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ABSTRACT

Disclosed are a drainage system and method, the drainage system comprises a water pump group provided with at least two water pumps, a control mechanism for controlling the operation of the water pump group, and at least one water level sensor for detecting water level information, the water pumps in the water pump group and the water level sensor are connected with the control mechanism; the water level sensor is configured to detect the water level information, and to send the detected water level information to the control mechanism; and the control mechanism is configured to command the water pumps in the water pump group to perform drainage when the water level information meets a preset condition.

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DRAINAGE SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims benefit of Chinese Patent Application No. 201711060147.X, filed on November 1, 2017, the contents of which are hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to the field of drainage technologies, and in particular to a drainage system and method.

BACKGROUND

With the high-yield and high-efficiency development of a coal industry, a mine safety problem has become a key factor that restricting the coal production. An underground drainage system is one of four systems in the coal production, and performs an important task in underground accumulated water drainage. The safety of the whole mine production is directly affected by the operation status of the underground drainage system. Once a failure occurs in the underground drainage system, not only the underground production is affected, but also a mine is even flooded, and the lives of workers are endangered.

At present, the underground main drainage system may be divided to two types of an manual on-site control system and an automatic control system, with the manual on-site control system has the following two existing problems: (1) assuming a mode of mainly manual controlling by a person, resulting in a poor precision of water level detection, a great randomness of operation, and an impossibility of a real-time monitoring of water inflow and a scientific scheduling of a drainage process. In the case of the water inflow is suddenly increased, and it is not discovered and treated in time by an operator, a serious safety accident will be caused; and (2) the high-strength workload cannot be avoided in the manual operation, especially the operation of a gate

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valve, needing the largest workload. Although the automatic control system solves partial problems of the manual on-site control system, the problems that control functions are incomplete, unattended underground automatic operation and real-time monitoring and controlling by a ground person cannot be realized are still existed; and the automatic control system has a high equipment failure rate.

For the problems of the automatic control system, many solutions are provided in the industry, for example, in an invention patent application with a publication number CN106194761A, named as "Automatic drainage system of transfer water sump", a negative pressure water tank and a centrifugal pump are used, and liquid in the transfer water sump is pumped by means of a negative pressure, and an existing water discharging electric gate valve, a water injection electric ball valve, an air exhausting electric ball valve and a bottom valve are omitted, such that the structure of the automatic drainage system is simplified, and it is easy for the automatic drainage system to maintain and replace, and the cost is reduced. However, the drainage system of this type has an onefold starting mode, and is not competent to a sudden water burst, a water permeating or a water gushing-out accident of the mine, but only to a local drainage problem, thus this drainage system is not competent to the drainage of the whole mine, and has a high equipment failure rate.

For another example, in a utility model patent with a notification number CN204041108U, named as " Automatic water drainage system used in coal mining area track dip tunneling process", a floating ball valve is used for automatically performing the drainage, it is simple to operate and reduces accidents caused by an operator who forgets to operate. However, the same problems that the drainage system of this type has an onefold starting mode and has a high equipment failure rate are still existed. And this patent is applied to drain distributed water holes, for example, only suitable for a drainage that a depth is less than 1 m, and the application of this drainage system is significantly limited.

SUMMARY

In view of this, the disclosure aims to provide a drainage system and method capable of handling sudden water burst, water permeating or water gushing-out accidents, and reducing an equipment failure rate.

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In order to achieve the above purpose, the technical solution of the disclosure is realized as follows.

The disclosure provides a drainage system, the drainage system includes: a water pump group provided with at least two water pumps, a control mechanism for controlling operation of the water pump group, and at least one water level sensor, the water pumps in the water pump group and the water level sensor are connected with the control mechanism.

The water level sensor is configured to detect water level information, and send the detected water level information to the control mechanism.

The control mechanism is configured to command the water pumps in the water pump group to perform drainage when the water level information meets a preset condition.

Preferably, the water level information includes a water level and a water level variation rate.

Two water level sensors are provided, each of which is positioned at a preset distance from a water suction port of the water pump.

Preferably, the control mechanism is a PLC, the control mechanism is provided with a recording component for recording an operation status of each water pump in the water pump group.

Preferably, each water pump in the water pump group is provided with a temperature sensor and a current sensor for detecting working load status of the water pump, the temperature sensor and the current sensor are connected with the control mechanism.

Preferably, each water pump in the water pump group is individually provided with a water inlet pipe and a drainage pipe, and each drainage pipe is provided with a water valve. A drainage pipe between each water valve and each water pump is internally provided with a water pressure sensor for detecting suction capacity of the water pump, and the drainage pipe at an outlet of each water valve is provided with a flow sensor for detecting the suction capacity of the water pump. The water valve, the water pressure sensor and the flow sensor are connected with the control mechanism.

Preferably, each of the water pumps in the water pump group is a centrifugal pump, a jet pump for assisting the centrifugal pump to generate a negative pressure is provided above the centrifugal pump; and the water valve is a gate valve.

Preferably, the drainage system further includes a remote console for remotely

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monitoring the drainage system, and an on-site operating platform for the ease of controlling the drainage system in maintenance.

The remote console and the on-site operating platform are connected with the control mechanism, and each of the remote console and the on-site operating platform is provided with an operating button for controlling the operation of the drainage system.

The disclosure further provides a drainage method, which includes the following acts.

Water level information detected by a water level sensor is acquired.

, A water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition.

Preferably, the act that the water level information detected by the water level sensor is acquired includes a water level and a water level variation rate detected by the water level sensor is acquired.

The act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition includes the water pump group provided with at least two water pumps is commanded to perform drainage when the water level exceeds a preset water level threshold value and/or the water level variation rate exceeds a preset water level variation rate threshold value.

Preferably, before the water level information detected by the water level sensor is acquired, the method further includes the following acts.

An operating status of each water pump in the water pump group is recorded.

According to the operating status of each water pump in the water pump group, a using priority of each water pump is determined.

Preferably, the act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition includes the following act.

According to the water level information and the using priority of each water pump, a water pump to be started in the water pump group is determined.

Preferably, the act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition includes the following acts.

A part of water pumps in the water pump group are commanded to perform

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drainage when the water level exceeds a first preset water level threshold value and/or the water level variation rate exceeds a first preset water level variation rate threshold value, and the present time is within a power consumption trough period.

All water pumps in the water pump group are commanded to perform drainage when the water level exceeds a second preset water level threshold value and/or the water level variation rate exceeds a second preset water level variation rate threshold value.

The water pump group is commanded to stop draining when the water level is lower than a third preset water level threshold value, or the present time is within a power consumption peak period and the water level is lower than a first preset water level threshold value.

Preferably, after the act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition, the method further includes the following acts.

A water pressure in a drainage pipe of each water pump is acquired, and a corresponding water pump is shut down when the water pressure is lower than a preset water pressure threshold value.

Preferably, after the act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition, the method further includes the following acts.

A flow in the drainage pipe of each water pump and an opening state of a water valve is acquired, and a corresponding water pump is shut down when the water valve is completely opened and the flow is lower than a preset flow threshold value.

Preferably, after the act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition, the method further includes the following acts.

An operation temperature and an operation current of a motor of each water pump is acquired, and a corresponding water pump is shut down when the operation temperature is greater than a preset temperature threshold value and/or the operation current is greater than a preset current threshold value.

The drainage system and method according to the embodiments of the disclosure provides at least one water level sensor for detecting a water level and a water level variation rate, and the start-up of water pumps in a water pump group in the drainage system may be determined according to the water level and/or the water level

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variation rate acquired by the water level sensor, thereby the water pump group in the drainage system may be started to perform drainage in time when sudden water burst, water permeating or water gushing-out accidents occur in a mine, so that safety accidents may be avoided. Further, at least two water pumps are provided, which may operate alternatively when a water discharge is not large, such that starting count and operating time of the water pumps may be reduced, and an equipment failure rate may be reduced.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic diagram of the drainage system according to a first embodiment of the disclosure;

FIG. 2 is a schematic diagram of the drainage system according to a second embodiment of the disclosure;

FIG. 3 is a flow schematic diagram of a drainage method according to a third embodiment of the disclosure;

FIG. 4 is a flow schematic diagram illustrating determination of the start-up of water pump according to a water level, a water level variation rate and a power consumption period according to a fourth embodiment of the disclosure;

FIG. 5 is a flow schematic diagram of the start-up of single water pump according to a fifth embodiment of the disclosure;

FIG. 6 is a flow schematic diagram of monitoring of the operation status of a water pump according to a sixth embodiment of the disclosure.

DETAILED DESCRIPTION

The disclosure provides a drainage system, including: a water pump group provided with at least two water pumps, a control mechanism for controlling the operation of the water pump group, and at least one water level sensor for detecting water level information. The water pumps in the water pump group and the water level sensor are connected with the control mechanism; when the water level information meets a preset condition, the control mechanism commands the water pump group to perform drainage.

A principle of the disclosure is as follows: at least one water level sensor for

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detecting a water level and a water level variation rate is provided, and the start-up of the water pumps in the water pump group in the drainage system may be determined according to the water level and/or the water level variation rate acquired by the water level sensor, such that the water pump group in the drainage system may be started in time to perform drainage in the case of sudden water burst, water permeating or water gushing-out accidents of the mine, thus safety accidents may be avoided, and by providing at least two water pumps, which operates alternatively in the case of a minor drainage, a start-up count of the water pumps and operating time may be reduced, as a result, an equipment failure rate may be reduced.

For the purpose of understanding the features and technical solutions of the embodiments of the disclosure in more details, the disclosure will be further described below with reference to the drawings and the specific application embodiments, the accompanying drawings are only for the reference, and are not intended to limit the embodiments of the disclosure.

First Embodiment

FIG. 1 is a schematic diagram of a drainage system according to the first embodiment of the disclosure. As shown in FIG. 1, the drainage system includes a water pump group 11, a control mechanism 12 and a water level sensor 13.

The water pump group 11 is configured to perform drainage according to an instruction of the control mechanism 12The water pump group 11 is provided with at least two water pumps, so that the water pumps may operate alternatively, thereby an equipment failure rate may be reduced.

The control mechanism 12 is configured to , command the water pump group 11 to perform drainage when the water level information meets a preset condition.

The water level information here includes a water level and a water level variation rate, the water level variation rate is also named as a water level variation ratio. For the convenience of processing, the water level variation rate in the case of the water level increasing is defined as a positive value, and in the case of the water level decreasing is defined as a negative value, thereby a large water level variation rate indicates that the water level is increasing in a great rate.

The water level information meeting a preset condition includes the water level exceeding a preset water level threshold value and/or the water level variation rate exceeding a preset water level variation rate threshold value.

The water level sensor 31 is configured to detect the water level information,

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and send the detected water level information to the control mechanism 12.

Second Embodiment

FIG. 2 is a schematic diagram of a drainage system according to the second embodiment of the disclosure. As shown in FIG. 2, the drainage system includes a water pump group 21, a PLC 22, a water level sensor 23, a gate valve 24, a water pressure sensor 25, a flow sensor 26, a temperature sensor 27, a current sensor 28, a remote console 29 and an on-site operating platform.

The water pump group 21 is configured to perform drainage according to an instruction of the PLC 22, the water pump group 21 is provided with at least two water pumps, so that the water pumps may operate alternatively, thereby an equipment failure rate may be reduced.

Each of the water pumps is a centrifugal pump, and a jet pump for assisting the centrifugal pump to generate a negative pressure is provided above each centrifugal pump. Specifically, a water pump starting flow includes: firstly the jet pump is started, making the centrifugal pump to generate a negative pressure, namely a vacuum degree, then water is sucked by a water inlet pipe, and the centrifugal pump is started.

The jet pump is provided with a negative pressure sensor, configured to detect a negative pressure of the jet pump. When the negative pressure reaches a preset negative pressure threshold value, a valve of the water inlet pipe of the centrifugal pump is opened, water is sucked to a cavity of the centrifugal pump, and the centrifugal pump is started.

The PLC 22 is configured to command the water pump group 21 to perform drainage when the water level information meets a preset condition.

The water level information meeting the preset condition includes the water level exceeding a preset water level threshold value and/or the water level variation rate exceeding a preset water level variation rate threshold value.

Further, the PLC 22 is configured to determine whether the drainage is needed according to the present time, except to determine whether the water pump group 21 needs to perform drainage according to water level information.

Specifically, in the case that the water level exceeds a first preset water level threshold value and/or the water level variation rate exceeds a first preset water level variation rate threshold value, and the present time is within a power consumption trough period, the part of water pumps in the water pump group 21 are commanded to perform drainage.

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In the case that the water level exceeds a second preset water level threshold value and/or the water level variation rate exceeds a second preset water level variation rate threshold value, all water pumps in the water pump group 21 are commanded to perform drainage.

The first preset water level threshold value, the first preset water level variation rate threshold value, the second preset water level threshold value and the second preset water level variation rate threshold value here are all set according to the specific circumstance of a site needing the drainage. For example, the first preset water level threshold value and the second preset water level threshold value may be determined according to a height of a mine tunnel, and the first preset water level variation rate threshold value and the second preset water level variation rate threshold value and the like may be determined according to a theoretical water storage of the mine tunnel.

The second preset water level threshold value and the second preset water level variation rate threshold value indicate that the water level or the water level variation rate is very high, an accident may be caused if the drainage is not performed immediately; and the first preset water level threshold value and the first preset water level variation rate threshold value indicate that the water level or the water level variation rate is a little high, but is still within a controllable range. When the present time is within the power consumption trough period, the drainage may be performed, and when the present time is not within the power consumption trough period, the drainage may be postponed.

The electricity price within the power consumption trough period is different from that within a non-power consumption trough period; thereby, a grid load may be balanced, and an electricity expenditure may be saved because of the different peak electricity price and trough electricity price; namely, a purpose of saving energy may be achieved by "shifting the peak to fill the trough" in the power consumption.

In the case that the water level is lower than a third preset water level threshold value, or the present time is within a power consumption peak period and the water level is lower than the first preset water level threshold value, the water pump group 21 is commanded to stop the drainage.

The third preset water level threshold value here is a lowest water level which may be realized by the drainage, namely water is drained away as much as possible in the power consumption trough period, so that a possible biggest volume of a water sump may be obtained; and in the power consumption peak period, as long as the water

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level is lower than the first preset water level threshold value, the drainage may be stopped.

In other words, the electric energy may be saved in a greatest degree by monitoring the grid load in real time, taking a control strategy "avoiding the peak but approaching the trough", and planning and scheduling the starting and stopping of the water pumps in the water pump group, thereby the water pumps are scheduled to be prevented from being started in a "peak period" as possible, but to operate in a power consumption "trough period" and "flat period". The water level in the water sump is lowered to a set low level, so that the possible biggest volume of the water sump may be obtained, thereby more mine inflow may be accommodated in the water sump during the "peak period" without starting the water pumps.

Further, the water level and the water level variation rate in the water level information may be set more threshold values besides those abovementioned, so that the number of the started water pumps in the water pump group 21 may be more accurate, and the energy consumption may be reduced better; namely, according to the water level, the water level variation rate and the peak and trough periods, not only the start-up of the water pumps may be determined, but also the number of the started water pumps may be determined.

It may be understood that the threshold value setting of the water level information may be continuously corrected according to using conditions.

Furthermore, the PLC 22 may record an operating status of each water pump in the water pump group 21, and determine a using priority of each water pump according to the operating status of each water pump in the water pump group 21, so that the water pumps with high using priority may be preferentially started; thereby an alternative operation of the water pumps may be realized on the basis of the using priority of each water pump, as a result, the equipment failure rate may be reduced, and the equipment service life may be improved.

The operating status of the water pumps may include accumulated operating time, latest using time, an accumulated using count, and an accumulated failure count and the like.

The PLC 22 may realize a function of recording the operation status of the water pump through programming a corresponding program, or through additionally providing a single recorder.

The PLC 22 is further configured to determine a suction capacity of each water

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pump according to a water pressure within a drainage pipe of the water pump, and shut the water pumps with a poor suction capacity down; determine the suction capacity of the water pump according to a flow in the drainage pipe and a opening status of the gate valve 24, and shut the water pump with a poor suction capacity down; or determine a working load status of each water pump according to an operation temperature and an operation current of a motor of the water pump, and shut the water pumps with a heavy working load down.

The water pressure in the drainage pipe here means a water body pressure in the drainage pipe between the gate valve 24 and the water pump group 21, namely the water pressure in close proximity to a water outlet of the water pump. In the case without other abnormal conditions, the water pressure may reflect the suction capacity of the water pump, and a low water pressure may indicate a poor suction capacity of the water pump, namely the water pump may being subject to a failure.

The flow in the drainage pipe means a drainage flow at the outlet of the gate valve 24, in the case that the gate valve 24 is completely opened, a low flow here may also indicate a poor suction capacity of the water pump.

In conclusion, the PLC 22 may monitor the performance and operation status of the water pump or the motor of the water pump according to the water pressure in the drainage pipe of each water pump or the flow in the drainage pipe, namely in the case that any one of the water pressure sensor 25 and the flow sensor 26 detects a low water pressure or a low flow, the water pump or the motor of the water pump may be subject to a poor performance or a poor operation status.

The operation temperature and operation current of each motor of the water pumps are intended to reflect the working load status of the motor of the water pump, when a water body contains impurities causing increased resistance, or a shaft or a bearing of the motor of the water pump is abraded or subject to a poor lubrication, causing an increased load, the operation temperature and/or the operation current of the motor of the water pump may increase as a result; certainly, the increased operation temperature and operation current of the motor of the water pump may be caused by other reasons in a small portion, such as long operation time, a high environment temperature and the like. However, no matter what the reason is, it may indicate that the water pump is subject to a failure, so shutting down the water pump with a high operation temperature or high operation current in time may reduce the equipment failure rate, and improve the equipment service life.

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Further, after the PLC 22 shutting the water pumps which may have a failure, other idle water pumps will be started, when there is no idle water pump, a corresponding warning message may be sent. Certainly, the water pump group of the drainage system is designed to have a certain margin in the total water drainage thereof, even if a certain water pump is shut down because of the failure, no big influence will be arisen.

The water level sensor 23 is configured to detect the water level information, and send the detected water level information to the PLC 22.

In order to accurately detect the water level information, two water level sensors 23 are provided, and each of the two water level sensors is positioned at a preset distance from a suction port of the water pump.

The preset distance may be set according to the specific circumstance of the site needing the drainage, for example, a length of a mine tunnel, so that make sure the two water level sensors 23 to be uniformly arranged in the mine tunnel.

The gate valve 24 is configured to open the valve to drain when the water pressure in the drainage pipe is greater than a preset water pressure threshold value. It is to be noted that when the water pressure is not greater than the preset water pressure threshold value, the valve should not be opened, otherwise, the negative pressure within the water pump will be prevented from being generated, so that the suction capacity of the water pumps will be affected, and the water pumps may be damaged.

Specifically, the gate valve 24 is further provided with a pressure sensor, the pressure sensor is configured to monitor the pressure at the bottom of a gate plate, so that the action of a hydraulic cylinder may be stopped in time, to avoid the problem that a hydraulic pump motor being locked, and the gate plate or other parts are deformed because of the over travel of the gate plate. In addition, an overflow valve is further provided in a hydraulic pipe of a gate valve hydraulic system, thereby, after the gate plate finishing to open or close, namely after the gate plate reaching a preset position, hydraulic oil in the hydraulic pipe may be unloaded via the overflow valve, to further avoid the problem that the hydraulic pump motor being locked, and the gate plate or other parts are deformed because of the over travel of the gate plate.

The preset water pressure threshold value is set according to types and specifications of the specific water pump, a manufacture factory may set a recommended value generally.

The gate valves 24 may be provided to be in one-to-one correspondence with

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the water pumps, namely the drainage pipe of each water pump is provided with the gate valve 24. FIG. 2 separately shows the gate valve 24, so that an electric connection relation between the gate valve 24 and the PLC 22 may be illustrated.

The water pressure sensor 25 is configured to detect a water pressure of the drainage pipe between the gate valve 24 and the water pump group 21.

The flow sensor 26 is configured to detect a drainage flow at the outlet of the gate valve 24.

The temperature sensor 27 and the current sensor 28 are configured to detect the operation temperature and the operation current of the motor of the water pump.

The remote console 29 is configured to receive information with respect to the operation status of the drainage system sent by the PLC 22, and display through a display screen and/or an indicating lamp, thereby remotely monitor the operation status of the whole drainage system; and the remote console is further configured to remotely operate the drainage system in an emergency circumstance. The remote console 29 is provided with an operating button for controlling the operation of the drainage system.

The remote operation of the remote console 29 includes two modes, a manual mode and a semi-automatic mode. In the manual mode, an operator manually controls the following operations: the starting or shutting of the water pump group 21, which water pumps to be started, how long the water pumps are started for, and whether shutting the water pumps immediately or not when a failure occurs to the water pumps and the like. In the semi-automatic mode, the operator starts or shuts the water pump group 21 according to the water level information situation, but the following operations are controlled by the drainage system automatically: which water pumps to be started, how long the water pumps being started for, and whether shutting the water pumps immediately or not when a failure occurs to the water pumps and the like.

The on-site operating platform is configured to manually control the drainage system in an emergency circumstance or maintenance. The on-site operating platform is provided with an operating button for controlling the operation of the drainage system.

In conclusion, the drainage system according to the disclosure may use multiple detection components, be capable of accurately acquiring the water level, the water level variation rate, the performance and operation status of the water pump, use multiple drainage modes, and be able to handling the sudden water burst, water permeating or water gushing-out accidents of the mine; the drainage system may

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further determine the using priority of each water pump according to the operation status of each water pump in the water pump group 21, so as to alternate the water pumps regularly, thereby the equipment failure rate may be greatly reduced. In addition, the drainage system may adapt to more applications and be more widely used because of using the multiple detection components and the multiple drainage modes.

Third Embodiment

FIG. 3 is a schematic diagram of a drainage method according to a third embodiment of the disclosure. As shown in FIG. 3, the method includes the following acts.

S301: water level information detected by a water level sensor is acquired.

Specifically, a drainage system includes a water pump group, a PLC and the water level sensor, the PLC acquires the water level information through the water level sensor.

The act that the water level information detected by the water level sensor is acquired includes the following acts.

A water level and a water level variation rate detected by the water level sensor are acquired by the PLC.

The water level variation rate here is also named as a water level variation ratio. for the convenience of processing, the water level variation rate in the case of the water level increasing is defined as a positive value, and in the case of the water level decreasing is defined as a negative value, thereby a large water level variation rate indicates that the water level is increasing in a great rate.

Further, before the water level information being acquired, the method further includes the following acts.

An operation status of each water pump in the water pump group is recorded by the PLC.

A using priority of each water pump is determined by the PLC according to the operation status of each water pump in the water pump group. Thus, an alternative operation of the water pumps may be realized on the basis of the using priority of each water pump, thereby the equipment failure rate may be reduced, and the equipment service life may be improved.

Specifically, the operation status of the water pumps may include accumulated operating time, latest using time, an accumulated using count, and an accumulated failure count and the like.

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The PLC may realize a function of recording the operation status of the water pump through programming a corresponding program, or through additionally providing a single recorder.

Furthermore, the drainage system is further provided with a remote console, the water level and the water level variation rate acquired by the PLC may be intuitively displayed on a display screen of the remote console.

S302: the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition.

The act that the water level information meets the preset condition includes: the water level exceeds a preset water level threshold value and/or the water level variation rate exceeds a preset water level variation rate threshold value.

Further, the act that the water pump group provided with at least two water pumps is commanded by the PLC to perform drainage when the water level information meets the preset condition includes the following act.

The water pumps to be started in the water pump group are determined by the PLC according to the water level information and a using priority of each water pump.

Thus, in the case that not all water pumps are needed, the water pumps may be started alternatively according to the using priority of each water pump, thereby the equipment failure rate may be reduced, and the equipment service life may be improved.

Further, the act that the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets the preset condition further includes the following acts.

A part of water pumps in the water pump group are commanded by the PLC to perform drainage when the water level exceeds a first preset water level threshold value and/or the water level variation rate exceeds a first preset water level variation rate threshold value, and the present time is within a power consumption trough period.

All water pumps in the water pump group are commanded by the PLC to perform drainage when the water level exceeds a second preset water level threshold value and/or the water level variation rate exceeds a second preset water level variation rate threshold value.

The first preset water level threshold value, the first preset water level variation rate threshold value, the second preset water level threshold value and the second preset

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water level variation rate threshold value are all set according to the specific circumstance of a site needing the drainage. For example, the first preset water level threshold value and the second preset water level threshold value may be determined according to a height of a mine tunnel, and the first preset water level variation rate threshold value and the second preset water level variation rate threshold value and the like may be determined according to a theoretical water storage of the mine tunnel.

The second preset water level threshold value and the second preset water level variation rate threshold value indicate that the water level or the water level variation rate is very high, an accident may be caused if the drainage is not performed immediately; and the first preset water level threshold value and the first preset water level variation rate threshold value indicate that the water level or the water level variation rate is a little high, but is still within a controllable range. When the present time is within the power consumption trough period, the drainage may be performed, and when the present time is not within the power consumption trough period, the drainage may be postponed.

The electricity price within the power consumption trough period is different from that within a non-power consumption trough period; thereby, a grid load may be balanced, and the electricity expenditure may be saved because of the different peak electricity price and trough electricity price; namely, a purpose of saving energy may be achieved by "shifting the peak to fill the trough" in the power consumption.

In the case that the water level is lower than a third preset water level threshold value, or the present time is within a power consumption peak period and the water level is lower than the first preset water level threshold value, the water pump group is commanded to stop the drainage.

The third preset water level threshold value here is a lowest water level which may be realized by the drainage, namely water is drained away as much as possible in the power consumption trough period, so that a possible biggest volume of a water sump may be obtained; and in the power consumption peak period, as long as the water level is lower than the first preset water level threshold value, the drainage may be stopped.

In other words, the electric energy may be saved in a greatest degree by monitoring the grid load in real time, taking a control strategy "avoiding the peak but approaching the trough", and planning and scheduling the starting and stopping of the water pumps in the water pump group, thereby the water pumps are scheduled to be

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prevented from being started in a "peak period" as possible, but to operate in a power consumption "trough period" and "flat period". The water level in the water sump is lowered to a set low level, so that the possible biggest volume of the water sump may be obtained, thereby more mine inflow may be accommodated in the water sump during the "peak period" without starting the water pumps.

Further, the water level and the water level variation rate in the water level information may be set more threshold values besides those above mentioned, so that the number of the started water pumps in the water pump group may be more accurate, and the energy consumption may be reduced better; namely, according to the water level, the water level variation rate and the peak and trough periods, not only the start-up of the water pumps may be determined, but also the number of the started water pumps may be determined.

In an emergency circumstance, the water pump group may be manually operated to perform drainage through an operation button provided on the remote console, or the water pump group may be started to perform drainage through the on-site operating platform.

Further, after the act that the water pump group provided with at least two water pumps being commanded to perform drainage when the water level information meets the preset condition, the method further includes the following acts.

A water pressure within a drainage pipe of each water pump is acquired by the PLC, and when the water pressure is less than a preset water pressure threshold value, the water pumps are shut by the PLC.

The water pressure in the drainage pipe here means a water body pressure in the drainage pipe between the gate valve and the water pump group, namely the water pressure in close proximity to a water outlet of the water pump. In the case without other abnormal conditions, the water pressure may reflect the suction capacity of the water pump, and a low water pressure may indicate a poor suction capacity of the water pump, namely the water pump may being subject to a failure. The preset water pressure threshold value may be set according to types, specifications and the like of the specific water pumps, and a manufacturer may set a recommended value generally.

Additionally, in the case that a cavity is not filled with water during the operation of the water pump, a relatively large suction force cannot be generated, such that relatively little water is sucked by a water inlet pipe, leading to an "operation without water" of the water pump, and the service life of the water pumps will be

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seriously affected.

Further, after the act that the water pump group provided with at least two water pumps being commanded to perform drainage when the water level information meets the preset condition, the method further includes the following acts.

A flow in the drainage pipe of each water pump and an opening state of a water valve is acquired by the PLC, when the water valve is completely opened, the corresponding water pump is shut in the case that the flow is less than a preset flow threshold value.

The flow within the drainage pipe means a drainage flow at the outlet of the gate valve, the flow here also may reflect the suction capacity of the water pump. In the case that the gate valve is completely opened, a flow less than a preset flow threshold value may indicate a poor suction capacity of the water pump. The preset flow threshold value may be set according to types, specifications and the like of the specific water pumps, and a manufacturer may set a recommended value generally.

Further, after the act that the water pump group provided with at least two water pumps being commanded to perform drainage when the water level information meets the preset condition, the method further includes the following acts.

An operation temperature and an operation current of each motor of water pumps is acquired by the PLC, the corresponding water pump is shut in the case that the operation temperature is greater than a preset temperature threshold value and/or the operation current is greater than a preset current threshold value.

The operation temperature and the operation current of each motor of the water pumps are intended to reflect the working load status of the motors of the water pumps, when a water body contains impurities causing increased resistance, or a shaft or a bearing of the motor of the water pump is abraded or subject to a poor lubrication, causing an increased load, the operation temperature and/or the operation current of the motor of the water pump may increase as a result; certainly, the increased operation temperature and operation current of the motor of the water pump may be caused by other reasons in a small portion, such as long operation time, a high environment temperature and the like. However, no matter what the reason is, it may indicate that the water pump is subject to a failure, so shutting down the water pump with a high operation temperature or high operation current in time may reduce the equipment failure rate, and improve the equipment service life.

The preset temperature threshold value and the preset current threshold value

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may be set according to types, specifications and the like of the specific water pumps, and a manufacturer may set a recommended value generally.

In an emergency circumstance, the corresponding water pump may be manually stopped through an operation button provided on the remote console, or the corresponding water pump may be directly stopped through the on-site operating platform.

Further, after the PLC shutting the water pumps which may have a failure, other idle water pumps will be started, when there is no idle water pump, a corresponding warning message may be sent. Certainly, the water pump group of the drainage system is designed to have a certain margin in the total water drainage thereof, even if a certain water pump is shut down because of the failure, no big influence will be arisen.

In conclusion, the drainage system according to the disclosure may use multiple detection components, be capable of accurately acquiring the water level, the water level variation rate, the performance and operation status of the water pump, use multiple drainage modes, and be able to handling the sudden water burst, water permeating or water gushing-out accidents of the mine; the drainage system may further determine the using priority of each water pump according to the operation status of each water pump in the water pump group, so as to alternate the water pumps regularly, thereby the equipment failure rate may be greatly reduced. In addition, the drainage system may adapt to more applications and be more widely used because of using the multiple detection components and the multiple drainage modes.

Fourth Embodiment

FIG. 4 is a flow schematic diagram illustrating determination of the start-up of water pump according to a water level, a water level variation rate and a power consumption period according to the fourth embodiment of the disclosure. As shown in FIG. 4, the flow includes the following acts.

S401: a water level variation ratio is read by a PLC from a water level sensor, in order to guarantee a reliable monitoring, at least two water level sensors are generally provided.

S402: it is determined whether the water level variation ratio is greater than t1; when the water level variation ratio is greater than t1, all water pumps of the drainage system are started and an alarm is sent, otherwise, S403 is performed.

Here, t1 is a preset water level variation ratio value, a water level variation ratio value greater than t1 indicates a very high water level variation rate, and needing all

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water pumps to be started and an alarm to be sent, otherwise, a serious consequence may be caused. The t1 may be set according to the specific circumstance of the site needing the drainage, for example, a theoretical water storage of a mine tunnel.

S403: the water level is read by the PLC from the water level sensor.

S404: it is determined whether the water level is greater than 2H; when the water level is greater than 2H, S405 is performed, otherwise, return to S401.

Here, H is a preset water level value, a water level value greater than 2H indicates a water level exceeding a normal water level, but it is not necessary to perform drainage immediately; a water level value greater than 3H indicates a water level being a little high, it is necessary to perform drainage, but in the case that it is not within a power consumption trough period, the drainage may be postponed, in order to save energy; and a water level value greater than 4H indicates that it is necessary to perform drainage immediately, and all water pumps are needed to be started. The H may be set according to the specific circumstance of a site needing the drainage, for example, a height of a mine tunnel.

S405: it is determined whether the water level is greater than 3H; when the water level is greater than 3H, S407 is performed, otherwise, S406 is performed.

S406: it is determined whether present time is within the power consumption trough period, which is called as a trough period for short; if yes, any one of the water pumps in the drainage system is started, otherwise, return to S405.

S407: it is determined whether the water level is greater than 4H; when the water level is greater than 4H, all water pumps in the drainage system are started to perform drainage, otherwise, S408 is performed;

S408: it is determined again whether the present time is within the power consumption trough period; if yes, one or a part of water pumps in the drainage system are started, otherwise, S409 is performed.

Further, one or a part of water pumps may be started alternatively according to a using priority of each water pump.

S409: the water level variation ratio is read again, in order to determine whether the water level variation ratio has a sudden change.

S410: it is determined whether the water level variation ratio is greater than t2; when the water level variation ratio is greater than t2, one or a part of water pumps in the drainage system are started, otherwise, return to S409.

Further, one or a part of water pumps may be started alternatively according to

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the using priority of each water pump.

Here, t2 is a preset water level variation ratio value, a water level variation ratio value greater than t2 indicates a little high water level variation rate, and it is necessary to perform drainage, but in the case that it is not within the power consumption trough period, the drainage may be postponed, in order to save energy. The t2 may be set according to the specific circumstance of the site needing the drainage, for example, the theoretical water storage of the mine tunnel.

It is to be noted that even if one or all water pumps are started to perform drainage, it is necessary to repeatedly perform the present flow at a preset time interval, in case that the water level or the water level variation rate, especially the water level variation rate, has a sudden change during the drainage.

The preset time interval may be set according to a general hydrological situation of the site needing the drainage, for example, a permeating status of a mine tunnel.

Fifth Embodiment

The present embodiment is suitable for a flow needing only one water pump to be started to perform drainage according to water level information. For the convenience of expression, the water pump started in the present flow and the pipes are called as a pump 1# for short.

FIG. 5 is a flow schematic diagram of the start-up of single water pump according to the fifth embodiment of the disclosure. As shown in FIG. 5, the flow includes the following acts.

S501: a jet pump is started; the jet pump is filled with water to exhaust air, so as to suck air from a centrifugal pump, thereby a preset negative pressure, namely certain vacuum is generated by the centrifugal pump; when the negative pressure reaches a preset negative pressure threshold value, a valve of a water inlet pipe of the centrifugal pump is opened, and the water is sucked into a cavity of the centrifugal pump.

The jet pump is provided with a negative pressure sensor or a vacuum meter for detecting the negative pressure. The preset negative pressure threshold value may be set according to types, specifications and the like of the specific water pumps, a manufacturer may set a recommended value generally.

S502: it is determined whether the cavity of the centrifugal pump is filled full of water by means of the negative pressure sensor or the vacuum meter; once it is determined that the cavity of the centrifugal pump is filled full of water, S503 is performed, otherwise, it is determined that the pump 1# has a failure, and will be

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alternated.

S503: the centrifugal pump is started; after that, the water in the cavity may be thrown out by an impeller of the centrifugal pump, and enters a drainage pipe, meanwhile, a negative pressure is generated again in the cavity of the centrifugal pump, and the water is sucked in again, such that the cycle may be continuously repeated.

S504: it is determined whether a water pressure at a water discharge port reaches a preset value.

The water pressure at the water discharge port means that in the drainage pipe between a gate valve of the drainage pipe and the centrifugal pump, namely a water pressure in close proximity to a water outlet of the centrifugal pump. In the case without other abnormal conditions, the water pressure at the water discharge port may reflect the operation status of the centrifugal pump, and a low water pressure indicates a poor suction capacity of the water pump.

When the water pressure at the water discharge port reaches the preset value, S505 is performed, otherwise, it is determined that the pump 1# has a failure, and will be alternated.

S505: the gate valve is opened to perform drainage; it is to be noted that the gate valve should not be opened when the water pressure at the water discharge port does not reach the preset value, otherwise, the negative pressure value of the cavity of the centrifugal pump may be affected.

S506: it is determined whether total water drainage reaches a preset value; because the water level information indicates that only one centrifugal pump is needed to be started to perform drainage, for the convenience of the alternative of the water pumps, the total water drainage of the single centrifugal pump is limited, and when the total water drainage reaches the preset value, the centrifugal pump stops the drainage; when the water level information indicates that the drainage is still needed, another centrifugal pump is started.

Embodiment 6

The present embodiment is suitable for monitoring operation status of a water pump in a drainage system by means of various sensors, so as to find a device out of order and repair it in time.

FIG. 6 is a flow schematic diagram of monitoring of the operation status of the water pump according to the sixth embodiment of the disclosure. As shown in FIG. 6, the flow includes the following acts.

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S601: it is determined whether the water pump is in operation; if yes, S602 is performed, otherwise, the monitoring of the operation status is stopped.

S602: it is monitored whether a water pump current is normal; if yes, S603 is performed, otherwise, an alarm signal of "current exceeding the limit" is sent, and the water pump out of order is locked, so as to stop the operation of the water pump.

The alarm may be sent by an acousto-optic alarm component, and the alarm may be performed on site, or on a remote console, or the alarm may be performed in both modes, the same as below.

S603: it is monitored whether a water pressure is normal; if yes, S604 is performed, otherwise, an alarm signal of "insufficient pressure" is sent, and the water pump out of order is locked, so as to stop the operation of the water pump.

S604: it is monitored whether a temperature is normal; if yes, S605 is performed, otherwise, an alarm signal of "temperature exceeding the limit" is sent, and the water pump out of order is locked, so as to stop the operation of the water pump.

S605: it is monitored whether a negative pressure is normal; if yes, S606 is performed, otherwise, an alarm signal of "insufficient negative pressure" is sent, and the operation of the water pump is stopped.

S606: it is monitored whether power is off; if yes, an Emergency Power Supply (EPS) is started; otherwise, return to S601.

The above are only preferred embodiments of the disclosure and are not intended to limit the scope of protection of the disclosure. Any modifications, equivalent replacements, improvements and the like made within the spirit and principle of the disclosure shall fall within the scope of protection of the disclosure.

INDUSTRIAL APPLICABILITY

The drainage system and method according to the embodiments of the disclosure provides at least one water level sensor for detecting a water level and a water level variation rate, and the start-up of water pumps in a water pump group in the drainage system may be determined according to the water level and/or the water level variation rate acquired by the water level sensor, thereby the water pump group in the drainage system may be started to perform drainage in time when sudden water burst, water permeating or water gushing-out accidents occur in a mine, as a result, safety

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accidents may be avoided. Further, at least two water pumps are provided, which may operate alternatively when a water discharge is not large, such that starting count and operating time of the water pumps may be reduced, and an equipment failure rate may be reduced.

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CLAIMS

1. A drainage system, comprising: a water pump group provided with at least two water pumps, a control mechanism for controlling operation of the water pump group, and at least one water level sensor, the water pumps in the water pump group and the water level sensor are connected with the control mechanism;

the water level sensor is configured to detect water level information, and send the detected water level information to the control mechanism;

the control mechanism is configured to command the water pumps in the water pump group to perform drainage respective to the water level information meeting a preset condition;

the control mechanism is provided with a recording component for recording an operation status of each water pump in the water pump group, and the control mechanism determines a using priority of each water pump according to the operating status of each water pump in the water pump group, the water pumps with a high using priority are preferentially started;

the operating status of water pumps comprises at least one of latest using time, an accumulated using count, or an accumulated failure count.

2. The drainage system as claimed in claim 1, wherein the water level information comprises a water level and a water level variation rate;

two water level sensors are provided, each of which is positioned at a preset distance from a water suction port of the water pump.

3. The drainage system as claimed in claim 1 or 2, wherein the control mechanism is a PLC.

4. The drainage system as claimed in claim 1 or 2, wherein each water pump in the water pump group is provided with a temperature sensor and a current sensor for

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detecting working load status of the water pump, the temperature sensor and the current sensor are connected with the control mechanism.

5. The drainage system as claimed in claim 1 or 2, wherein each water pump in the water pump group is individually provided with a water inlet pipe and a drainage pipe, and each drainage pipe is provided with a water valve; a drainage pipe between each water valve and each water pump is internally provided with a water pressure sensor for detecting suction capacity of the water pump, and the drainage pipe at an outlet of each water valve is provided with a flow sensor for detecting the suction capacity of the water pump; the water valve, the water pressure sensor and the flow sensor are connected with the control mechanism.

6. The drainage system as claimed in claim 5, wherein each of the water pumps in the water pump group is a centrifugal pump, a jet pump for assisting the centrifugal pump to generate a negative pressure is provided above the centrifugal pump; and the water valve is a gate valve.

7. The drainage system as claimed in claim 6, wherein the drainage system further comprises a remote console for remotely monitoring the drainage system, and an on-site operating platform for the ease of controlling the drainage system in maintenance;

the remote console and the on-site operating platform are connected with the control mechanism, and each of the remote console and the on-site operating platform is provided with an operating button for controlling the operation of the drainage system.

8. A drainage method, comprising:

acquiring water level information detected by a water level sensor;

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commanding a water pump group provided with at least two water pumps to perform drainage respective to the water level information meeting the preset condition;

wherein before acquiring the water level information detected by the water level sensor, the method further comprises:

recording an operating status of each water pump in the water pump group;

according to the operating status of each water pump in the water pump group, determining a using priority of each water pump;

the operating status of water pumps comprises at least one of latest using time, an accumulated using count, or an accumulated failure count.

9. The method as claimed in claim 8, wherein acquiring water level information detected by the water level sensor comprises: acquiring a water level and a water level variation rate detected by the water level sensor;

commanding the water pump group provided with at least two water pumps to perform drainage respective to the water level information meeting the preset condition comprises: commanding the water pump group provided with at least two water pumps to perform drainage responsive to at least one of: the water level exceeding a preset water level threshold value or the water level variation rate exceeding a preset water level variation rate threshold value.

10. The method as claimed in claim 8 or 9, wherein commanding the water pump group provided with at least two water pumps to perform drainage respective to the water level information meeting the preset condition comprises:

according to the water level information and the using priority of each water pump, determining a water pump to be started in the water pump group.

11. The method as claimed in claim 9, wherein commanding the water pump group provided with at least two water pumps to perform drainage respective to the water level information meeting the preset condition comprises:

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commanding a part of water pumps in the water pump group are commanded to perform drainage responsive to at least one of: the water level exceeding a first preset water level threshold value or the water level variation rate exceeding a first preset water level variation rate threshold value, and the present time is within a power consumption trough period;

commanding all water pumps in the water pump group to perform drainage responsive to at least one of: the water level exceeding a second preset water level threshold value or the water level variation rate exceeding a second preset water level variation rate threshold value;

commanding the water pump group to stop draining responsive to the water level is lower than a third preset water level threshold value, or the present time is within a power consumption peak period and the water level is lower than the first preset water level threshold value.

12. The method as claimed in claim 8 or 9, wherein after commanding a water pump group provided with at least two water pumps to perform drainage responsive to the water level information meeting the preset condition, the method further comprises:

acquiring a water pressure in a drainage pipe of each water pump, and shutting down a corresponding water pump responsive to the water pressure is lower than a preset water pressure threshold value.

13. The method as claimed in claim 8 or 9, wherein after commanding the water pump group provided with at least two water pumps to perform drainage respective to the water level information meeting the preset condition, the method further comprises:

acquiring a flow in the drainage pipe of each water pump and an opening state of a water valve, and shutting down a corresponding water pump responsive to the water valve being completely opened and the flow is lower than a preset flow threshold value.

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14. The method as claimed in claim 8 or 9, wherein after commanding the water pump group provided with at least two water pumps to perform drainage responsive to the water level information meeting the preset condition, the method further comprises:

acquiring an operation temperature and an operation current of a motor of each water pump, and a corresponding water pump is shut down responsive to at least one of: the operation temperature is greater than a preset temperature threshold value or the operation current is greater than a preset current threshold value.

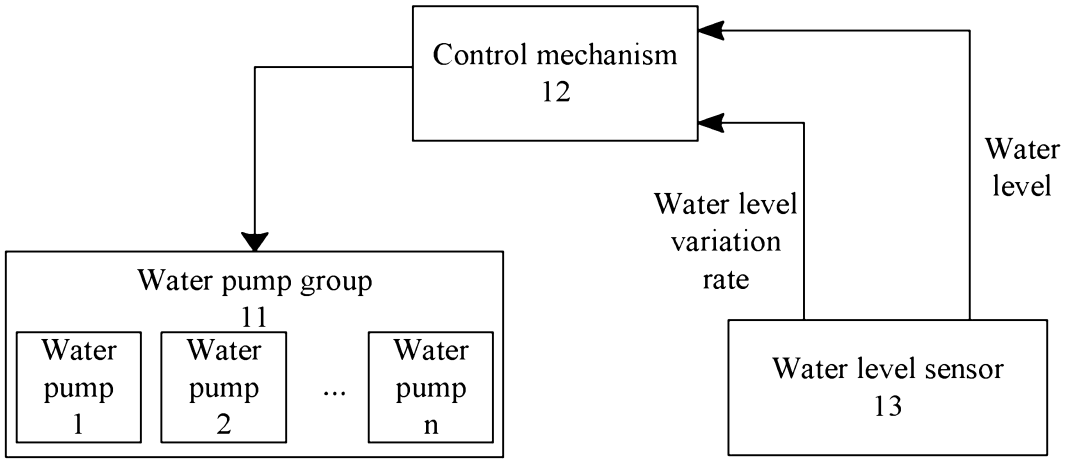

Control mechanism
12
Water level
Water level variation rate
Water pump group
11
Water pump 1
Water pump 2
...
Water pump n
Water level sensor
13

FIG. 1

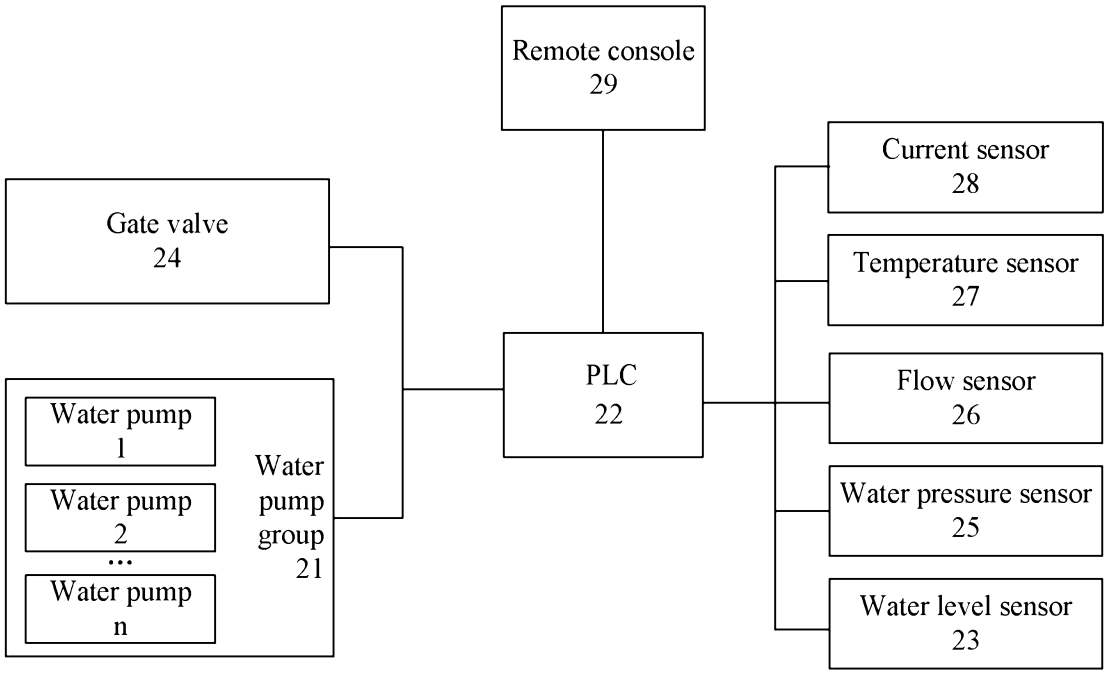

Remote console
29
Current sensor
28
Gate valve
24
Temperature sensor
27
PLC
22
Flow sensor
26
Water pump
1
Water pump
2
...
Water pump
n
Water
pump
group
21
Water pressure sensor
25
Water level sensor
23

Fig. 2

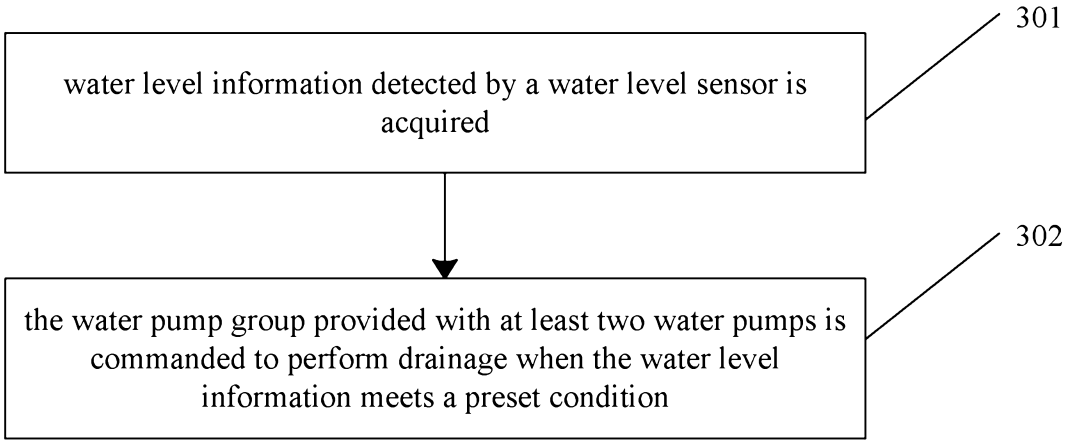

301
water level information detected by a water level sensor is acquired
302
the water pump group provided with at least two water pumps is commanded to perform drainage when the water level information meets a preset condition

FIG. 3

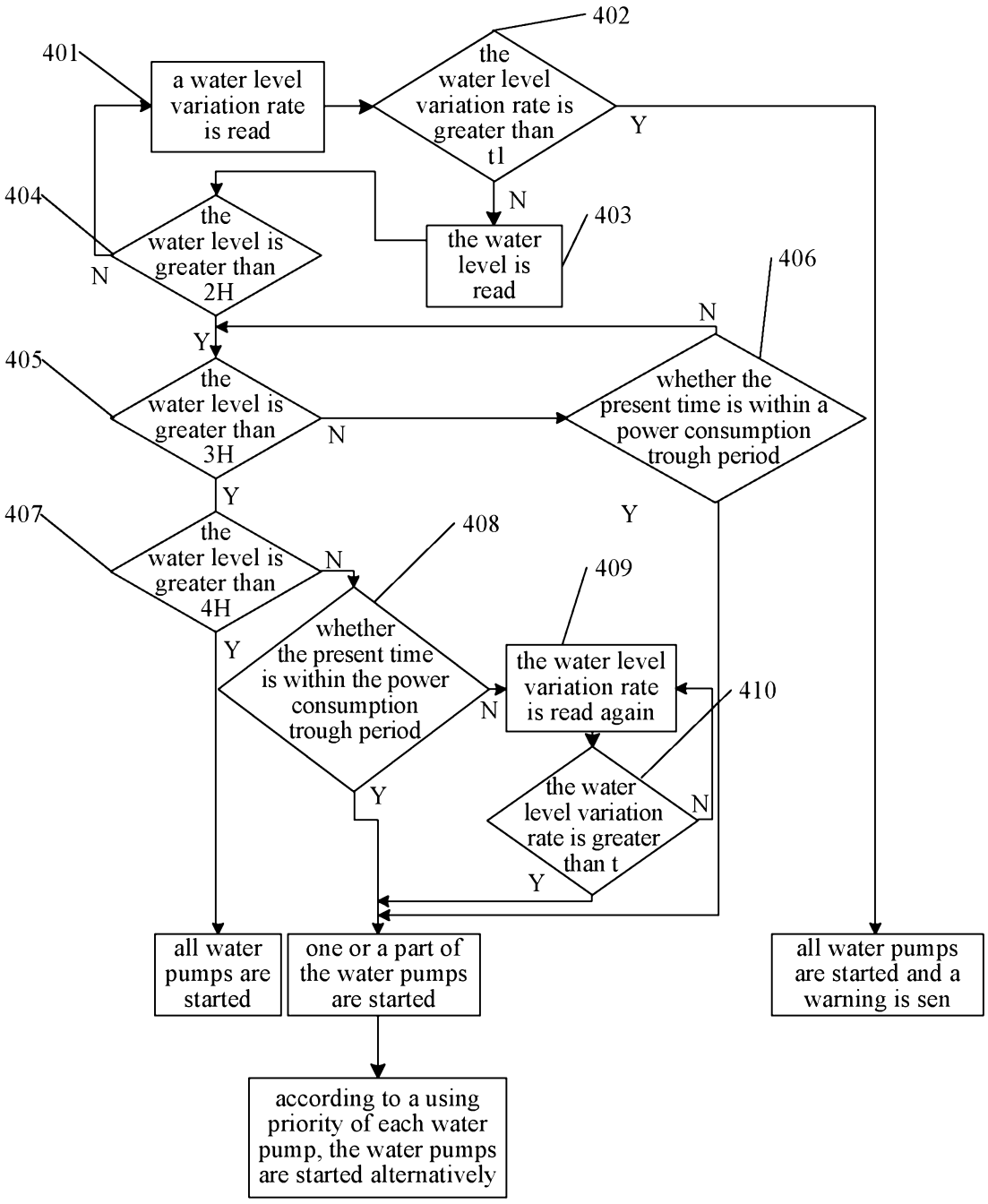

401
a water level variation rate is read
402
the water level variation rate is greater than t1
Y
N
403
the water level is read
404
the water level is greater than 2H
N
Y
405
the water level is greater than 3H
N
406
whether the present time is within a power consumption trough period
N
Y
407
the water level is greater than 4H
N
Y
408
whether the present time is within the power consumption trough period
N
Y
409
the water level variation rate is read again
410
the water level variation rate is greater than t
N
Y
all water pumps are started
one or a part of the water pumps are started
all water pumps are started and a warning is sen
according to a using priority of each water pump, the water pumps are started alternatively

FIG. 4

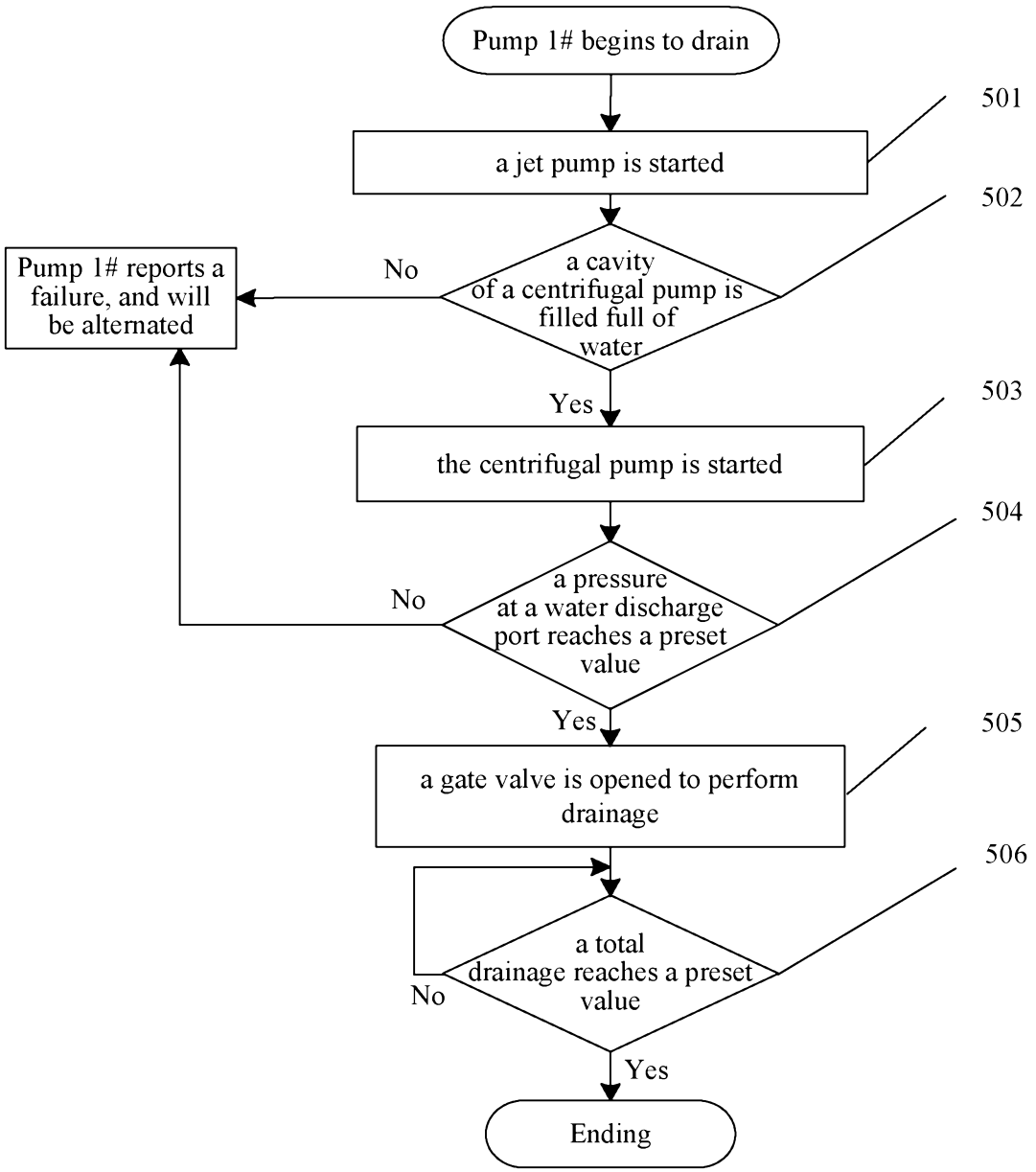

Pump 1# begins to drain
501
a jet pump is started
502
a cavity of a centrifugal pump is filled full of water
No
Pump 1# reports a failure, and will be alternated
Yes
503
the centrifugal pump is started
504
a pressure at a water discharge port reaches a preset value
No
Yes
505
a gate valve is opened to perform drainage
506
a total drainage reaches a preset value
No
Yes
Ending

FIG. 5

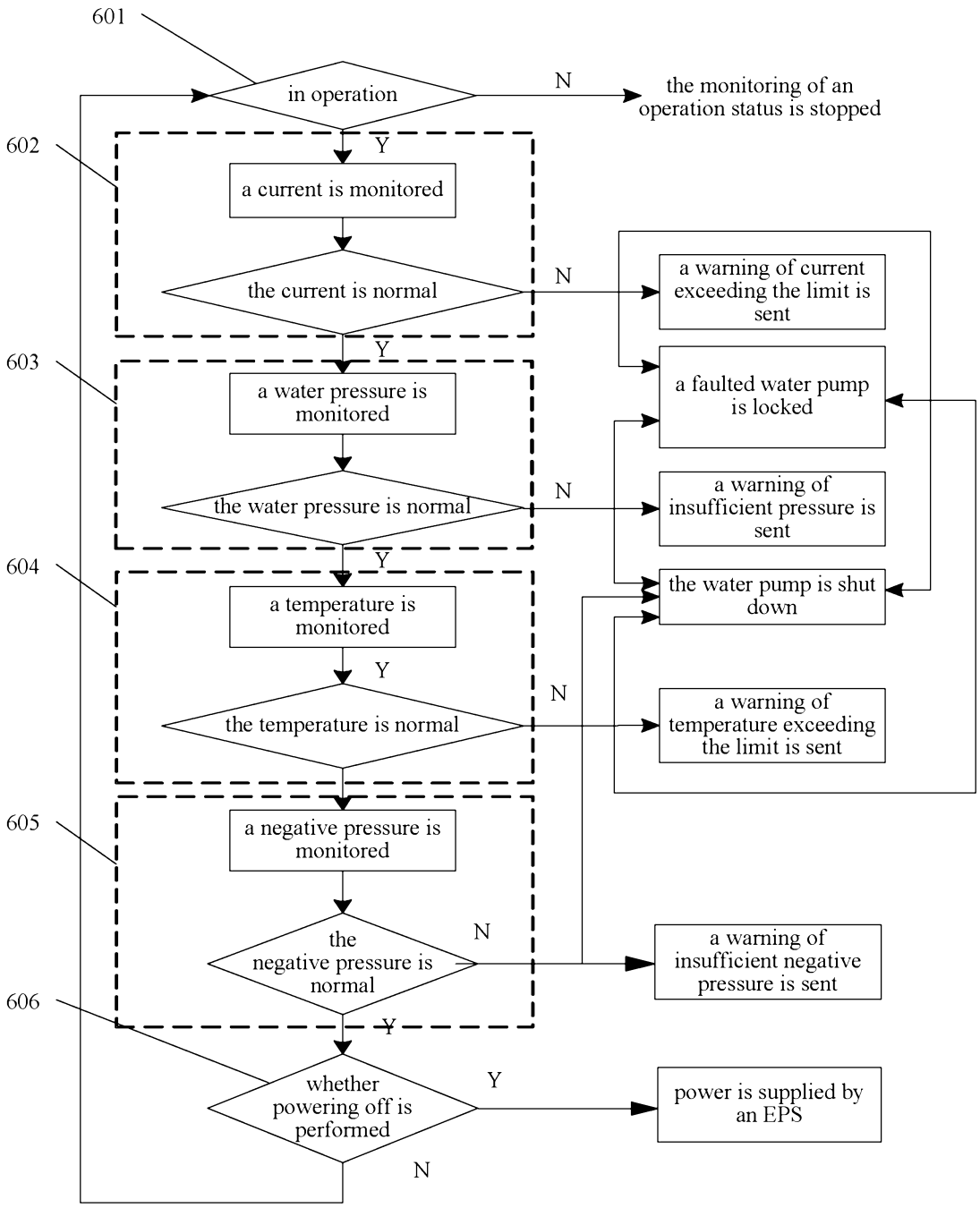

601
in operation
N
the monitoring of an operation status is stopped
Y
602
a current is monitored
the current is normal
N
a warning of current exceeding the limit is sent
Y
603
a water pressure is monitored
a faulted water pump is locked
the water pressure is normal
N
a warning of insufficient pressure is sent
Y
604
a temperature is monitored
the water pump is shut down
Y
the temperature is normal
N
a warning of temperature exceeding the limit is sent
605
a negative pressure is monitored
the negative pressure is normal
N
a warning of insufficient negative pressure is sent
Y
606
whether powering off is performed
Y
power is supplied by an EPS
N

FIG. 6