine pumping energy storage unit 5 to press water into the pressure tank 7 through the water pipes 2, 4, and 6 to compress the gas in the tank.
The energy storage process ends and valve 3 is closed.
When releasing energy, valves 9 and 12 are opened, valve 3 is closed, and the high-pressure air in the pressure tank 7 delivers water to the reservoir 1 through the water pipes 8, 10, 11, 13 and valves 9 and 12, and drives the three-machine pumped energy storage unit 5 to generate electricity.
The energy release process is completed and valves 9 and 12 are closed.
[0055]

Generally, the energy storage and energy release processes do not run at the same time. When storing energy, the water pump and the motor of the three-machine pumped energy storage unit 5 work, and the turbine and the generator are turned off; when releasing energy, the opposite is true.
The turbine and the generator of the three-machine pumped energy storage unit 5 work, and the water pump and the motor are turned off.
[0056]

FIG. 3 is a diagram of Embodiment 3 of the pumped compressed air energy storage system of the present invention.
The reversible pumped compressed air energy storage system of the present invention has the same main structure as that of Example 1, but uses a reversible pumped energy storage unit to replace the four-machine pumped energy storage unit in Example 1.
Among them, there are a water reservoir 1, water pipelines 8, 10, 11, 13, a reversible pumped energy storage unit 5, valves 9, 12 and a pressure tank 7.
The reversible pumped energy storage unit comprises a reversible motor-generator and a reversible water pump-turbine; the reversible motor-generator is fixedly connected to the transmission shaft of the reversible water pump-turbine.
[0057]

The water reservoir 1 is connected to the reversible pumped energy storage unit 5 via water pipes 11, 13 and a valve 12, and the pumped energy storage unit 5 is connected to the air pressure tank 7 via water pipes 8, 10 and a valve 9.
[0058]

When storing energy, valves 9 and 12 are opened, and the low-valley (low-price) electricity drives the reversible pumped energy storage unit 5 to press water into the pressure tank 7 through the water pipes 13, 11, 10, 8 and valves 12 and 9 to compress the gas in the tank.
The energy storage process is completed and valves 9 and 12 are closed.
When releasing energy, valves 9 and 12 are opened, and the high-pressure air in the pressure tank 7 delivers water to the water reservoir 1 through the water pipes 8, 10, 11, 13 and valves 9 and 12, and drives the reversible pumped energy storage unit 5 to generate electricity.
The energy release process is completed and valves 9 and 12 are closed.
[0059]

Generally, the energy storage and energy release processes do not operate at the same time. When storing energy, the reversible pumped energy storage unit 5 works in the water pump-motor mode; when releasing energy, on the contrary, the reversible pumped energy storage unit 5 works in the turbine-generator mode.
[0060]

FIG. 4 is a fourth embodiment of the water-pumping compressed air energy storage system of the present invention.
The reversible water-pumping compressed air energy storage system of the present invention has the same main structure as that of Example 3, but uses a diaphragm-type air pressure tank instead of the air bag-type air pressure tank in Example 3, and the diaphragm divides the air pressure tank into two parts, upper and lower.
Among them, there are a water reservoir 1, water pipelines 8, 10, 11, 13, a reversible pumped energy storage unit 5, valves 9, 12 and a pressure tank 14.
The reversible pumped energy storage unit comprises a reversible motor-generator and a reversible water pump-turbine; the reversible motor-generator is fixedly connected to the transmission shaft of the reversible water pump-turbine.
[0061]

The connection status of the components of the system, the energy storage and release process, and the working mode of the pumped storage unit are basically the same as those in Example 3.
[0062]

The reversible pumped storage unit can also be a four-machine pumped storage unit or a three-machine pumped storage unit, and its main structure is the same as that of embodiments 1 and 2 respectively.
[0063]

FIG. 5 is a fifth embodiment of the water-pumping compressed air energy storage system of the present invention.
The main structure of the reversible water-pumping compressed air energy storage system of the present invention is the same as that of Example 4, but in the diaphragm-type air pressure tank, the diaphragm divides the air pressure tank into left and right parts.
Among them, there are a water reservoir 1, water pipelines 8, 10, 11, 13, a reversible pumped energy storage unit 5, valves 9, 12 and a pressure tank 15.

The reversible pumped energy storage unit comprises a reversible motor-generator and a reversible water pump-turbine; the reversible motor-generator is fixedly connected to the transmission shaft of the reversible water pump-turbine.
[0064]

The connection status of the components of the system, the energy storage and release process, and the working mode of the pumped storage unit are basically the same as those in Example 4.
[0065]

The reversible pumped storage unit can also be a four-machine pumped storage unit or a three-machine pumped storage unit, and its main structure is the same as that of embodiments 1 and 2 respectively.
[0066]

FIG. 6 is a sixth embodiment of the water-pumping compressed air energy storage system of the present invention.
The reversible water-pumping compressed air energy storage system of the present invention has the same main structure as that of Example 4, but uses a full-displacement air pressure tank instead of the diaphragm air pressure tank in Example 4, which can increase the water storage capacity of the air pressure tank.
Among them, there are a water reservoir 1, pipelines 8, 10, 11, 13, 17, 19, a reversible pumped energy storage unit 5, valves 9, 12, 18, a pressure tank 16 and a gas cylinder 20.
The reversible pumped energy storage unit comprises a reversible electric motor-generator and a reversible water pump-turbine; the reversible electric motor-generator is fixedly connected to the transmission shaft of the reversible water pump-turbine.
[0067]

The valve 18 is a common rotary valve or a pressure-holding valve; the gas cylinder 20 is a high-pressure gas cylinder or a medium-pressure gas cylinder.
[0068]

The water reservoir 1 is connected to the reversible pumped energy storage unit 5 via pipes 11, 13 and valve 12, the pumped energy storage unit 5 is connected to the pressure tank 16 via pipes 8, 10 and valve 9, and the pressure tank 16 is connected to the gas cylinder 20 via pipes 19, 17 and valve 18.
[0069]

When storing energy, valves 12, 9, and 18 are opened, and the low-valley (low-price) electricity drives the reversible pumped energy storage unit 5 to send water into the pressure tank 16 through pipes 13, 11, 10, 8 and valves 12 and 9, and press the gas in the tank into the gas cylinder 20 through pipes 17, 19 and valve 18.
The energy storage process ends and valves 12, 9, and 18 are closed.
When releasing energy, valves 18, 9, and 12 are opened, and the air in the gas cylinder 20 presses out the water in the air pressure tank 16 through pipes 19, 17 and valve 18, and is sent to the water reservoir 1 through pipes 8, 10, 11, 13 and valves 9 and 12, and drives the reversible pumped energy storage unit 5 to generate electricity.
The energy release process is completed and valves 18, 9, and 12 are closed.
[0070]

The working mode of the reversible pumped energy storage unit in the system is the same as that in Example 4.
[0071]

The reversible pumped storage unit can also be a four-machine pumped storage unit or a three-machine pumped storage unit, and its main structure is the same as that of embodiments 1 and 2 respectively.
[0072]

FIG. 7 is a seventh embodiment of the pumped compressed air energy storage system of the present invention.
The reversible water-pumping compressed air energy storage system of the present invention has the same main structure as that of Example 4, but uses a horizontal diaphragm air pressure tank instead of the vertical diaphragm air pressure tank in Example 4.
Among them, there are a water reservoir 1, water pipelines 8, 10, 11, 13, a reversible pumped energy storage unit 5, valves 9, 12 and a pressure tank 21.
The reversible pumped energy storage unit comprises a reversible electric motor-generator and a reversible water pump-turbine; the reversible electric motor-generator is fixedly connected to the transmission shaft of the reversible water pump-turbine.
[0073]

The connection status of the components of the system, the energy storage and release process, and the working mode of the pumped storage unit are basically the same as those in Example 4.
[0074]

The reversible pumped storage unit can also be a four-machine pumped storage unit or a three-machine pumped storage unit, and its main structure is the same as that of embodiments 1 and 2 respectively.
[0075]

The air pressure tank can also be of bladder type or full displacement type.
[0076]

FIG8 is an embodiment 8 of the water-pumping compressed air energy storage system of the present invention.
The main structure of the ground water storage tank pumping compressed air energy storage system of the present invention is the same as that of Example 4. The water storage tank is installed on the ground and adopts a vertical diaphragm pressure tank. The diaphragm divides the pressure tank into upper and lower parts.
Among them, there are a water reservoir 1, water pipelines 23, 24, 26, 11, 10, 8, a reversible pumped energy storage unit 5, valves 9, 22, 25, an air pressure tank 14, and a foundation 27.
The reversible pumped energy storage unit comprises a reversible motor-generator and a reversible water pump-turbine; the reversible motor-generator is fixedly connected to the transmission shaft of the reversible water pump-turbine.
[0077]

Valves 22 and 25 are one-way valves, and their flow directions are shown in FIG. 8 .
[0078]

When storing energy, valves 9 and 25 are opened, valve 22 is closed, and the low-valley (low-price) electricity drives the reversible pumped energy storage unit 5 to press water into the pressure tank 14 through pipes 24, 26, 11, 10, 8 and valves 25 and 9 to compress the gas in the tank.
The energy storage process is completed and valves 9 and 25 are closed.

When releasing energy, valves 22 and 9 are opened, valve 25 is closed, and the air in the pressure tank 14 delivers water to the reservoir 1 through pipes 8, 10, 11, 23 and valves 9 and 22, and drives the reversible pumped energy storage unit 5 to generate electricity.
The energy release process is completed and valves 22 and 9 are closed.
[0079]

The working mode of the reversible pumped energy storage unit in the system is the same as that in Example 4.
[0080]

The reversible pumped storage unit can also be a four-machine pumped storage unit or a three-machine pumped storage unit, and its main structure is the same as that of embodiments 1 and 2 respectively.
[0081]

The structure of the pressure tank can also be a diaphragm type, an air bag type or a full displacement type in which the pressure tank is divided into left and right parts by a diaphragm, and the support form can also be a horizontal type.
CLAIMS CN102797613A
1.

A pumped compressed air energy storage system, comprising a pumped energy storage unit, an air pressure tank, a water reservoir, a valve and a water pipeline; characterized in that:
The pumped energy storage unit has at least one motor, one water pump, one turbine, and one generator. The water reservoir is connected to the water pump inlet of the pumped energy storage unit through a water pipeline and a first valve, and the water pump outlet is connected to the inner cavity through a water pipeline and an air pressure tank inlet.
The outlet of the air pressure tank is connected to the water storage tank through a water pipeline, multiple valves, and the turbine of the pumped energy storage unit;
The motor drive shaft is fixedly connected to the water pump shaft, and the turbine drive shaft is fixedly connected to the generator shaft;
Its workflow is:
When storing energy, the electric motor is started to drive the water pump to press water from the water reservoir through the water pipeline and valve into the compressed air in the pressure tank for storage; when releasing energy, the high-pressure air in the pressure tank presses the water out, drives the turbine through the water pipeline and valve, and the turbine drives the generator to generate electricity.
2.

The pumped compressed air energy storage system according to claim 1 is characterized in that: the plurality of valves are two, respectively arranged on both sides of the turbine of the pumped energy storage unit, the second valve is located upstream of the turbine, and the third valve is located downstream of the turbine.
3.

The pumped compressed air energy storage system according to claim 1 is characterized in that: the pumped energy storage unit is a four-machine or three-machine pumped energy storage unit. When storing energy, the first valve is opened, and the second valve, the third valve, the turbine, and the generator are closed; when releasing energy, the second valve and the third valve are opened, and the first valve, the motor, and the water pump are closed.
4.

A micro pumping compressed air energy storage system, comprising a pumping energy storage unit, an air pressure tank, a water reservoir, a valve and a water pipeline; characterized in that:
The pumped energy storage unit is a reversible pumped energy storage unit, including a reversible motor-generator and a reversible water pump-turbine, and the transmission shafts of the reversible motor-generator and the reversible water pump-turbine are fixedly connected;
The reversible pumped energy storage unit is connected to the inner cavity of the air pressure tank and the water storage tank through a water pipeline and multiple valves;
Its workflow is:
When storing energy, multiple valves are opened, and the reversible electric-generator is started to drive the water pump to press water from the reservoir through the water pipeline and multiple valves into the compressed air in the pressure tank for storage; when releasing energy, multiple valves are opened, and the high-pressure air in the pressure tank presses the water out, drives the reversible water pump-turbine through the water pipeline and multiple valves, and the turbine drives the generator to generate electricity.
5.

The pumped compressed air energy storage system according to claim 4 is characterized in that: the plurality of valves are two and are respectively arranged on both sides of the pumped energy storage unit, the second valve is located upstream of the pumped energy storage unit, and the third valve is located downstream of the pumped energy storage unit.
6.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: the power supply of the starting motor is one or more of conventional power station off-peak electricity, nuclear power, wind power, solar power generation, hydropower or tidal power generation.
7.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: the energy storage process is enabled during power troughs and when renewable energy generation is redundant; the energy release process is enabled during power peaks, power accidents, and when renewable energy generation does not meet requirements.
8.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: when there are multiple water pumps, turbines or reversible pump-turbines, the multiple water pumps, turbines or reversible pump-turbines are connected in series or in parallel; in the parallel form, each sub-shaft is dynamically connected to the main drive shaft.
9.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: the air pressure tank is one of a vertical or horizontal air bag type, a diaphragm type, and a full displacement type.
10.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: the water reservoir is installed above ground or underground.
11.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: the water pump and reversible water pump-turbine, the water pump is an impeller pump or a positive displacement pump; the turbine is a reaction turbine or an impulse turbine.

12.

The pumped compressed air energy storage system according to claim 11 is characterized in that: the impeller pump is one of axial flow, mixed flow or centrifugal; the positive displacement pump is one of a gear pump, a screw pump, a Roots pump or a vane pump.

13.

The pumped compressed air energy storage system according to claim 11 is characterized in that: the reaction turbine is one of axial flow, mixed flow, diagonal flow or cross-flow; the impulse turbine is one of bucket type, oblique impact type or double impact type.

14.

The pumped compressed air energy storage system according to claim 1 or 4 is characterized in that: when storing energy, the energy storage capacity is adjusted by controlling the flow rate of the water pump and shutting down some water pumps; when releasing energy, the power generation capacity is adjusted by controlling the flow rate of the turbine and shutting down some turbines.

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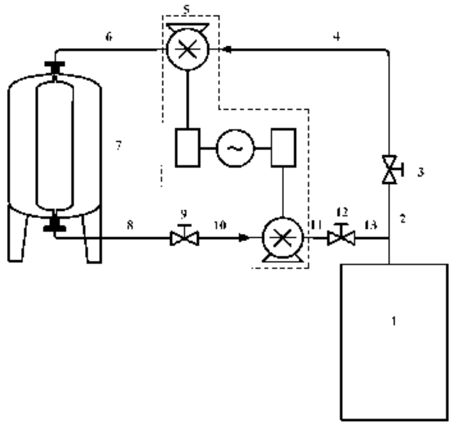
(54)发明名称

一种抽水压缩空气储能系统

(57)摘要

本发明公开了一种抽水压缩空气储能系统，涉及电力存储技术，该系统在用电低谷时通过水泵将水从蓄水池压入气压罐使罐内气体受到压缩，从而将电能转化为空气的内能存储起来；在用电高峰时，气压罐中高压空气将水压出，经输水管道驱动水轮机并带动发电机发电。本发明的系统利用气压罐工作特点，使抽水储能和压缩空气储能系统微型化，从而解决了大规模抽水储能系统和传统压缩空气储能系统对地理条件的依赖问题。同时具有造价低、不受储能周期限制、适用于各种类型电源、对环境友好等特点，具有广阔的应用前景。

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1. 一种抽水压缩空气储能系统，包括抽水储能机组、气压罐、蓄水池、阀门及输水管道；其特征在于：

抽水储能机组至少有一电动机、一水泵、一水轮机、一发电机，蓄水池经输水管道、第一阀门与抽水储能机组的水泵入口相通连，水泵出口经输水管道经气压罐入口与内腔相通连；

气压罐出口经输水管道、多个阀门、抽水储能机组的水轮机与蓄水池相通连；

电动机驱动轴与水泵转轴固接，水轮机驱动轴与发电机转轴固接；

其工作流程为：

储能时，启动电动机驱动水泵将水从蓄水池经输水管道、阀门压入气压罐压缩空气存储；释能时，气压罐中的高压空气将水压出，经输水管道、阀门驱动水轮机，水轮机带动发电机发电。

2. 根据权利要求 1 所述的抽水压缩空气储能系统，其特征在于：所述多个阀门，为二个，分别设在抽水储能机组的水轮机两侧，第二阀门位于水轮机上游，第三阀门位于水轮机下游。

3. 根据权利要求 1 所述的抽水压缩空气储能系统，其特征在于：所述抽水储能机组，为四机式或三机式抽水储能机组，储能时，第一阀门开启，第二阀门、第三阀门、水轮机、发电机关闭；释能时，第二阀门、第三阀门开启，第一阀、电动机、水泵关闭。

4. 一种微型抽水压缩空气储能系统，包括抽水储能机组、气压罐、蓄水池、阀门及输水管道；其特征在于：

抽水储能机组为可逆式抽水储能机组，包括可逆式电动－发电机、可逆式水泵－水轮机，可逆式电动－发电机与可逆式水泵－水轮机的传动轴固接；

可逆式抽水储能机组经输水管道、多个阀门分别与气压罐内腔、蓄水池相通连；

其工作流程为：

储能时，开启多个阀门，启动可逆式电动－发电机驱动水泵将水从蓄水池经输水管道、多个阀门压入气压罐压缩空气存储；释能时，开启多个阀门，气压罐中的高压空气将水压出，经输水管道、多个阀门驱动可逆式水泵－水轮机，水轮机带动发电机发电。

5. 根据权利要求 4 所述的抽水压缩空气储能系统，其特征在于：所述多个阀门，为二个，分别设在抽水储能机组的两侧，第二阀门位于抽水储能机组上游，第三阀门位于抽水储能机组下游。

6. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：所述启动电动机的电源是常规电站低谷电、核电、风电、太阳能发电、水电或潮汐发电其中的一种或多种。

7. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：所述储能过程在电力低谷、可再生能源发电冗余时启用；释能过程在用电高峰、电力事故、可再生能源发电不符合要求时启用。

8. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：当有多台水泵、水轮机或可逆式水泵－水轮机时，多台水泵、水轮机或者可逆式水泵－水轮机为串联形式或者并联形式；并联形式中，各分轴与主驱动轴动连接。

9. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：所述气压罐，为立式或卧式的气囊式、隔膜式、全置换式的其中之一。

10. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：所述蓄水池，安装在地上或地下。

11. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：所述水泵、可逆式水泵－水轮机，其水泵是叶轮式泵或容积式泵；其水轮机是反击式水轮机或冲击式水轮机。

12. 根据权利要求 11 所述的抽水压缩空气储能系统，其特征在于：所述叶轮式泵，为轴流式、混流式或离心式其中之一；容积式泵，为齿轮泵、螺杆泵、罗茨泵或滑片泵其中之一。

13. 根据权利要求 11 所述的抽水压缩空气储能系统，其特征在于：所述反击式水轮机，为轴流式、混流式、斜流式或贯流式其中之一；冲击式水轮机，为水斗式、斜击式或双击式其中之一。

14. 根据权利要求 1 或 4 所述的抽水压缩空气储能系统，其特征在于：储能时，通过控制水泵的流量、关停部分水泵来调节储能能力；释能时，通过控制水轮机的流量、关停部分水轮机来调节发电能力。

# 一种抽水压缩空气储能系统

## 技术领域

[0001] 本发明涉及电力存储技术领域，特别是一种抽水压缩空气储能系统。

## 背景技术

[0002] 长期以来，为满足不断增加的电力负荷要求，电力部门不得不根据最大负荷要求建设发电能力。这一方面造成了大量发电能力的过剩和浪费，另一方面，电力部门又不得不在用电高峰时段限制用电。因此迫切需要经济、稳定、可靠、高效的电力储能系统与之相配套并改善系统负荷峰谷差异过大的情况。特别对于核电站等仅能高位运行的电力系统，电力储能系统的需求就更为迫切。更为重要的是，电力储能系统是将风能、太阳能等间歇式能源"拼接"起来，提高可再生能源（具有间歇性特点）利用率的有效手段。同时，电力储能系统还是分布式能源系统的关键技术。分布式能源系统采用大量小型分布式电力系统代替常规大型集中式电力系统，具有能源综合利用、热效率高、低污染等优点，但同时由于线路、运行等原因造成的系统故障率会高于常规大型集中式电力系统。并且，由于系统的容量较小，系统负荷的波动也将大幅增加，因此，采用电力储能系统作为负荷平衡装置和备用电源是分布式能源系统必须考虑的措施。

[0003] 目前已有电力存储技术包括抽水储能、压缩空气储能、蓄电池储能、超导储能、飞轮储能和电容器储能等，但由于容量、储能周期、能量密度、充放电效率、寿命、运行费用、环保等原因，目前已在大型商业系统中运行的只有抽水储能和压缩空气储能两种。

[0004] 抽水储能系统在用电低谷通过水泵将水从低位水库送到高位水库，从而将电能转化为水的势能存储起来，在用电高峰，水从高位水库排放至低位水库驱动水轮机发电。抽水储能系统具有技术成熟、效率高、储能容量大、储能周期不受限制等优点，是目前广泛使用的电力储能系统。但是，大规模抽水储能系统需要特殊的地理条件建造两个水库和水坝，建设周期很长，初期投资巨大。更为棘手的是，建造大型水库会大面积淹没植被甚至城市，造成生态和移民问题，因此建造大规模抽水储能系统受到了越来越大的限制。

[0005] 传统压缩空气储能系统是基于燃气轮机技术开发的一种储能系统，在用电低谷将空气压入储气室中，从而将电能转化为空气内能存储起来；在用电高峰将高压空气从储气室释放，进入燃气轮机燃烧室同燃料一起燃烧，然后驱动透平发电。传统压缩空气储能系统具有储能容量较大、储能周期长、效率较高和单位投资相对较小等优点；但是压缩空气储能系统仍然依赖燃烧化石燃料提供热源，一方面面临化石燃料逐渐枯竭和价格上涨的威胁，另一方面其燃烧仍然产生氮氧化物、硫化物和二氧化碳等，不符合绿色能源发展要求；更为致命的是，传统压缩空气储能系统也需要特定的地理条件建造大型储气室，如岩石洞穴、盐洞、废弃矿井等，从而大大限制了传统压缩空气储能系统的应用范围。

[0006] 目前，急需解决大型抽水储能系统和传统储能系统面临的主要问题，即对特殊地理条件的依赖问题。

## 发明内容

[0007]　本发明的目的是公开一种抽水压缩空气储能系统，在用电低谷时通过水泵将水从蓄水池压入气压罐使罐内气体受到压缩，从而将电能转化为空气的内能存储起来；在用电高峰时，气压罐中高压空气将水压出，经输水管道驱动水轮机并带动发电机发电。本发明系统充分利用气压罐的工作特点，使抽水储能和压缩空气储能系统微型化，从而解决了大规模抽水储能和传统压缩空气储能系统对地理条件的依赖问题。

[0008]　为达到上述目的，本发明的技术解决方案是：

[0009]　一种抽水压缩空气储能系统，包括抽水储能机组、气压罐、蓄水池、阀门及输水管道；其中：

[0010]　抽水储能机组至少有一电动机、一水泵、一水轮机、一发电机，蓄水池经输水管道、第一阀门与抽水储能机组的水泵入口相通连，水泵出口经输水管道经气压罐入口与内腔相通连；

[0011]　气压罐出口经输水管道、多个阀门、抽水储能机组的水轮机与蓄水池相通连；

[0012]　电动机驱动轴与水泵转轴固接，水轮机驱动轴与发电机转轴固接；

[0013]　其工作流程为：

[0014]　储能时，启动电动机驱动水泵将水从蓄水池经输水管道、阀门压入气压罐压缩空气存储；释能时，气压罐中的高压空气将水压出，经输水管道、阀门驱动水轮机，水轮机带动发电机发电。

[0015]　所述的抽水压缩空气储能系统，其所述多个阀门，为二个，分别设在抽水储能机组的水轮机两侧，第二阀门位于水轮机上游，第三阀门位于水轮机下游。

[0016]　所述的抽水压缩空气储能系统，其所述抽水储能机组，为四机式或三机式抽水储能机组，储能时，第一阀门开启，第二阀门、第三阀门、水轮机、发电机关闭；释能时，第二阀门、第三阀门开启，第一阀、电动机、水泵关闭。

[0017]　一种微型抽水压缩空气储能系统，包括抽水储能机组、气压罐、蓄水池、阀门及输水管道；其中：

[0018]　抽水储能机组为可逆式抽水储能机组，包括可逆式电动－发电机、可逆式水泵－水轮机，可逆式电动－发电机与可逆式水泵－水轮机的传动轴固接；

[0019]　可逆式抽水储能机组经输水管道、多个阀门分别与气压罐内腔、蓄水池相通连；

[0020]　其工作流程为：

[0021]　储能时，开启多个阀门，启动可逆式电动－发电机驱动水泵将水从蓄水池经输水管道、多个阀门压入气压罐压缩空气存储；释能时，开启多个阀门，气压罐中的高压空气将水压出，经输水管道、多个阀门驱动可逆式水泵－水轮机，水轮机带动发电机发电。

[0022]　所述的抽水压缩空气储能系统，其所述多个阀门，为二个，分别设在抽水储能机组的两侧，第二阀门位于抽水储能机组上游，第三阀门位于抽水储能机组下游。

[0023]　所述的抽水压缩空气储能系统，其所述启动电动机的电源是常规电站低谷（低价）电、核电、风电、太阳能发电、水电或潮汐发电其中的一种或多种。

[0024]　所述的抽水压缩空气储能系统，其所述储能过程在电力低谷（低价）、可再生能源发电冗余时启用；释能过程在用电高峰（高价）、电力事故、可再生能源发电不符合要求时启用。

[0025]　所述的抽水压缩空气储能系统，其当有多台水泵、水轮机或可逆式水泵－水轮机

时，多台水泵、水轮机或者可逆式水泵－水轮机为串联形式或者并联形式；并联形式中，各分轴与主驱动轴动连接。

[0026] 所述的抽水压缩空气储能系统，其所述气压罐，为立式或卧式的气囊式、隔膜式、全置换式的其中之一。

[0027] 所述的抽水压缩空气储能系统，其所述蓄水池，安装在地上或地下。

[0028] 所述的抽水压缩空气储能系统，其所述水泵、可逆式水泵－水轮机，其水泵是叶轮式泵或容积式泵；其水轮机是反击式水轮机或冲击式水轮机。

[0029] 所述的抽水压缩空气储能系统，其所述叶轮式泵，为轴流式、混流式或离心式其中之一；容积式泵，为齿轮泵、螺杆泵、罗茨泵或滑片泵其中之一。

[0030] 所述的抽水压缩空气储能系统，其所述反击式水轮机，为轴流式、混流式、斜流式或贯流式其中之一；冲击式水轮机，为水斗式、斜击式或双击式其中之一。

[0031] 所述的抽水压缩空气储能系统，其储能时，通过控制水泵的流量、关停部分水泵来调节储能能力；释能时，通过控制水轮机的流量、关停部分水轮机来调节发电能力。

[0032] 本发明的优点在于：利用气压罐的工作特点，使抽水储能和压缩空气储能系统微型化，从而解决了大规模抽水储能和传统压缩空气储能系统对地理条件的依赖问题。同时具有造价低、不受储能周期限制、适用于各种类型电源、对环境友好等特点，具有广阔的应用前景。

## 附图说明

[0033] 图 1 为本发明抽水压缩空气储能系统的实施例 1 结构示意图；

[0034] 图 2 为本发明抽水压缩空气储能系统的实施例 2 结构示意图；

[0035] 图 3 为本发明抽水压缩空气储能系统的实施例 3 结构示意图；

[0036] 图 4 为本发明抽水压缩空气储能系统的实施例 4 结构示意图；

[0037] 图 5 为本发明抽水压缩空气储能系统的实施例 5 结构示意图；

[0038] 图 6 为本发明抽水压缩空气储能系统的实施例 6 结构示意图；

[0039] 图 7 为本发明抽水压缩空气储能系统的实施例 7 结构示意图；

[0040] 图 8 为本发明抽水压缩空气储能系统的实施例 8 结构示意图。

## 具体实施方式

[0041] 本发明公开了一种抽水压缩空气储能系统，它在用电低谷通过水泵将水从蓄水池压入气压罐使罐内气体受到压缩，从而将电能转化为空气的内能存储起来；在用电高峰，气压罐中高压空气将水压出，经输水管道驱动水轮机并带动发电机发电。它利用气压罐工作特点，使抽水储能和压缩空气储能系统微型化，从而解决了大规模抽水储能系统和传统压缩空气储能系统对地理条件的依赖问题。同时具有造价低、不受储能周期限制、适用于各种类型电源、对环境友好等特点，具有广阔的应用前景。

[0042] 实施例：

[0043] 图 1 是本发明的抽水压缩空气储能系统的实施例 1。本发明的四机式抽水压缩空气储能系统，其采用四机式抽水储能机组，气压罐为立式气囊式。其中，蓄水池 1，输水管道 2、4、6、8、10、11、13，四机式抽水储能机组 5，阀门 3、9、12 和气压罐 7。四机式抽水储能机组

包括电动机、水泵、水轮机和发电机；电动机与水泵的传动轴固接，发电机与水轮机的传动轴固接。

[0044]　蓄水池 1 与四机式抽水储能机组 5 经输水管道 2、4、11、13 及阀门 3、12 相通连，四机式抽水储能机组 5 与气压罐 7 经输水管道 6、8、10 及阀门 9 相通连。

[0045]　储能时，阀门 3 打开，阀门 9、12 关闭，低谷（低价）电驱动四机式抽水储能机组 5，将水通过输水管道 2、4、6 压入气压罐 7 使罐内气体受到压缩。储能过程结束，阀门 3 关闭。释能时，阀门 9、12 打开，阀门 3 关闭，气压罐 7 中高压空气将水经输水管道 8、10、11、13 及阀门 9、12 送到蓄水池 1，并驱动四机式抽水储能机组 5 发电。释能过程结束，阀门 9、12 关闭。

[0046]　一般情况下，储能和释能过程不同时运行，储能时，四机式抽水储能机组 5 的水泵和电动机工作，水轮机和发电机关闭；释能时则相反，四机式抽水储能机组 5 的水轮机和发电机工作，水泵和电动机关闭。

[0047]　图 2 是本发明的抽水压缩空气储能系统的实施例 2。本发明的三机式抽水压缩空气储能系统，其主体结构与实施例 1 相同，但采用三机式抽水储能机组代替实施例 1 中的四机式抽水储能机组。其中，蓄水池 1，输水管道 2、4、6、8、10、11、13，三机式抽水储能机组 5，阀门 3、9、12 和气压罐 7。三机式抽水储能机组包括水轮机、水泵和可逆式电动 - 发电机；水泵和水轮机与可逆式电动 - 发电机的传动轴固接。

[0048]　蓄水池 1 与三机式抽水储能机组 5 经输水管道 2、4、11、13 及阀门 3、12 相通连，三机式抽水储能机组 5 与气压罐 7 经输水管道 6、8、10 及阀门 9 相通连。

[0049]　储能时，阀门 3 打开，阀门 9、12 关闭，低谷（低价）电驱动三机式抽水储能机组 5，将水通过输水管道 2、4、6 压入气压罐 7 使罐内气体受到压缩。储能过程结束，阀门 3 关闭。释能时，阀门 9、12 打开，阀门 3 关闭，气压罐 7 中高压空气将水经输水管道 8、10、11、13 及阀门 9、12 送到蓄水池 1，并驱动三机式抽水储能机组 5 发电。释能过程结束，阀门 9、12 关闭。

[0050]　一般情况下，储能和释能过程不同时运行，储能时，三机式抽水储能机组 5 的水泵和电动机工作，水轮机和发电机关闭；释能时则相反，三机式抽水储能机组 5 的水轮机和发电机工作，水泵和电动机关闭。

[0051]　图 3 是本发明的抽水压缩空气储能系统的实施例 3。本发明的可逆式抽水压缩空气储能系统，其主体结构与实施例 1 相同，但采用可逆式抽水储能机组代替实施例 1 中的四机式抽水储能机组。其中，蓄水池 1，输水管道 8、10、11、13，可逆式抽水储能机组 5，阀门 9、12 和气压罐 7。可逆式抽水储能机组包括可逆式电动 - 发电机和可逆式水泵 - 水轮机；可逆式电动 - 发电机与可逆式水泵 - 水轮机的传动轴固接。

[0052]　蓄水池 1 与可逆式抽水储能机组 5 经输水管道 11、13 及阀门 12 相通连，抽水储能机组 5 与气压罐 7 经输水管道 8、10 及阀门 9 相通连。

[0053]　储能时，阀门 9、12 打开，低谷（低价）电驱动可逆式抽水储能机组 5，将水通过输水管道 13、11、10、8 及阀门 12、9 压入气压罐 7 使罐内气体受到压缩。储能过程结束，阀门 9、12 关闭。释能时，阀门 9、12 打开，气压罐 7 中高压空气将水经输水管道 8、10、11、13 及阀门 9、12 送到蓄水池 1，并驱动可逆式抽水储能机组 5 发电。释能过程结束，阀门 9、12 关闭。

[0054] 一般情况下，储能和释能过程不同时运行，储能时，可逆式抽水储能机组 5 在水泵 - 电动机模式下工作；释能时则相反，可逆抽水储能机组 5 在水轮机 - 发电机模式下工作。

[0055] 图 4 是本发明的抽水压缩空气储能系统的实施例 4。本发明的可逆式抽水压缩空气储能系统，其主体结构与实施例 3 相同，但采用隔膜式气压罐和代替实施例 3 中气囊式气压罐，隔膜将气压罐分为上下两部分。其中，蓄水池 1，输水管道 8、10、11、13，可逆式抽水储能机组 5，阀门 9、12 和气压罐 14。可逆式抽水储能机组包括可逆式电动 - 发电机和可逆式水泵 - 水轮机；可逆式电动 - 发电机与可逆式水泵 - 水轮机的传动轴固接。

[0056] 该系统的各部件连接状态、储能及释能过程还有抽水蓄能机组的工作模式与实施例 3 基本相同。

[0057] 可逆式抽水储能机组也可为四机式抽水储能机组或者三机式抽水储能机组，其主体结构分别与实施例 1、2 相同。

[0058] 图 5 为本发明的抽水压缩空气储能系统的实施例 5。本发明的可逆式抽水压缩空气储能系统，其主体结构与实施例 4 相同，但在隔膜式气压罐中隔膜将气压罐分为左右两部分。其中，蓄水池 1，输水管道 8、10、11、13，可逆式抽水储能机组 5，阀门 9、12 和气压罐 15。可逆式抽水储能机组包括可逆式电动 - 发电机和可逆式水泵 - 水轮机；可逆式电动 - 发电机与可逆式水泵 - 水轮机的传动轴固接。

[0059] 该系统的各部件连接状态、储能及释能过程还有抽水蓄能机组的工作模式与实施例 4 基本相同。

[0060] 可逆式抽水储能机组也可为四机式抽水储能机组或者三机式抽水储能机组，其主体结构分别与实施例 1、2 相同。

[0061] 图 6 为本发明的抽水压缩空气储能系统的实施例 6。本发明的可逆式抽水压缩空气储能系统，其主体结构与实施例 4 相同，但采用全置换式气压罐和代替实施例 4 中隔膜式气压罐，这样可以增加气压罐储水容量。其中，蓄水池 1，管道 8、10、11、13、17、19，可逆式抽水储能机组 5，阀门 9、12、18，气压罐 16 和气瓶 20。可逆式抽水储能机组包括可逆式电动 - 发电机和可逆式水泵 - 水轮机；可逆式电动 - 发电机与可逆式水泵 - 水轮机的传动轴固接。

[0062] 阀门 18 是普通旋拧阀或持压阀；气瓶 20 是高压气瓶或中压气瓶。

[0063] 蓄水池 1 与可逆式抽水储能机组 5 经管道 11、13 及阀门 12 相通连，抽水储能机组 5 与气压罐 16 经管道 8、10 及阀门 9 相通连，气压罐 16 与气瓶 20 经管道 19、17 及阀门 18 相通连。

[0064] 储能时，阀门 12、9、18 打开，低谷（低价）电驱动可逆式抽水储能机组 5，将水通过管道 13、11、10、8 及阀门 12、9 送入气压罐 16，并使罐内气体经管道 17、19 及阀门 18 压入气瓶 20 中。储能过程结束，阀门 12、9、18 关闭。释能时，阀门 18、9、12 打开，气瓶 20 中的空气经管道 19、17 及阀门 18 将气压罐 16 中的水压出，并经管道 8、10、11、13 及阀门 9、12 送到蓄水池 1，并驱动可逆式抽水储能机组 5 发电。释能过程结束，阀门 18、9、12 关闭。

[0065] 系统中的可逆抽水储能机组的工作模式与实施例 4 相同。

[0066] 可逆式抽水储能机组也可为四机式抽水储能机组或者三机式抽水储能机组，其主体结构分别与实施例 1、2 相同。

[0067] 图 7 为本发明的抽水压缩空气储能系统的实施例 7。本发明的可逆式抽水压缩空气储能系统，其主体结构与实施例 4 相同，但采用卧式隔膜式气压罐和代替实施例 4 中立式隔膜式气压罐。其中，蓄水池 1，输水管道 8、10、11、13，可逆式抽水储能机组 5，阀门 9、12 和气压罐 21。可逆式抽水储能机组包括可逆式电动 - 发电机和可逆式水泵 - 水轮机；可逆式电动 - 发电机与可逆式水泵 - 水轮机的传动轴同接。

[0068] 该系统的各部件连接状态、储能及释能过程还有抽水蓄能机组的工作模式与实施例 4 基本相同。

[0069] 可逆式抽水储能机组也可为四机式抽水储能机组或者三机式抽水储能机组，其主体结构分别与实施例 1、2 相同。

[0070] 气压罐还可以是气囊式或全置换式。

[0071] 图 8 为本发明的抽水压缩空气储能系统的实施例 8。本发明的地面蓄水池的抽水压缩空气储能系统，其主体结构与实施例 4 相同，蓄水池安装在地面上，采用立式隔膜式气压罐，隔膜将气压罐分为上下两部分。其中，蓄水池 1，输水管道 23、24、26、11、10、8，可逆式抽水储能机组 5，阀门 9、22、25，气压罐 14，地基 27。可逆式抽水储能机组包括可逆式电动 - 发电机和可逆式水泵 - 水轮机；可逆式电动 - 发电机与可逆式水泵 - 水轮机的传动轴同接。

[0072] 阀门 22、25 是单向阀，其流通方向如图 8 所示。

[0073] 储能时，阀门 9、25 打开，阀门 22 关闭，低谷（低价）电驱动可逆式抽水储能机组 5，将水通过管道 24、26、11、10、8 及阀门 25、9 压入气压罐 14 使罐内气体受到压缩。储能过程结束，阀门 9、25 关闭。释能时，阀门 22、9 打开，阀门 25 关闭，气压罐 14 内的空气将水经管道 8、10、11、23 及阀门 9、22 送到蓄水池 1，并驱动可逆式抽水储能机组 5 发电。释能过程结束，阀门 22、9 关闭。

[0074] 系统中的可逆抽水储能机组的工作模式与实施例 4 相同。

[0075] 可逆式抽水储能机组也可为四机式抽水储能机组或者三机式抽水储能机组，其主体结构分别与实施例 1、2 相同。

[0076] 气压罐结构也可为隔膜将气压罐分为左右部分的隔膜式、气囊式或全置换式，支承形式也可为卧式。

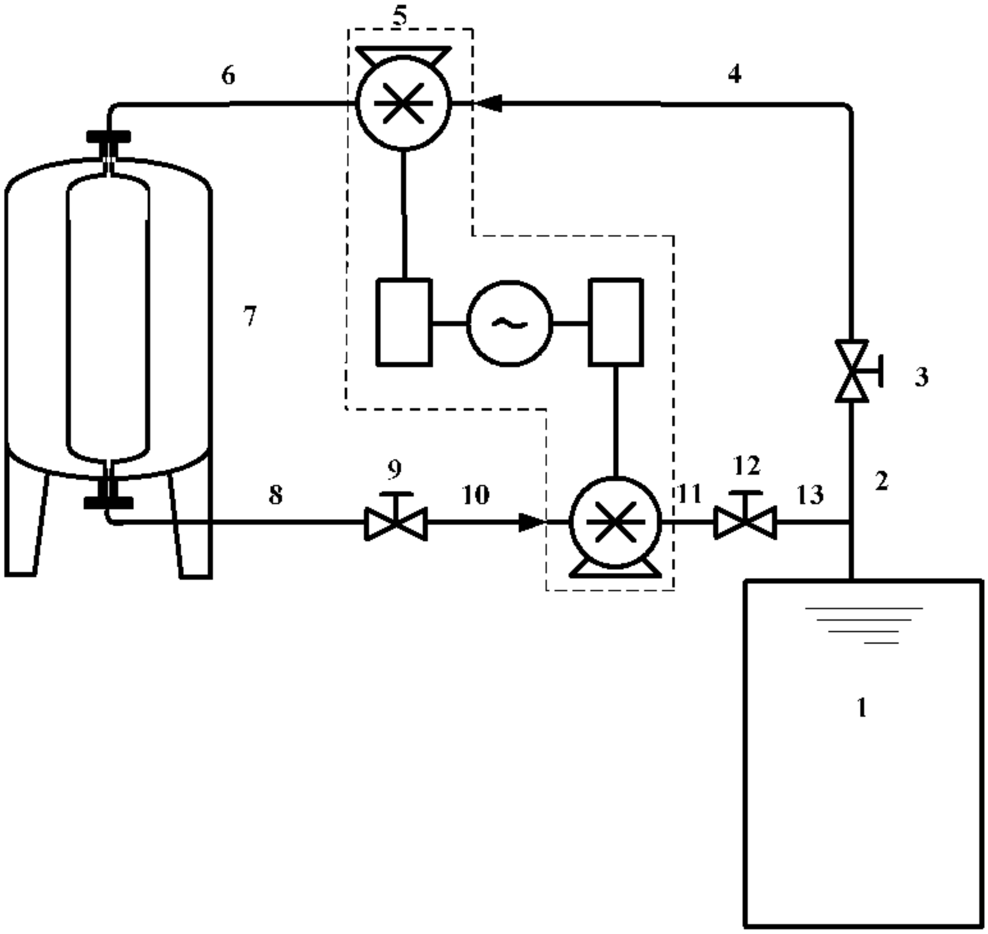


图 1

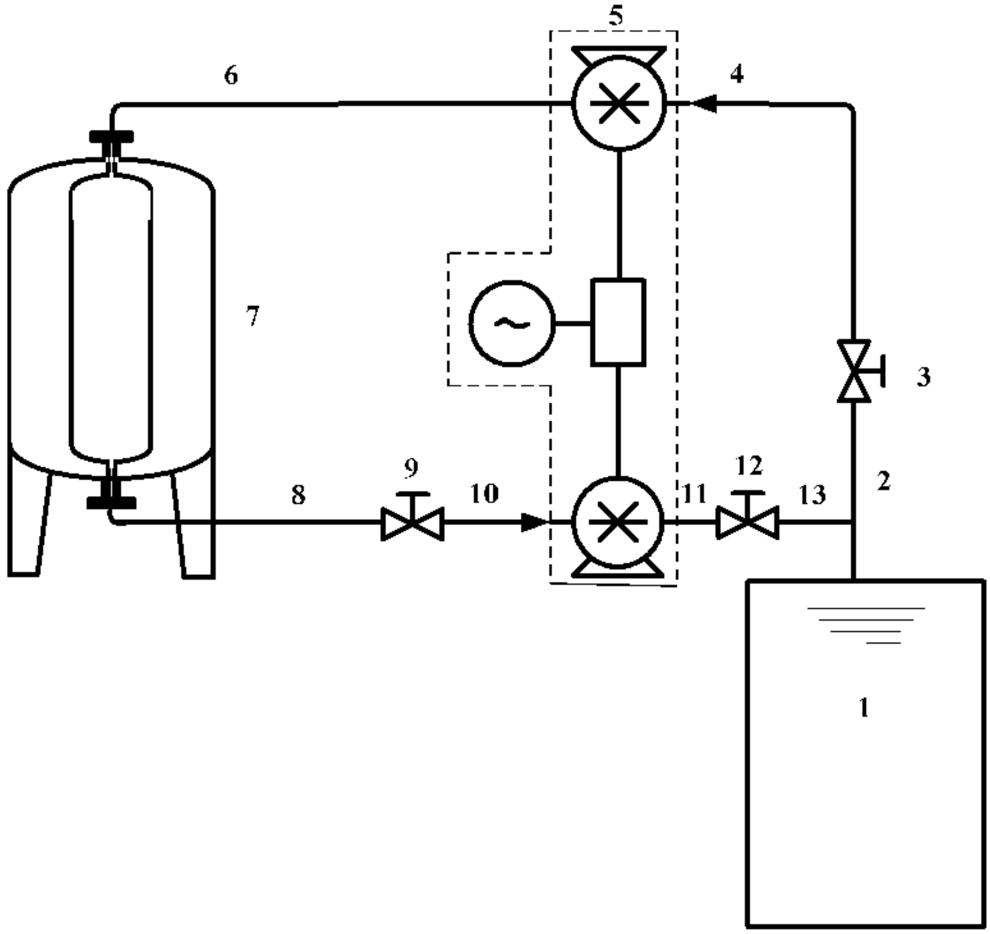


图 2

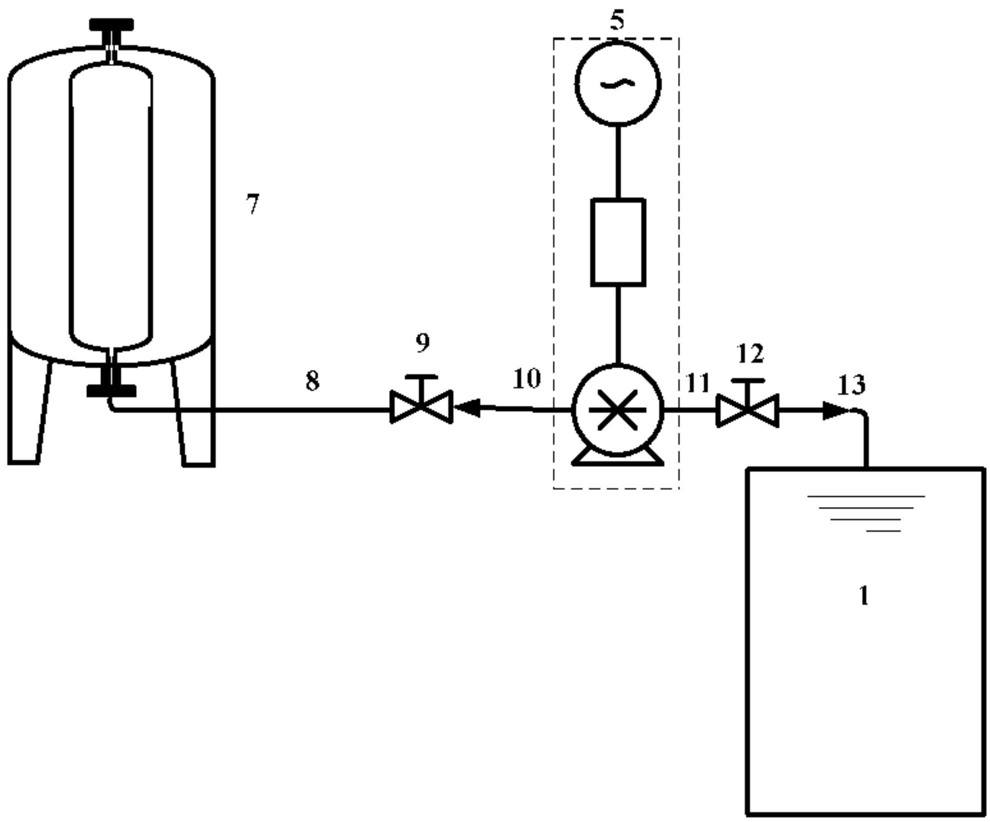


图 3

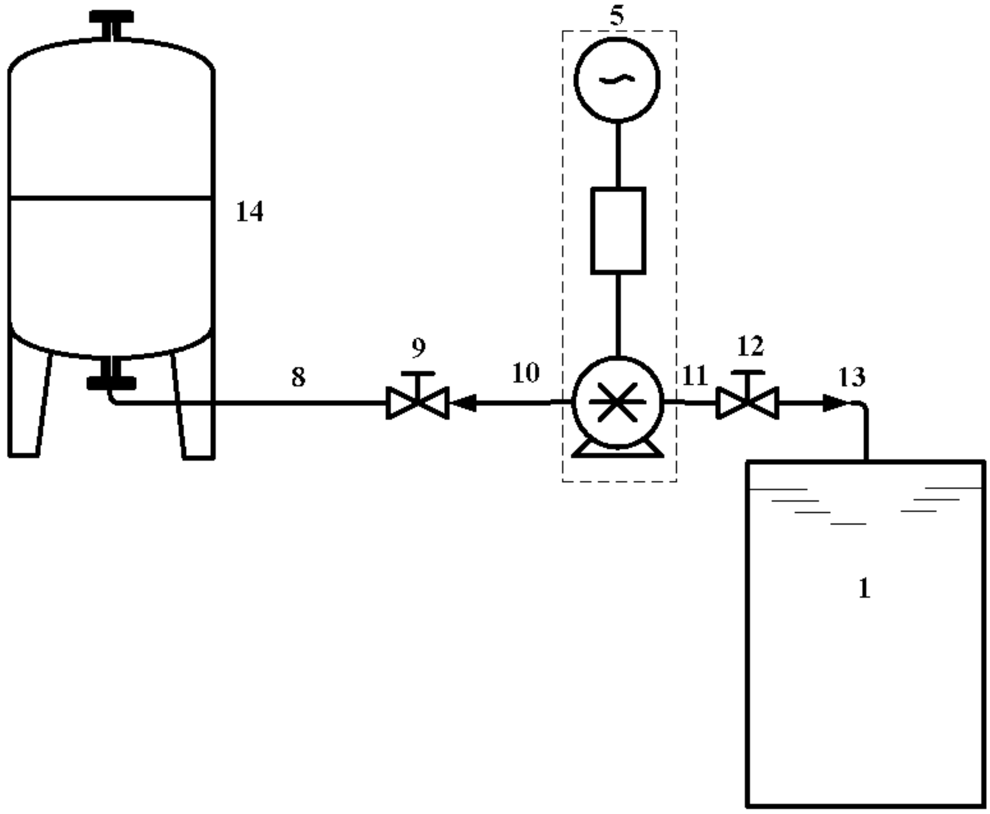


图 4

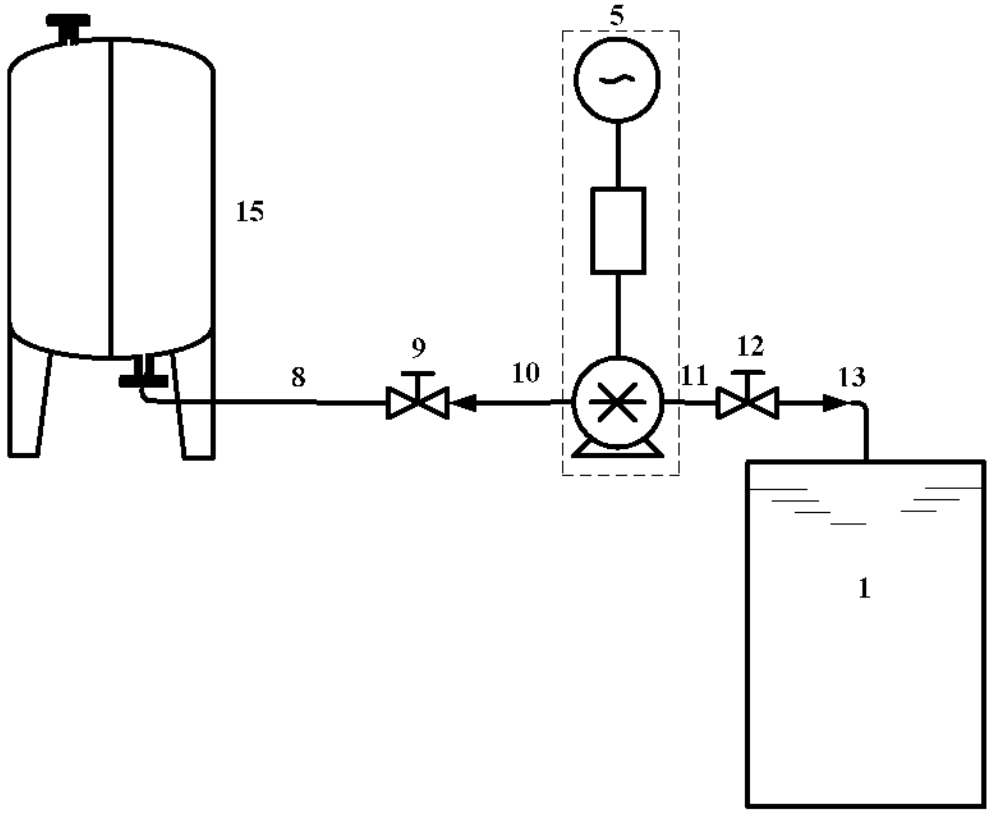


图 5

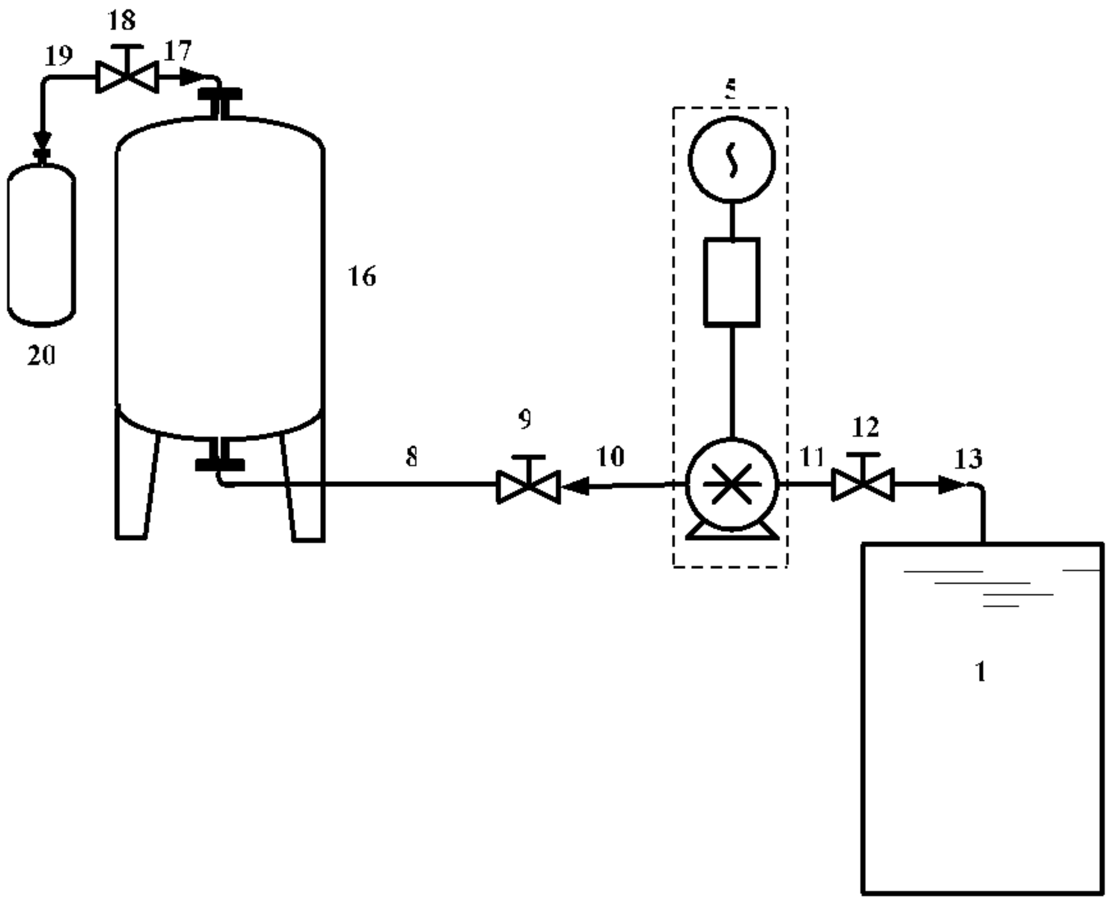


图 6

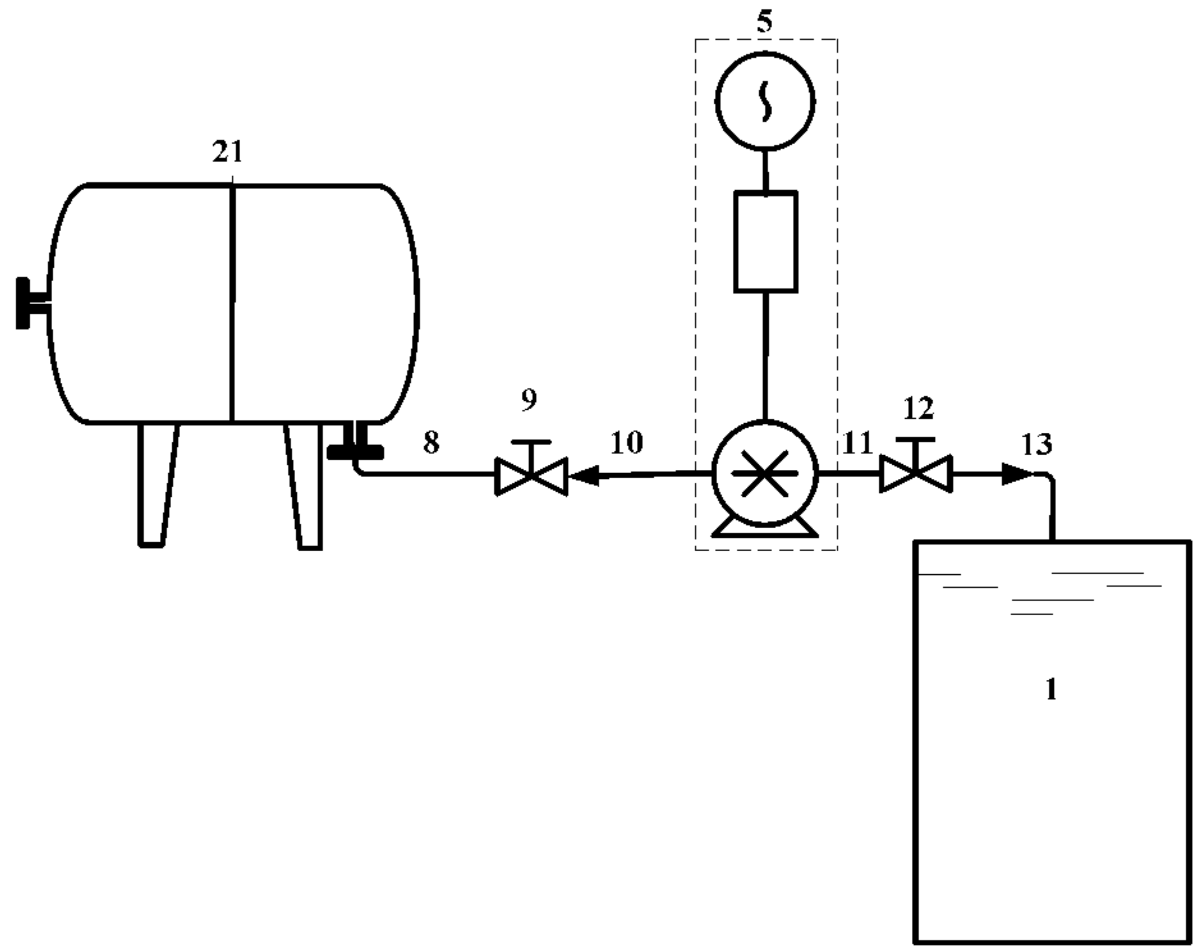


图 7

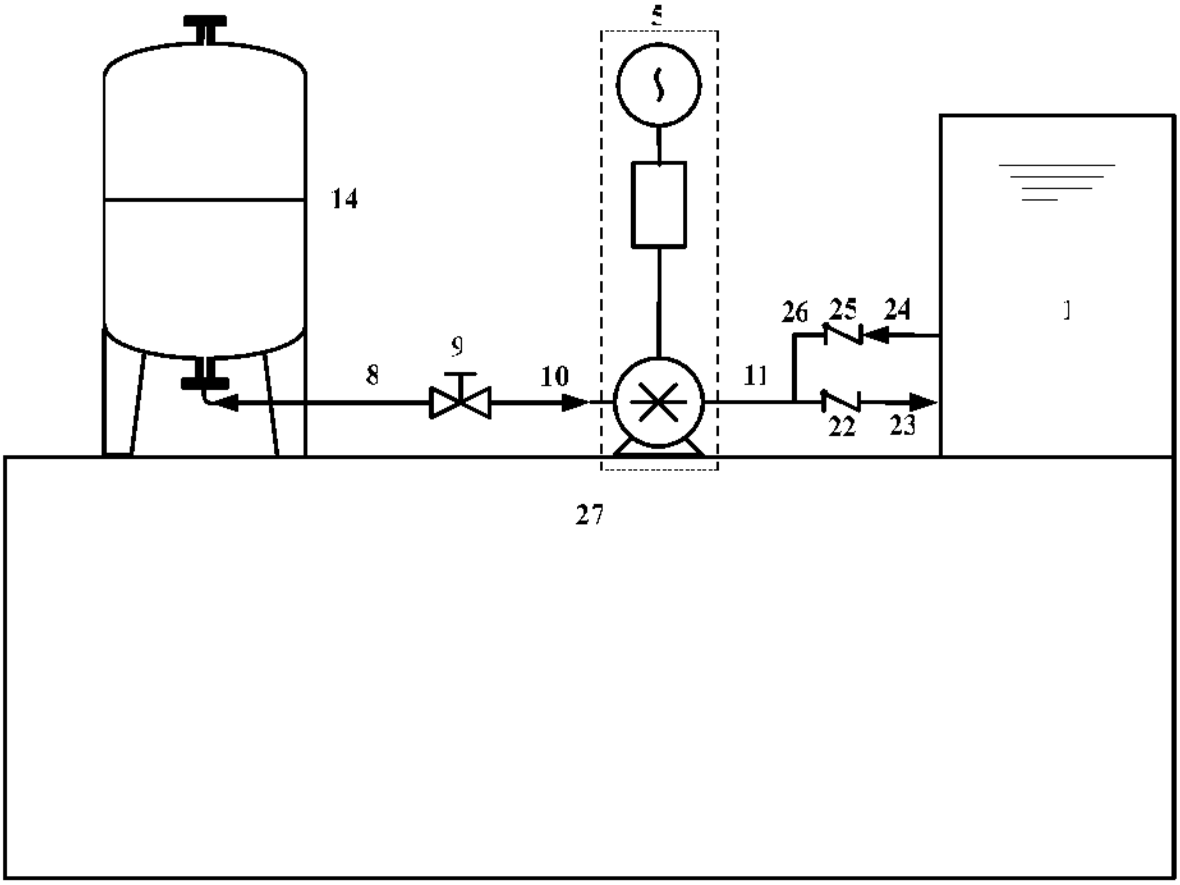


图 8

Espacenet

## Bibliographic data: CN207420643 (U) — 2018-05-29

### Compressed air energy storage system that draws water

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**Classification:** **- international:** ***F01K7/02 ; F03B13/00; F04B23/02; F04B41/02***
**- cooperative:**

**Application number:** CN201720966239U 20170803

**Priority number(s):** CN201720966239U 20170803

### Abstract of CN207420643 (U)

The utility model discloses a compressed air energy storage system that draws water, it includes air compression unit, air expansion steady voltage unit, hydraulic turbine, hydraulic pump group, highpressure gasholder, middling pressure gas holder, high -pressure water storage tank and ordinary pressure water storage tank. Wherein, middling pressure gas holder, air compression unit connect gradually with high pressure gasholder and form the energy storage passageway, high pressure gasholder, air expansion steady voltage unit, high -pressure water storage tank, hydraulic turbine and ordinary pressure water storage tank connect gradually and form the energy release passageway, ordinary pressure water storage tank, hydraulic pump group connect gradually with high -pressure water storage tankand form water return channel. Compressed air energy storage system that draws water regards as gas storage container to avoid the problem of traditional compressed air energy storage system cavern site selection difficulty with air reservoir to replace the water of height with high pressure's water, replace the gravity flood peak of water with the pressure head of water, eliminated the traditionreliance of energy storage power station to the ground potential difference of drawing water.

DESCRIPTION CN207420643U
Compressed air pumped water energy storage system
[0001]

Technical Field
[0002]

The utility model relates to the technical field of power storage, in particular to a compressed air pumping energy storage system.
[0003]

Background Art
[0004]

As the capacity of my country's power grid continues to grow, the peak-to-valley difference continues to increase. Some power grids have been forced to take compulsory power outages due to the shortage of peak power supply. This not only hinders the development of productivity, but may also bring social problems. Therefore, introducing energy storage systems into the power grid is an urgent need to achieve peak load regulation.
In addition, with the vigorous development of renewable energy, distributed energy supply and smart grids, the actual demand for large-scale development of the energy storage industry is also increasing.
[0005]

Conventional energy storage technologies mainly include flywheel energy storage, battery energy storage, superconducting energy storage, supercapacitor energy storage, pumped storage and compressed air energy storage.
However, energy storage technologies that can output large capacities for hours at a lower cost mainly include battery storage, pumped storage and compressed air storage.
Battery energy storage is currently difficult to promote to the large-scale energy storage field due to its high cost and environmental pollution problems in production and subsequent processing.
As the most mature large-scale energy storage application technology, pumped storage has the advantages of high efficiency, large storage capacity, and mature equipment technology. However, it is also limited by the difficulty in selecting reservoir sites, which hinders its large-scale promotion and application. Compressed air energy storage stores energy in the form of air's internal energy, but traditional compressed air energy storage technology requires underground salt caverns as gas storage space, which also has the problem of difficult site selection.
[0006]

The compressed air pumped water energy storage system combines the characteristics of compressed air energy storage. In the process of storing energy, the air is compressed and stored in a high-pressure air tank. In the process of releasing energy, the high-pressure air is released, compressing the water in the water tank to a high-pressure state. The high-pressure water drives the turbine to generate electricity.
Compressed air does not have to be stored in underground caves, and the pressure head of water replaces the gravity head. There is no need to send water to a reservoir at a very high location, which solves the problem of difficult site selection in compressed air energy storage and pumped water energy storage. Compressed air pumped energy storage systems are more flexible and can be large or small in scale, making them more suitable for urban power storage systems. Moreover, electricity consumption is mainly concentrated in cities, so compressed air pumped energy storage systems are of great significance in alleviating the peak-shaving pressure of the power grid.
[0007]

Utility Model Content
[0008]

Based on this, it is necessary to provide a compressed air pumped energy storage system that can effectively realize the miniaturization of pumped storage power stations.
[0009]

The utility model discloses a compressed air pumping energy storage system, which includes a first air storage tank, an air compression unit, a second air storage tank, an air expansion and pressure stabilizing unit, a first water storage tank, a turbine unit, a second water storage tank and a water pump unit, wherein the first air storage tank, the air compression unit and the second air storage tank are connected in sequence to form an energy storage channel; the second air storage tank, the air expansion and pressure stabilizing unit, the first water storage tank, the turbine unit and the second water storage tank are connected in sequence to form an energy release channel; the second water storage tank, the water pump unit and the first water storage tank are connected in sequence to form a water return channel.
[0010]

Preferably, the air compression unit comprises n (n≥1) stages of compressors connected in series, and a stop valve is installed at the inlet of the air compression unit.
[0011]

Preferably, a three-way valve is installed at the compressor outlet of each stage of the air compression unit except the last stage, and the two outlets of the three-way valve are respectively connected to a stop valve. Among the two stop valves, the outlet of one stop valve is connected to the inlet of the compressor of the next stage, and the outlet of the other stop valve is connected to the second air storage tank, and the second air storage tank is a high-pressure air storage tank.
[0012]

Preferably, the n compressors in the air compression unit are a combination of one or more of screw type, piston type or centrifugal type.
[0013]

Preferably, the second air storage tank is a high-pressure air storage tank, and its air working pressure range is 1.0MPa to 50.0MPa(A).
[0014]

Preferably, the air expansion and pressure stabilization unit is composed of m (m≥1) stages of expanders connected in series, and a stop valve is installed at the inlet of the air expansion and pressure stabilization unit.
[0015]

Preferably, a three-way valve is installed at the inlet of each expander of the air expansion and pressure stabilization unit except the last one, and the two outlets of the three-way valve are respectively connected to a stop valve. Among the two stop valves, one stop valve outlet is connected to the inlet of the expander of the current stage, and the other stop valve outlet is connected to the three-way valve before the inlet of the expander of the next stage. If the expander of the next stage is the last stage, the stop valve outlet of the current stage is directly connected to the inlet of the expander of the last stage.
[0016]

Preferably, the m expanders of the air expansion and pressure stabilization unit 20 are one or more combinations of screw type, piston type or centrifugal type.
[0017]

Preferably, the first air storage tank is a medium-pressure air storage tank, and the air/water working pressure range between it and the second water storage tank is 0.2MPa~40.0MPa(A), and its working pressure is lower than the air working pressure in the second air storage tank.
[0018]

Preferably, the first gas storage tank and the first water storage tank share the same storage tank.
[0019]

The utility model discloses a compressed air pumping energy storage system, comprising a first air storage tank, an air compression unit, a second air storage tank, an air expansion and pressure stabilizing unit, a first water storage tank, a turbine unit, a second water storage tank and a water pump unit, wherein the first air storage tank, the air compression unit and the second air storage tank are connected in sequence to form an energy storage channel; the second air storage tank, the air expansion and pressure stabilizing unit, the first water storage tank, the turbine unit and the second water storage tank are connected in sequence to form an energy release channel; the second water storage tank, the water pump unit and the first water storage tank are connected in sequence to form a water return channel.
The compressed air pumped energy storage system uses an air storage tank as an air storage container to avoid the problem of difficult underground cave site selection for traditional compressed air energy storage systems, and replaces high-position water with high-pressure water, and replaces water gravity head with water pressure head, eliminating the traditional pumped energy storage power station's reliance on terrain differences.
[0020]

BRIEF DESCRIPTION OF THE DRAWINGS
[0021]

FIG1 is a schematic diagram of the composition of a compressed air pumping energy storage system provided by the utility model;
[0022]

FIG2 is a schematic diagram of the combination of the air compression unit and the air expansion and pressure stabilization unit shown in FIG1 ;
[0023]

FIG3 is a first schematic diagram of the energy storage process of the compressed air energy storage system provided by the present invention;
[0024]

FIG4 is a second schematic diagram of the energy storage process of the compressed air energy storage system provided by the present invention;
[0025]

FIG5 is a third schematic diagram of the energy storage process of the compressed air energy storage system provided by the present invention;
[0026]

FIG6 is a schematic diagram of the water return process of the compressed air energy storage system provided by the present invention;
[0027]

FIG7 is a first schematic diagram of the energy release process of the compressed air energy storage system provided by the present invention;
[0028]

FIG8 is a second schematic diagram of the energy release process of the compressed air energy storage system provided by the present invention;
[0029]

FIG. 9 is a third schematic diagram of the energy release process of the compressed air energy storage system provided by the present invention.
[0030]

DETAILED DESCRIPTION
[0031]

In order to facilitate the understanding of the present invention, the present invention will be described in more detail below.
The following embodiments provide preferred embodiments of the present invention.
However, the present invention may be implemented in many different forms and is not limited to the embodiments described herein.
On the contrary, the purpose of providing these embodiments is to make the understanding of the disclosure of the present utility model more thorough and comprehensive.
[0032]

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.
The terms used in the description of the present invention are only for the purpose of describing specific embodiments and are not intended to limit the present invention.
[0033]

Please refer to Figure 1. The utility model provides a compressed air pumping energy storage system, including a first air storage tank 6, an air compression unit 10, a second air storage tank 5, an air expansion and pressure stabilizing unit 20, a first water storage tank 6, a turbine unit 30, a second water storage tank 7 and a water pump unit 40.
Among them, the second air storage tank 5 is a high-pressure air storage tank 5, and the second water storage tank 7 is a normal-pressure water storage tank 7.
[0034]

The first air tank 6, the air compression unit 10 and the high-pressure air tank 5 are connected in sequence to form an energy storage channel, and the first air tank 6 is a medium-pressure air tank 6 in the energy storage channel; the high-pressure air tank 5, the air expansion and pressure stabilizing unit 20, the first water tank 6, the turbine unit 30 and the normal-pressure water tank 7 are connected in sequence to form an energy release channel, and the first water tank 6 is a high-pressure water tank 6 in the energy release channel; the second water tank, the water pump unit and the first water tank are connected in sequence to form a return water channel, and the first water tank 6 is a high-pressure water tank 6 in the return water channel.

In this embodiment, in order to save costs, the first gas storage tank 6 and the first water storage tank 6 can be the same tank, but they have different functions in different channels, such as a medium-pressure gas storage tank 6 or a high-pressure water storage tank 6.
Of course, the medium-pressure gas storage tank 6 or the high-pressure water storage tank 6 can also be different storage tanks in the compressed air pumping energy storage system.
[0035]

Please refer to FIG. 2 . In this embodiment, the air compression unit 10 includes n (n≥1) stages of compressors connected in series, and a stop valve Vc<sub>1</sub> is installed at the inlet of the air compression unit 10 .
The air compression unit 10 takes its i-th (i<n) stage compression as an example, and a three-way valve Tc<sub>i</sub> is installed at the outlet of the i-th stage compressor, and the two outlets of the three-way valve Tc<sub>i</sub> are respectively connected to the stop valve Vc<sub>i1</sub> and the stop valve Vc<sub>i2</sub>, wherein the outlet of the stop valve Vc<sub>i1</sub> is connected to the inlet of the i+1-th stage compressor, and the outlet of the stop valve Vc<sub>i2</sub> is connected to the high-pressure air storage tank 5.
In this embodiment, the n compressors in the air compression unit 10 are a combination of one or more types of screw type, piston type or centrifugal type.
[0036]

In the utility model, the compression process is a non-steady-state process, and the pressure ratio of the compressor is constantly changing. The utility model adopts a multi-stage compression method, which can achieve a maximum pressure ratio variation range of 1 to 50 MPa, while it is difficult for traditional compressors to achieve such a large pressure ratio adjustment range. Moreover, the multi-stage compression solution includes a control pipeline part, which can adjust the start and stop of each single-stage compressor during the non-steady-state compression process, so that each stage of the compressor can work within its own appropriate pressure ratio range.
[0037]

Please refer to FIG. 2 . In this embodiment, the air expansion and pressure stabilization unit 20 includes m (m≥1) stages of series expansion units, and a stop valve Ve<sub>1</sub> is installed at the inlet of the air expansion and pressure stabilization unit 20 .
The air expansion and pressure stabilizing unit 20 takes the i-th (i<m) stage expansion as an example, and a three-way valve Te<sub>i</sub> is installed at the inlet of the i-th stage expansion machine, and the two outlets of the three-way valve Te<sub>i</sub> are respectively connected to the stop valve Ve<sub>i1</sub> and the stop valve Ve<sub>i2</sub>, wherein the outlet of the stop valve Ve<sub>i1</sub> is connected to the inlet of the i-th stage expansion machine, and the outlet of the stop valve Ve<sub>i2</sub> is connected to the inlet of the three-way valve Te<sub>i+1</sub> (if i=m-1, the outlet of the stop valve Ve<sub>i2</sub> is directly connected to the inlet of the m-th stage expansion machine).
In this embodiment, the m expanders of the air expansion and pressure stabilization unit 20 are one or more combinations of screw type, piston type or centrifugal type.
[0038]

Please refer to Figure 1. In this embodiment, the working pressure range of the high-pressure gas storage tank 5 in the compressed air pumped water energy storage system is 1.0MPa~50.0MPa(A); the air/water working pressure range of the medium-pressure gas storage/high-pressure water storage tank 6 is 0.1MPa~40.0MPa(A), and its working pressure is lower than the air working pressure in the high-pressure gas storage tank 5.
[0039]

Please refer to Figure 1. In this embodiment, the turbine unit 30 includes a turbine 31 and a stop valve 32. The turbine 31 is a reaction turbine or an impulse turbine. The reaction turbine is one of a mixed flow type, an axial flow type, an oblique flow type or a cross-flow type; the mixed flow turbine is one of a bucket type, an oblique flow type or a double-flow type.
[0040]

Please refer to FIG. 1 . In this embodiment, the water pump unit 40 includes a water pump 41 and a stop valve 42 . The water pump 41 is one of a centrifugal pump, a vortex pump, an axial flow pump, a piston pump, a Roots pump or a screw pump.
[0041]

Please refer to FIG. 1 . In this embodiment, a vent valve 8 and a vent valve 9 are installed on the top of the medium-pressure gas storage/high-pressure water storage tank 6 and the atmospheric-pressure water storage tank 7 , respectively.
[0042]

It should be further explained that the main power generation unit of the present invention is the turbine, so the efficiency of the turbine directly affects the overall efficiency of the system.
In order to ensure the efficient operation of the turbine, it is necessary to achieve a stable operating condition of the turbine.
The inlet operating parameters of the turbine mainly refer to the inlet pressure. Therefore, in order to achieve efficient operation of the entire system, it is necessary to ensure the stability of the turbine inlet pressure. The utility model adopts a multi-stage air expansion pressure stabilizing unit to achieve the stability of the turbine inlet pressure during the non-steady-state operation of the system. This is also the reason why the utility model has to set a medium-pressure air storage tank.
[0043]

The working principle of the compressed air water pumping energy storage system provided by the utility model is introduced below according to the three stages of energy storage-water return-energy release.
[0044]

Please refer to Figures 3 to 5. The working principle of the energy storage process of the compressed air pumped water energy storage system is as follows:
[0045]

At the beginning of the energy storage process, all valves are closed.
At this time, the storage tank 6 is a medium-pressure gas storage tank 6, the high-pressure gas storage tank 5 and the medium-pressure gas storage tank 6 are both filled with air, and the air pressures in the two storage tanks are the same, and the normal-pressure water storage tank is filled with water.
At this time, close the stop valve Ve<sub>1</sub> of the air expansion and pressure stabilizing unit 20, the stop valve 32 of the turbine unit 30, the stop valve 42 of the pump unit 40, the vent valve 8 and the vent valve 9, and open the stop valve Vc<sub>1</sub> of the air compression unit 10.
Close the stop valve Vc<sub>11</sub>, open the stop valve Vc<sub>12</sub>, start the first-stage compressor, the air in the medium-pressure air storage tank 6 is continuously extracted, the pressure drops, and the pressure in the high-pressure air storage tank 5 rises (please refer to Figure 3 for the air flow direction at this time).
When the pressure in the high-pressure gas storage tank 5 rises to a certain level and exceeds the regulating capacity of the first-stage compressor, open the stop valve Vc<sub>11</sub> and the stop valve Vc<sub>22</sub>, close the stop valve Vc<sub>12</sub> and the stop valve

Vc<sub>21</sub>, and start the second-stage compressor at the same time (please refer to Figure 4 for the air flow direction at this time).
For the i-th stage compressor, when the air pressure in the high-pressure air storage tank 5 exceeds the regulating capacity of the i-th stage compressor, the stop valves Vc<sub>i1</sub> and Vc<sub>(i+1)2</sub> are opened, the stop valves Vc<sub>i2</sub> and Vc<sub>(i+1)1</sub> are closed, and the compressor i+1 is turned on.
Proceed in sequence, when the pressure in the high-pressure gas storage tank 5 exceeds the regulating capacity of the compressor n-1, open the stop valve Vc<sub>(n-1)1</sub>, close the stop valve Vc<sub>(n-1)2</sub>, and start the nth stage compressor (please refer to Figure 5 for the air flow direction at this time).
at this time.
When the pressure in the high-pressure gas storage tank 5 reaches the set pressure, all air compressors are shut down, and all stop valves are closed, and the energy storage process ends.
[0046]

Please refer to FIG6 , the working principle of the water return process of the compressed air pumping energy storage system is as follows:
[0047]

At the beginning of the water return process, all valves are closed.
At this time, the storage tank 6 is a high-pressure water storage tank 6. Open the drain valve 8 and the vent valve 9, open the stop valve 42, and start the water pump 41 to continuously pump water from the normal-pressure water storage tank 7 and send it into the high-pressure water storage tank 6 until all the water in the normal-pressure water storage tank 7 is pumped out, the water pump 41 is stopped, all valves are closed, and the water return stage ends.
It should be noted that, at this stage, the water in the high-pressure water storage tank 6 is still at normal pressure or at a very low pressure state.
[0048]

Please refer to Figures 7 to 9, the working principle of the energy release process of the compressed air pumped water energy storage system is as follows:
[0049]

At the beginning of the energy release process, all valves are closed.
At this time, open the stop valve Ve<sub>1</sub> of the air expansion and pressure stabilizing unit 20; for each stage of the expansion machine, taking the i-th stage as an example, open the stop valve Ve<sub>i1</sub> and close the stop valve Ve<sub>i2</sub>; open the stop valve 32 of the turbine unit and the vent valve 9 of the normal pressure water outlet tank.
Start the expansion machines at all levels and start the turbine 31.
The air from the high-pressure air storage tank 5 is expanded and decompressed through each stage of the expander in sequence, reaches the set pressure at the outlet of the m-th stage expander, and enters the high-pressure water storage tank 6 to compress the water to high pressure. The high-pressure water enters the turbine 31 through the stop valve 32, driving the turbine 31 to generate power, and the water discharged from the turbine 31 enters the normal-pressure water storage tank 7 for storage (please refer to Figure 7 for the air flow direction at this time).
As the energy release process proceeds, the air pressure in the high-pressure gas storage tank 5 gradually decreases. When its pressure is lower than the minimum intake pressure of the first-stage expander, the stop valve Ve<sub>12</sub> is opened, the stop valve Ve<sub>11</sub> is closed, the first-stage expander is shut down, and the air in the high-pressure gas storage tank 5 directly enters the second-stage expander, and passes through the subsequent stages of expanders in turn for expansion and decompression (please refer to Figure 8 for the air flow direction at this time).

For the i-th stage expansion, when the air pressure in the high-pressure gas tank 5 drops to the minimum intake pressure at the inlet of the expander i, the stop valve Ve<sub>i2</sub> is opened, the stop valve Ve<sub>i1</sub> is closed, the expander i is shut down, and the air in the high-pressure gas tank 5 directly enters the (i+1)-th stage expander, and passes through the subsequent stages of expanders in turn for expansion and decompression.
The process continues in sequence. When the air pressure in the high-pressure gas storage tank 5 is lower than the inlet pressure of the (m-1)th stage expansion machine, the stop valve Ve<sub>(m-1)2</sub> is opened, the stop valve Ve<sub>(m-1)1</sub> is closed, the (m-1)th stage expansion machine is shut down, and the air in the high-pressure gas storage tank 5 directly enters the inlet of the mth stage expansion machine (please refer to Figure 8 for the air flow direction at this time).
When all the water in the high-pressure water storage tank 6 is pushed out, the m-th stage expander and the water turbine 31 are shut down, all the stop valves are closed, and the energy release process ends.
[0050]

The utility model belongs to the field of power storage, discloses a compressed air pumping energy storage system, relates to compressed air energy storage technology and pumping energy storage technology, and is used for a miniaturized pumping energy storage system.
The compressed air pumping energy storage system comprises an air compression unit, an air expansion and pressure stabilization unit, a turbine unit, a water pump unit, a high-pressure air storage tank, a medium-pressure air storage tank, a high-pressure water storage tank, and a normal-pressure water storage tank.
Among them, the medium-pressure gas tank, the air compression unit and the high-pressure gas tank are connected in sequence to form an energy storage channel; the high-pressure gas tank, the air expansion pressure stabilizing unit, the high-pressure water tank, the turbine unit and the normal-pressure water tank are connected in sequence to form an energy release channel; the normal-pressure water tank, the water pump unit and the high-pressure water tank are connected in sequence to form a return water channel.
The compressed air pumped energy storage system uses an air storage tank as an air storage container to avoid the problem of difficult underground cave site selection for traditional compressed air energy storage systems; high-pressure water replaces high-position water, and water pressure head replaces water gravity head, eliminating the traditional pumped energy storage power station's reliance on terrain differences.
The maximum pressure head of the utility model is 40MPa. Under the condition of the same power generation capacity, the volume of the reservoir can be reduced by dozens of times, effectively realizing the miniaturization of the pumped storage power station.
[0051]

The technical features of the above-described embodiments may be arbitrarily combined. To make the description concise, not all possible combinations of the technical features in the above-described embodiments are described. However, as long as there is no contradiction in the combination of these technical features, they should be considered to be within the scope of this specification.
[0052]

The above-mentioned embodiments only express several implementation methods of the utility model. The descriptions thereof are relatively specific and detailed, but they cannot be understood as limiting the scope of the utility model patent.
It should be pointed out that, for ordinary technicians in this field, several modifications and improvements can be made without departing from the concept of the utility model, which all belong to the protection scope of the utility model.

Therefore, the protection scope of this utility model patent should be based on the attached claims.

CLAIMS CN207420643U
1.

A compressed air pumping energy storage system, characterized in that it includes a first air storage tank, an air compression unit, a second air storage tank, an air expansion and pressure stabilizing unit, a first water storage tank, a turbine unit, a second water storage tank and a water pump unit, wherein the first air storage tank, the air compression unit and the second air storage tank are connected in sequence to form an energy storage channel; the second air storage tank, the air expansion and pressure stabilizing unit, the first water storage tank, the turbine unit and the second water storage tank are connected in sequence to form an energy release channel; the second water storage tank, the water pump unit and the first water storage tank are connected in sequence to form a return water channel.
2.

The compressed air pumped water energy storage system according to claim 1 is characterized in that the air compression unit includes n stages of compressors connected in series, $n \geq 1$, and a stop valve is installed at the inlet of the air compression unit.
3.

The compressed air pumped energy storage system according to claim 2 is characterized in that a three-way valve is installed at the compressor outlet of each stage of the air compression unit except the last stage, and the two outlets of the three-way valve are respectively connected to a stop valve, and one of the two stop valves is connected to the inlet of the compressor of the next stage, and the other stop valve outlet is connected to the second air storage tank, and the second air storage tank is a high-pressure air storage tank.
4.

The compressed air pumped water energy storage system according to claim 3 is characterized in that the n compressors in the air compression unit are a combination of one or more of screw type, piston type or centrifugal type.
5.

The compressed air pumped water energy storage system according to claim 1 is characterized in that the second air storage tank is a high-pressure air storage tank, and its air working pressure range is 1.0 MPa to 50.0 MPa (A).
6.

The compressed air pumped energy storage system according to claim 1 is characterized in that the air expansion and pressure stabilization unit is composed of m-stage series expansion machines, $m \geq 1$, and a stop valve is installed at the inlet of the air expansion and pressure stabilization unit.
7.

The compressed air pumped energy storage system as described in claim 6 is characterized in that a three-way valve is installed at the inlet of each expander of the air expansion and pressure stabilization unit except the last stage, and the two outlets of the three-way valve are respectively connected to a stop valve, and one of the two stop valves is connected to the inlet of the current expander, and the other stop valve outlet is connected to the three-way valve before the inlet of the next expander. If the next expander is the last stage, the stop valve outlet of the current stage is directly connected to the inlet of the last expander.
8.

The compressed air pumped water energy storage system according to claim 7 is characterized in that the m expanders of the air expansion and pressure stabilization unit 20 are one or more combinations of screw type, piston type or centrifugal type.

9.

The compressed air pumped energy storage system according to claim 1 is characterized in that the first air storage tank is a medium-pressure air storage tank, and the air/water working pressure range between the first air storage tank and the second water storage tank is 0.2MPa~40.0MPa(A), and its working pressure is lower than the air working pressure in the second air storage tank.

10.

The compressed air pumped water energy storage system according to claim 1 is characterized in that the first air storage tank and the first water storage tank share the same storage tank

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(12)实用新型专利

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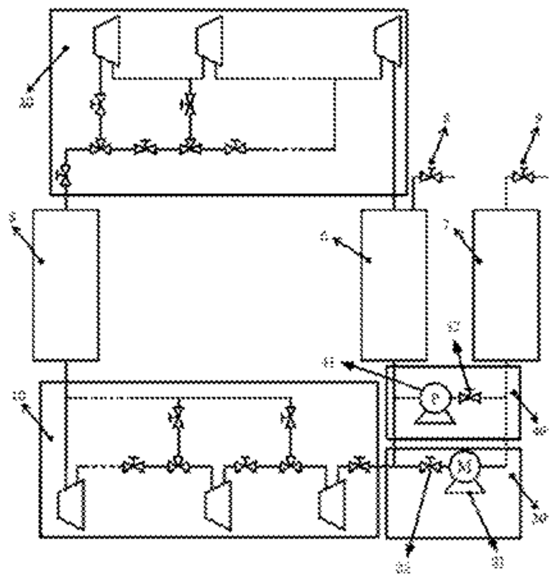
(54)实用新型名称

压缩空气抽水储能系统

(57)摘要

本实用新型公开了一种压缩空气抽水储能系统,其包括空气压缩单元、空气膨胀稳压单元、水轮机组、水泵机组、高压储气罐、中压储气罐、高压储水罐、以及常压储水罐。其中,中压储气罐、空气压缩单元与高压储气罐依次连接形成储能通道;高压储气罐、空气膨胀稳压单元、高压储水罐、水轮机组与常压储水罐依次连接形成释能通道;常压储水罐、水泵机组与高压储水罐依次连接形成回水通道。所述压缩空气抽水储能系统以空气储罐作为储气容器避免了传统压缩空气储能系统地下洞穴选址困难的问题,并以高压力的水代替高位置的水,以水的压力水头代替水的重力水头,消除了传统抽水储能电站对地势差的依赖。



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1. 一种压缩空气抽水储能系统，其特征在于，包括第一储气罐、空气压缩单元、第二储气罐、空气膨胀稳压单元、第一储水罐、水轮机组、第二储水罐以及水泵机组，其中，所述第一储气罐、所述空气压缩单元与所述第二储气罐依次连接形成储能通道；所述第二储气罐、所述空气膨胀稳压单元、所述第一储水罐、所述水轮机组与所述第二储水罐依次连接形成释能通道；所述第二储水罐、所述水泵机组与所述第一储水罐依次连接形成回水通道。

2. 如权利要求1所述的压缩空气抽水储能系统，其特征在于，所述空气压缩单元包括n级串联的压缩机，n≥1，且所述空气压缩单元入口处安装有截止阀。

3. 如权利要求2所述的压缩空气抽水储能系统，其特征在于，所述空气压缩单元除最后一级的每一级的压缩机出口都安装有三通阀，所述三通阀的两个出口分别与一个截止阀相连通，所述两个截止阀中，其中一个截止阀出口与下一级压缩机入口连通，另外一个截止阀出口与第二储气罐连通，所述第二储气罐为高压储气罐。

4. 如权利要求3所述的压缩空气抽水储能系统，其特征在于，所述空气压缩单元中的n个压缩机为螺杆式、活塞式或离心式其中一种或多种的组合。

5. 如权利要求1所述的压缩空气抽水储能系统，其特征在于，所述第二储气罐为高压储气罐，其空气工作压力范围为1.0MPa～50.0MPa(A)。

6. 如权利要求1所述的压缩空气抽水储能系统，其特征在于，所述空气膨胀稳压单元由m级串联膨胀机组成，m≥1，且所述空气膨胀稳压单元入口安装有截止阀。

7. 如权利要求6所述的压缩空气抽水储能系统，其特征在于，所述空气膨胀稳压单元除最后一级的每一级膨胀机的入口都安装有三通阀，所述三通阀的两个出口分别与一个截止阀相连通，所述两个截止阀中，其中一个截止阀出口与当前一级的膨胀机入口相连通，另一个截止阀出口与下一级膨胀机入口之前的三通阀相连通，若下一级膨胀机为最后一级，则当前一级的截止阀出口直接与最后一级膨胀机入口相连通。

8. 如权利要求7所述的压缩空气抽水储能系统，其特征在于，所述空气膨胀稳压单元的m个膨胀机为螺杆式、活塞式或离心式其中一种或多种组合。

9. 如权利要求1所述的压缩空气抽水储能系统，其特征在于，所述第一储气罐为中压储气罐，其与第二储水罐的空气/水工作压力范围为0.2MPa～40.0MPa(A)，且其工作压力低于第二储气罐中空气工作压力。

10. 如权利要求1所述的压缩空气抽水储能系统，其特征在于，所述第一储气罐与第一储水罐共用同一储罐。

# 压缩空气抽水储能系统

## 技术领域

[0001]　本实用新型涉及电力储存技术领域，尤其涉及一种压缩空气抽水储能系统。

## 背景技术

[0002]　随着我国电网容量的不断增长，峰谷差不断增大，已有一些电网由于高峰供电缺额的存在，不得不采取强制性拉闸限电的措施，这不仅阻碍了生产力的发展，而且可能会带来社会问题，故而在电网中引入储能系统是实现电网调峰的迫切需求。另外，随着再生能源、分布式供能和智能电网的蓬勃发展，对大规模发展储能产业的现实需求也越来越大。

[0003]　常规的储能技术主要有飞轮储能、电池储能、超导储能、超级电容器储能、抽水储能和压缩空气储能等。但是能够以较低成本持续数小时进行大容量输出的储能技术主要包括电池储能、抽水储能和压缩空气储能。电池储能因其成本高，生产及后续处理存在环境污染等问题，目前难以推广至大规模储能领域。抽水储能作为当前最为成熟的大规模储能应用技术，具有效率高，储能容量大，设备技术成熟等优势，但同时受到蓄水池选址困难的限制，阻碍了其大规模的推广应用。压缩空气储能以空气内能形式进行能量储存，但传统压缩空气储能技术需要以地下盐穴作为储气空间，同样具有选址困难的问题。

[0004]　压缩空气抽水储能系统，结合压缩空气储能的特点，在储存能量的过程中将空气进行压缩并存储于高压储气罐中，而在释放能量的过程中，高压空气被释放，将储水罐中的水压缩至高压状态，高压水推动水轮机做功发电。压缩空气不必存储于地下洞穴，而且以水的压力水头代替重力水头，不需要将水送往很高位置处的水库，解决了压缩空气储能和抽水储能中选址困难的问题。压缩空气抽水储能系统更具有灵活性，规模可大可小，更适合用于城市电力存储系统，而且电力消耗主要集中于城市，因此压缩空气抽水储能系统对于缓解电网的调峰压力具有重大意义。

## 实用新型内容

[0005]　基于此，有必要提供一种压缩空气抽水储能系统，能有效实现抽水蓄能电站的小型化。

[0006]　本实用新型揭示了一种压缩空气抽水储能系统，其包括第一储气罐、空气压缩单元、第二储气罐、空气膨胀稳压单元、第一储水罐、水轮机组、第二储水罐以及水泵机组，其中，所述第一储气罐、所述空气压缩单元与所述第二储气罐依次连接形成储能通道；所述第二储气罐、所述空气膨胀稳压单元、所述第一储水罐、所述水轮机组与所述第二储水罐依次连接形成释能通道；所述第二储水罐、所述水泵机组与所述第一储水罐依次连接形成回水通道。

[0007]　优先的，所述空气压缩单元包括n（n≥1）级串联的压缩机，且所述空气压缩单元入口处安装有截止阀。

[0008]　优先的，所述空气压缩单元除最后一级的每一级的压缩机出口都安装有三通阀，所述三通阀的两个出口分别与一个截止阀相连通，所述两个截止阀中，其中一个截止阀出

口与下一级压缩机入口连通，另外一个截止阀出口与第二储气罐连通，所述第二储气罐为高压储气罐。

[0009] 优先的，所述空气压缩单元中的n个压缩机为螺杆式、活塞式或离心式其中一种或多种的组合。

[0010] 优先的，所述第二储气罐为高压储气罐，其空气工作压力范围为1.0MPa～50.0MPa(A)。

[0011] 优先的，所述空气膨胀稳压单元由m(m≥1)级串联膨胀机组成，且所述空气膨胀稳压单元入口安装有截止阀。

[0012] 优先的，所述空气膨胀稳压单元除最后一级的每一级膨胀机的入口都安装有三通阀，所述三通阀的两个出口分别与一个截止阀相连通，所述两个截止阀中，其中一个截止阀出口与当前一级的膨胀机入口相连通，另一个截止阀出口与下一级膨胀机入口之前的三通阀相连通，若下一级膨胀机为最后一级，则当前一级的截止阀出口直接与最后一级膨胀机入口相连通。

[0013] 优先的，所述空气膨胀稳压单元20的m个膨胀机为螺杆式、活塞式或离心式其中一种或多种组合。

[0014] 优先的，所述第一储气罐为中压储气罐，其与第二储水罐的空气/水工作压力范围为0.2MPa～40.0MPa(A)，且其工作压力低于第二储气罐中空气工作压力。

[0015] 优先的，所述第一储气罐与第一储水罐共用同一储罐。

[0016] 本实用新型公开了一种压缩空气抽水储能系统，包括第一储气罐、空气压缩单元、第二储气罐、空气膨胀稳压单元、第一储水罐、水轮机组、第二储水罐以及水泵机组，其中，所述第一储气罐、所述空气压缩单元与所述第二储气罐依次连接形成储能通道；所述第二储气罐、所述空气膨胀稳压单元、所述第一储水罐、所述水轮机组与所述第二储水罐依次连接形成释能通道；所述第二储水罐、所述水泵机组与所述第一储水罐依次连接形成回水通道。所述压缩空气抽水储能系统以空气储罐作为储气容器避免了传统压缩空气储能系统地下洞穴选址困难的问题，并以高压力的水代替高位置的水，以水的压力水头代替水的重力水头，消除了传统抽水储能电站对地势差的依赖。

## 附图说明

[0017] 图1为本实用新型提供的压缩空气抽水储能系统的组成示意图；

[0018] 图2为图1所示空气压缩单元与空气膨胀稳压单元的组合示意图；

[0019] 图3为本实用新型提供的压缩空气储能系统储能过程第1示意图；

[0020] 图4为本实用新型提供的压缩空气储能系统储能过程第2示意图；

[0021] 图5为本实用新型提供的压缩空气储能系统储能过程第3示意图；

[0022] 图6为本实用新型提供的压缩空气储能系统回水过程示意图；

[0023] 图7为本实用新型提供的压缩空气储能系统释能过程第1示意图；

[0024] 图8为本实用新型提供的压缩空气储能系统释能过程第2示意图；

[0025] 图9为本实用新型提供的压缩空气储能系统释能过程第3示意图。

## 具体实施方式

[0026] 为了便于理解本实用新型，下面将对本实用新型进行更全面的描述。下述实施例中给出了本实用新型的较佳的实施例。但是，本实用新型可以以许多不同的形式来实现，并不限于本文所描述的实施例。相反地，提供这些实施例的目的是使对本实用新型的公开内容的理解更加透彻全面。

[0027] 除非另有定义，本文所使用的所有的技术和科学术语与属于本实用新型的技术领域的技术人员通常理解的含义相同。本文中在本实用新型的说明书中所使用的术语只是为了描述具体的实施例的目的，不是旨在于限制本实用新型。

[0028] 请参阅图1，本实用新型提供了一种压缩空气抽水储能系统，包括第一储气罐6、空气压缩单元10、第二储气罐5、空气膨胀稳压单元20、第一储水罐6、水轮机组30、第二储水罐7以及水泵机组40。其中，所述第二储气罐5为高压储气罐5，所述第二储水罐7为常压储水罐7。

[0029] 所述第一储气罐6、所述空气压缩单元10与所述高压储气罐5依次连接形成储能通道，所述第一储气罐6在储能通道中为中压储气罐6；所述高压储气罐5、所述空气膨胀稳压单元20、所述第一储水罐6、所述水轮机组30与所述常压储水罐7依次连接形成释能通道，所述第一储水罐6在释能通道中为高压储水罐6；所述第二储水罐、所述水泵机组与所述第一储水罐依次连接形成回水通道，所述第一储水罐6在回水通道中为高压储水罐6。在本实施例中，为节约成本，第一储气罐6和第一储水罐6可为同一储罐，只是在不同通道中作用不同，如为中压储气罐6或高压储水罐6。当然，中压储气罐6或高压储水罐6在压缩空气抽水储能系统中也可以为不同的储罐。

[0030] 请参阅图2，本实施例中，所述空气压缩单元10包含n(n≥1)级串联的压缩机，且空气压缩单元10的入口处安装有截止阀$V_{c1}$。所述空气压缩单元10以其第i(i<n)级压缩为例，在第i级压缩机出口安装有三通阀$T_{ci}$，所述三通阀$T_{ci}$的两个出口分别连接截止阀$V_{ci1}$和截止阀$V_{ci2}$，其中，截止阀$V_{ci1}$出口与第i+1级压缩机的入口连通，而截止阀$V_{ci2}$出口与高压储气罐5连通。本实施例中，所述空气压缩单元10中的n个压缩机为螺杆式、活塞式或离心式其中一种或多种的组合。

[0031] 本实用新型中，压缩过程方面是一个非稳态过程，压缩机的压比一直在变化，本实用新型采用多级压缩的方式，可以实现压比最大变化范围为1～50MPa，而传统压缩机很难实现这样大的压比调节范围，而且，所述多级压缩的方案包含了控制管路部分，可以实现在非稳态压缩过程中调节各单级压缩机的启停，从而实现各级压缩机能够工作在自己合适的压比范围内。

[0032] 请参阅图2，本实施例中，所述空气膨胀稳压单元20包含m(m≥1)级串联膨胀机组，且所述空气膨胀稳压单元20入口安装有截止阀$V_{e1}$。所述空气膨胀稳压单元20以第i(i<m)级膨胀为例，在第i级膨胀机入口安装有三通阀$T_{ei}$，所述三通阀$T_{ei}$的两个出口分别连接截止阀$V_{ei1}$和截止阀$V_{ei2}$，其中，截止阀$V_{ei1}$出口与第i级膨胀机的入口连通，截止阀$V_{ei2}$出口与三通阀$T_{ei+1}$的入口连通(若i＝m-1，则截止阀$V_{ei2}$出口直接与第m级膨胀机的入口连通)。本实施例中，所述空气膨胀稳压单元20的m个膨胀机为螺杆式、活塞式或离心式其中一种或多种组合。

[0033] 请参阅图1，在本实施例中，所述压缩空气抽水储能系统中高压储气罐5工作压力范围为1.0MPa～50.0MPa(A)；所述中压储气/高压储水罐6的空气/水工作压力范围为

0.1MPa～40.0MPa(A)，且其工作压力低于高压储气罐5中空气工作压力。

[0034]　请参阅图1，本实施例中，所述水轮机组30包含水轮机31和截止阀32，所述水轮机31为反击式水轮机或者冲击式水轮机，所述反击式水轮机为混流式、轴流式、斜流式或贯流式其中之一；所述混流式水轮机为水斗式、斜流式或双击式其中之一。

[0035]　请参阅图1，本实施例中，所述水泵机组40包含水泵41和截止阀42，所述水泵41为离心泵、涡旋泵、轴流泵、活塞泵、罗茨泵或螺杆泵其中之一。

[0036]　请参阅图1，本实施例中，所述中压储气/高压储水罐6与常压储水罐7顶部分别安装有放空阀8和放空阀9。

[0037]　需进一步说明的是，本实用新型的发电主要单元是水轮机，因此水轮机的效率直接影响了系统整体效率。为保证水轮机的高效运转，需要能够实现水轮机稳定的工况。水轮机的进口工况参数主要是指进口压力，因此，为实现系统整体的高效运转，需要保证水轮机进口压力的稳定，本实用新型采用多级空气膨胀稳压单元可以实现系统非稳态运行过程中水轮机进口压力的稳定，这也是本实用新型要设置中压储气罐的原因。

[0038]　下面按照储能-回水-释能依次进行的三个阶段来介绍本实用新型所提供的压缩空气抽水储能系统工作原理。

[0039]　请参阅图3-图5，所述压缩空气抽水储能系统的储能过程的工作原理如下：

[0040]　储能过程的初始时刻，所有阀门均关闭。此时，储罐6为中压储气罐6，高压储气罐5和中压储气罐6均充满空气，而且两个储罐中空气压力相同，常压储水罐中充满水。此时，关闭空气膨胀稳压单元20的截止阀$V_{e1}$、水轮机组30的截止阀32、水泵机组40的截止阀42、放空阀8和放空阀9，打开空气压缩单元10的截止阀$V_{c1}$。关闭截止阀$V_{c11}$，打开截止阀$V_{c12}$，开启第1级压缩机，中压储气罐6中空气不断被抽出，压力下降，高压储气罐5中压力上升(此时空气流动方向请参阅图3)。当高压储气罐5中压力升高到一定程度，超出第1级压缩机的调节能力的时候，打开截止阀$V_{c11}$和截止阀$V_{c22}$，关闭截止阀$V_{c12}$和截止阀$V_{c21}$，同时开启第2级压缩机(此时空气流动方向请参阅图4)。对于第i级压缩机，当高压储气罐5中空气压力超出第i级压缩机的调节能力时，则开启截止阀$V_{ci1}$和$V_{c(i-1)2}$，关闭截止阀$V_{ci2}$和$V_{c(i-1)1}$，并开启压缩机i+1。依次往下进行，当高压储气罐5中压力超过压缩机n-1的调节能力的时候，打开截止阀$V_{c(n-1)1}$，关闭截止阀$V_{c(n-1)2}$，开启第n级压缩机(此时空气流动方向请参阅图5)。此时。高压储气罐5中压力达到设定压力，所有空气压缩机均停机，并关闭所有截止阀，储能过程结束。

[0041]　请参阅图6，所述压缩空气抽水储能系统的回水过程的工作原理如下：

[0042]　回水过程的初始时刻，所有阀门均闭合。此时储罐6为高压储水罐6，打开放空阀8和放空阀9，打开截止阀42，开启水泵41，将水不断的从常压储水罐7中抽出，并送入高压储水罐6中，直至将常压储水罐7中水全部抽出，水泵41停机，关闭所有阀门，回水阶段结束。需要指明的是，这一阶段高压储水罐6中的水仍然是常压或者在很低的压力状态。

[0043]　请参阅图7-图9，所述压缩空气抽水储能系统释能过程的工作原理如下：

[0044]　释能过程的初始时刻，所有阀门均闭合。此时打开空气膨胀稳压单元20截止阀$V_{e1}$；各级膨胀机，以第i级为例，打开截止阀$V_{ei1}$，关闭截止阀$V_{ei2}$；打开水轮机组的截止阀32以及常压出水罐的放空阀9。开启各级膨胀机，并开启水轮机31。空气从高压储气罐5依次经过各级膨胀机进行膨胀减压，在第m级膨胀机出口达到设定压力，并进入高压储水罐6，将水

压缩至高压，高压水经截止阀32进入水轮机31，推动水轮机31做功发电，水轮机31排出的水进入常压储水罐7存储(此时空气流动方向请参阅图7)。随着释能过程的进行，高压储气罐5中的气压逐渐减小，当其压力低于第1级膨胀机的最小进气压力时，打开截止阀$V_{e12}$，关闭截止阀$V_{e11}$，第1级膨胀机停机，高压储气罐5中空气直接进入第2级膨胀机，并依次经过其后各级膨胀机进行膨胀减压(此时空气流动方向请参阅图8)。对于第i级膨胀，当高压储气罐5中空气压力降低至膨胀机i入口最小进气压力时，开启截止阀$V_{ei2}$，关闭截止阀$V_{ei1}$，膨胀机i停机，高压储气罐5中空气直接进入第(i+1)级膨胀机，并依次经过其后各级膨胀机进行膨胀减压。依次进行下去，当高压储气罐5中空气压力低于第(m-1)级膨胀机入口压力时，打开截止阀$V_{e(m-1)2}$，关闭截止阀$V_{e(m-1)1}$，第(m-1)级膨胀机停机，高压储气罐5中空气直接进入第m级膨胀机入口(此时空气流动方向请参阅图8)。当高压储水罐6中的水全部被推出时，第m级膨胀机和水轮机31停机，关闭所有截止阀，释能过程结束。

[0045] 本实用新型属于电力储存领域，公开了一种压缩空气抽水储能系统，涉及压缩空气储能技术与抽水储能技术，用于可以小型化的抽水储能系统。所述压缩空气抽水储能系统包括空气压缩单元、空气膨胀稳压单元、水轮机组、水泵机组、高压储气罐、中压储气罐、高压储水罐、以及常压储水罐。其中，中压储气罐、空气压缩单元与高压储气罐依次连接形成储能通道；高压储气罐、空气膨胀稳压单元、高压储水罐、水轮机组与常压储水罐依次连接形成释能通道；常压储水罐、水泵机组与高压储水罐依次连接形成回水通道。所述压缩空气抽水储能系统以空气储罐作为储气容器避免了传统压缩空气储能系统地下洞穴选址困难的问题；以高压力的水代替高位置的水，以水的压力水头代替水的重力水头，消除了传统抽水储能电站对地势差的依赖。本实用新型最大压力水头为40MPa，在相同发电容量的条件下，可实现将蓄水库容积缩小数十倍，有效实现抽水蓄能电站的小型化。

[0046] 以上所述实施例的各技术特征可以进行任意的组合，为使描述简洁，未对上述实施例中的各个技术特征所有可能的组合都进行描述，然而，只要这些技术特征的组合不存在矛盾，都应当认为是本说明书记载的范围。

[0047] 以上所述实施例仅表达了本实用新型的几种实施方式，其描述较为具体和详细，但并不能因此而理解为对实用新型专利范围的限制。应当指出的是，对于本领域的普通技术人员来说，在不脱离本实用新型构思的前提下，还可以做出若干变形和改进，这些都属于本实用新型的保护范围。因此，本实用新型专利的保护范围应以所附权利要求为准。

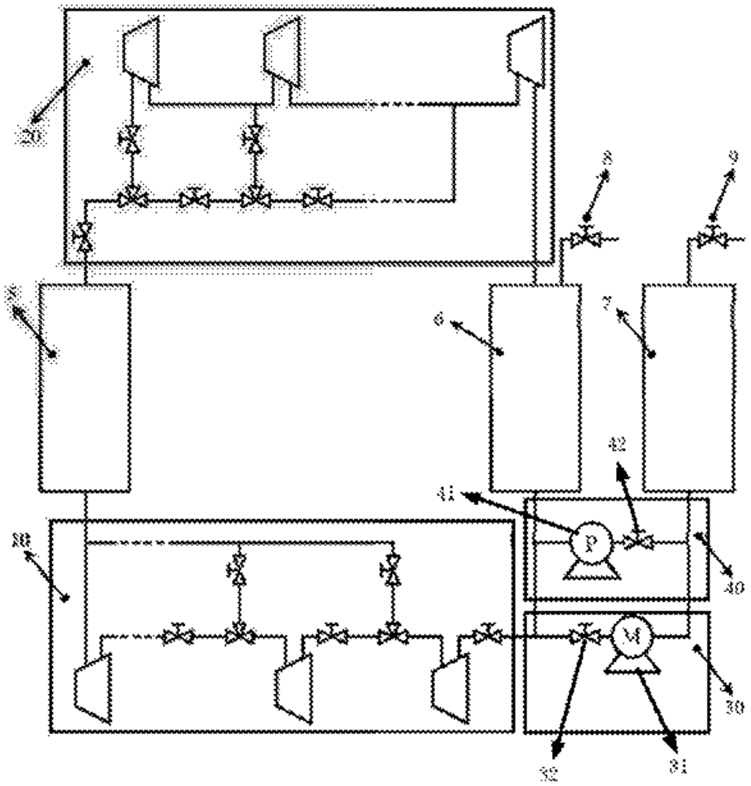


图1

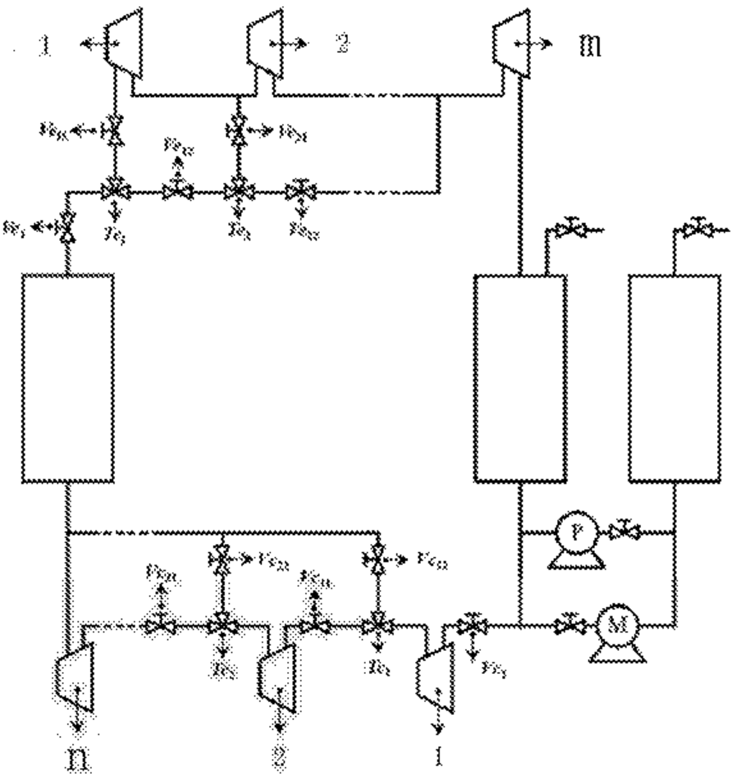


图2

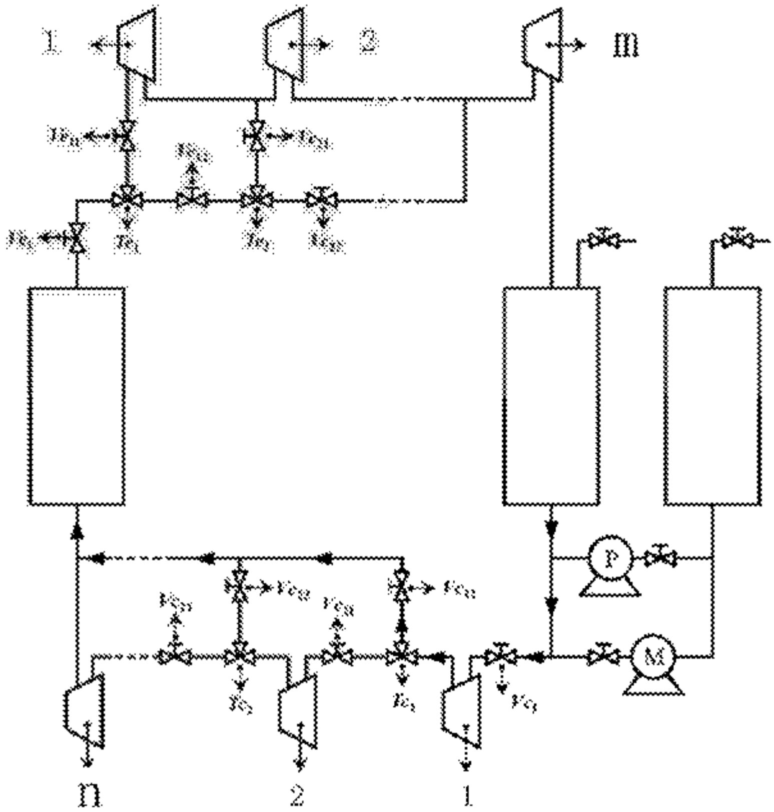


图3

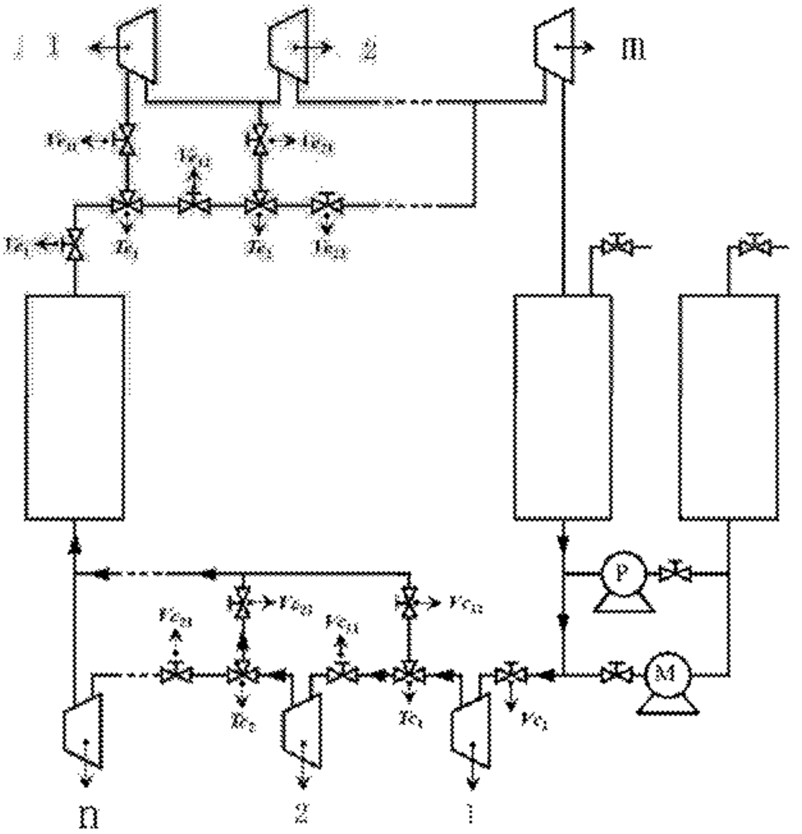


图4

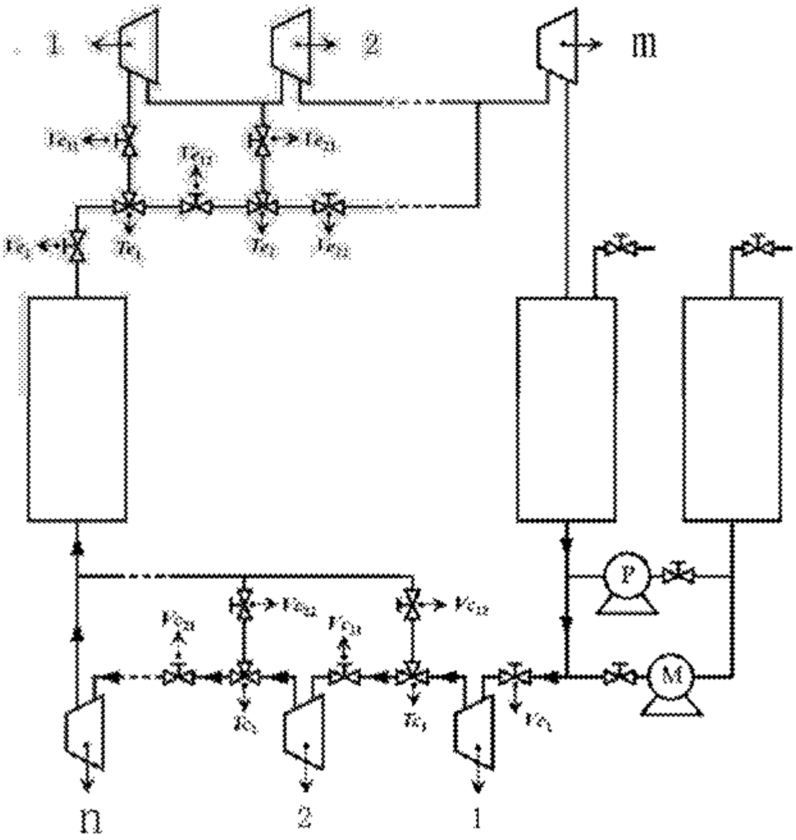


图5

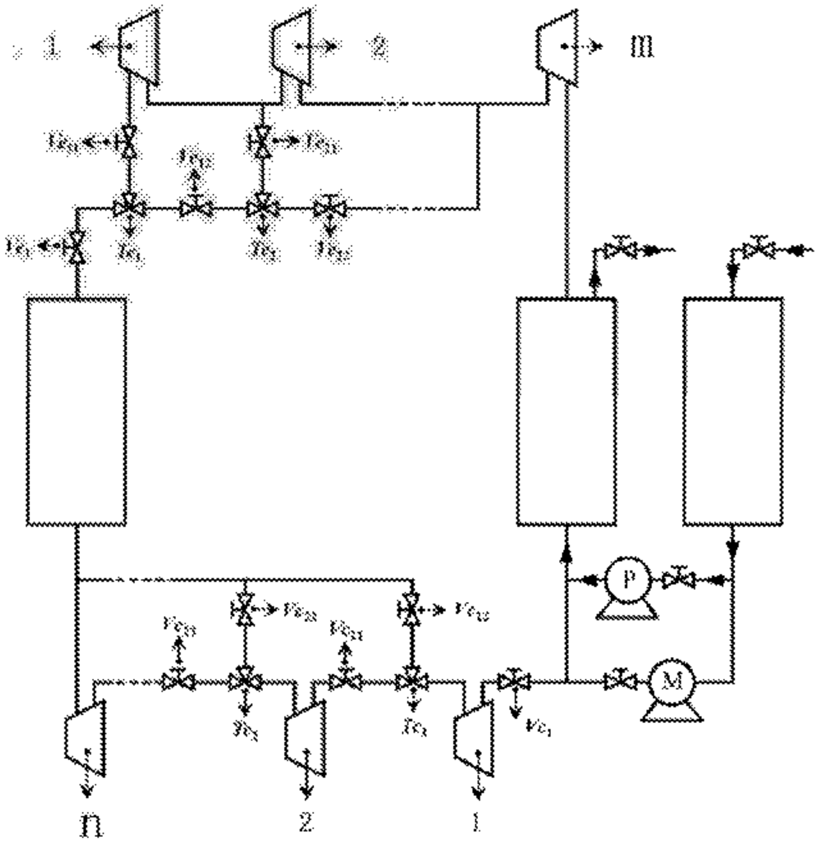

图6

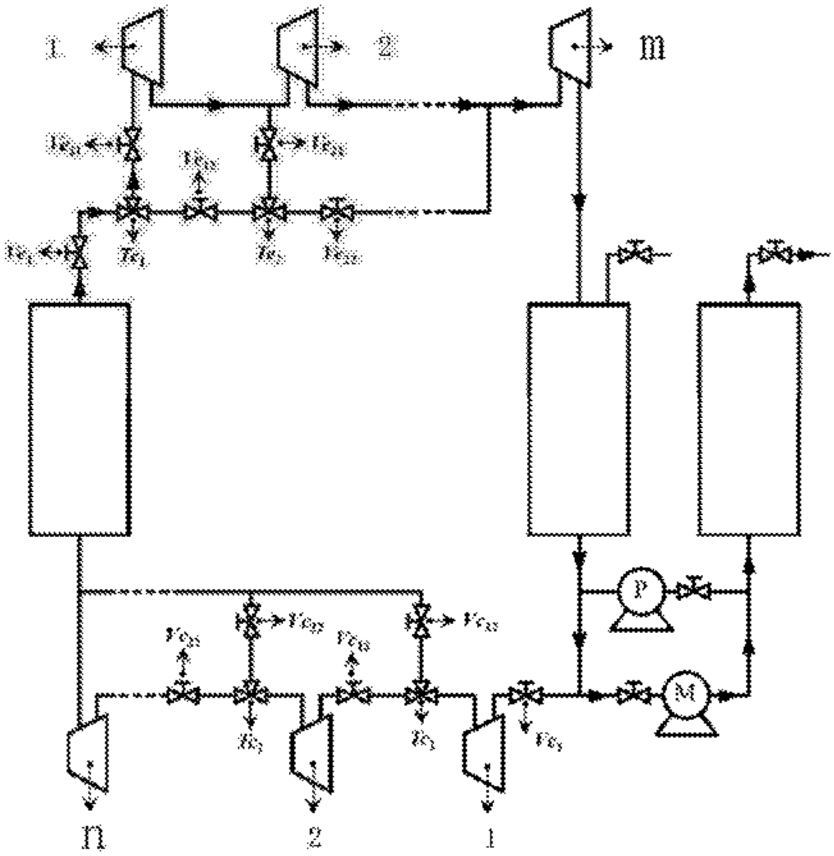

图7

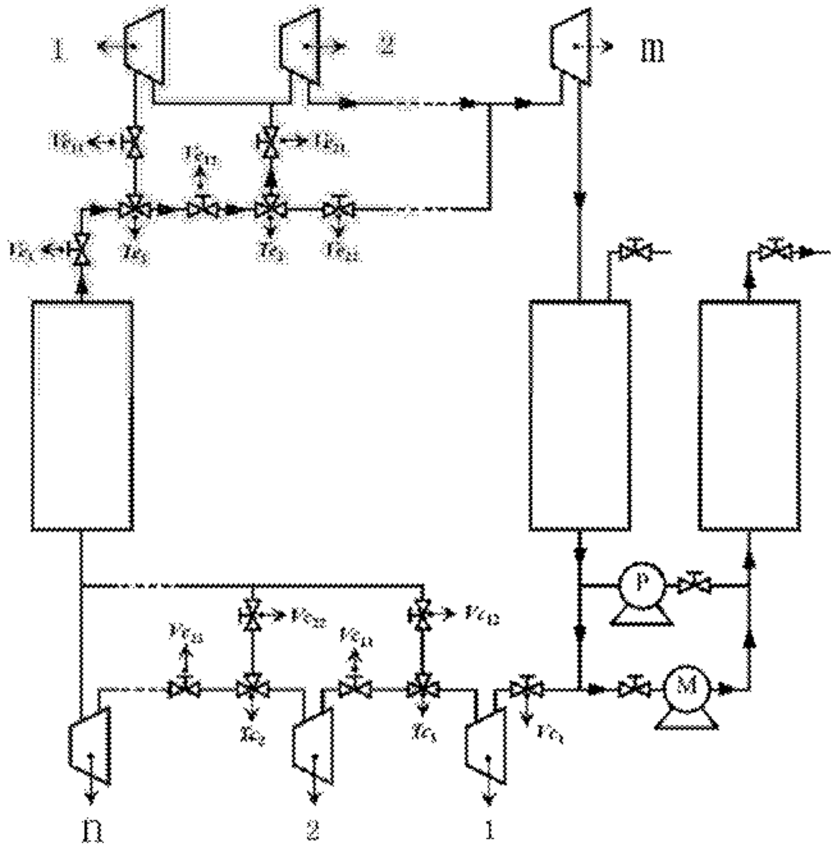


图8

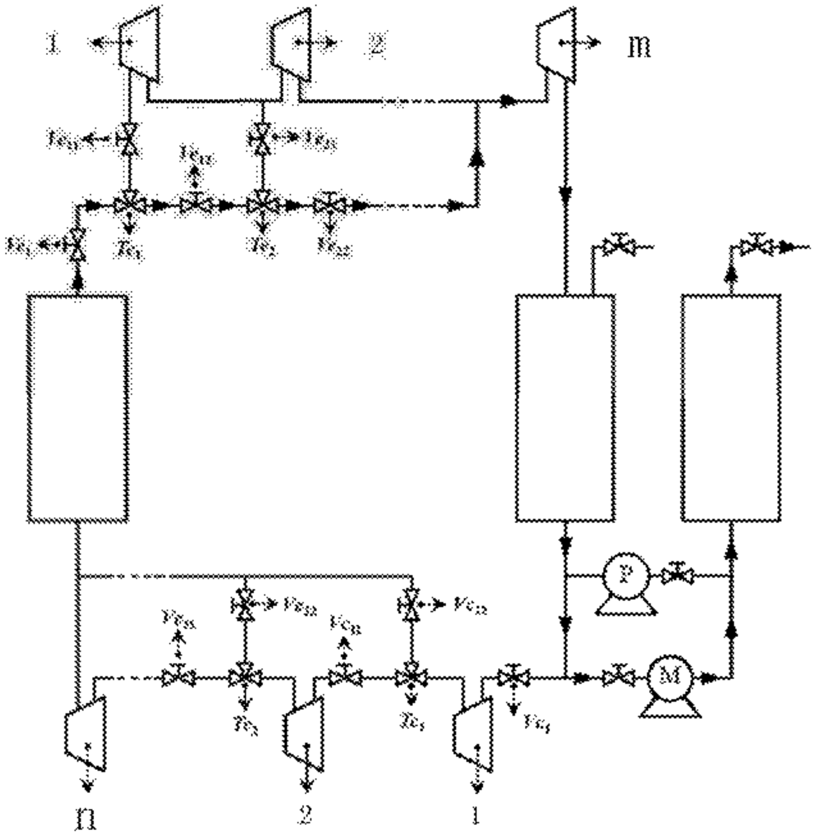

图9