APPARATUS FOR CONTROLLING PUMP AND TURBINE OPERATIONS

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This invention relates generally to hydraulic power-accumulation systems wherein a hydraulic turbine and a pump are alternatively operated so as to generate power during peak loads with water stored in a reservoir or pond of limited capacity, and then during periods of off-peak loads the pump is operated by current supplied from any suitable power source so as to pump water back into the pond whereby this water can again be used during peak load to drive the turbine. The invention however is equally applicable to any installations in which the pump and turbine are commonly connected to the electrical machine such as the motor-generator.

The invention has particular reference to an improved method and apparatus for controlling the water in the hydraulic turbine in order to facilitate changing from turbine to pump operation and to obtain a high degree of operating efficiency during operation.

In the operation of installations for which my invention is suited, it is usual to expel water from the turbine casing and depress the water level therein so as to unwater the turbine runner and thus permit operation of the pump unit with minimum frictional resistance from the turbine unit, the two units being driven from a common motor-generator usually of the synchronous type. The water level has usually been depressed by directly connecting an air pump to the discharge passage or draft tube of the turbine, thus causing the draft tube in such an arrangement to serve as the receiver for the compressed air. Due to the relatively large volumetric capacity of the draft tube a relatively large volume of air must be supplied thereto in order to depress the water level to the proper limit. If it is necessary, as is usually the case, to depress the water in a relatively short period of time it is seen that a relatively large air pump must be employed even though such a pump would only have to discharge at a relatively low pressure which is exactly equal to the head of water being depressed.

It is an object of my invention to provide an improved apparatus whereby the water level may be depressed relatively quickly without employing relatively large air pump equipment. In accomplishing this I have provided an arrangement which while it necessitates a higher discharge pressure for the air pump than that required for the prior arrangements, yet the economies effected by my improved arrangement are sufficient to offset the operation of the air pump at the higher pressure, it being understood that this higher pressure is greater than the pressure which is actually present in the draft tube when the water is depressed. Notwithstanding this apparently adverse factor I effect not only a more economical arrangement in initial cost and operation but also one which will permit transfer of the installation from turbine to pump operation in at least the same period of time if not shorter than that required for the systems heretofore used, and in addition there is a greater degree of assurance that break down of the air pump will not interfere with the change over operation.

The foregoing and other objects of my invention will be more readily apparent to those skilled in the art from the following description of the accompanying drawings, wherein:

Fig. 1 is a vertical section through a turbine-pump installation with my improved equipment embodied therein, the parts of the machines being shown in elevation; and

Fig. 2 is a plan view of a modified form of arrangement.

I have shown merely for purposes of illustrating one specific embodiment of the invention, a turbine-pump installation of the horizontal shaft type comprising a turbine 1 of any form desired, having a conical draft tube or discharge passage 2 connected through an outlet passage 3 to a horizontal passage 4 which leads to the tailwater 5. The turbine drives a motor-generator 6 connected to the common shaft 7 to which is connected a pump 8 through a releasable starting clutch 9 of any desired type. The pump and turbine are provided with usual wicket gates 10 diagrammatically indicated at G. The inlet casing 11' for the turbine and the outlet casing 8' for the pump are shown herein of the volute type. The specific arrangement of the hydraulic passages and pump and turbine settings does not per se constitute a part of my invention. It is shown merely for purposes of illustrating one specific application of my improved control which obviously can be applied equally as well to the turbine and pump arrangements.

As seen from Fig. 1 the level of tailwater 5 is above the turbine 1 so that it is impossible to unwater the turbine runner merely by introducing atmosphere into the draft tube as is usually done where the tailwater level is below the turbine. In order to expel the air from the draft tube 1 I have interposed between the turbine casing and a small air pump, diagrammatically indicated at 10, a receiver 11 connected to the pump by a pipe 12 and to the turbine 1.
casing by a pipe 13 provided with a hand valve 14. The air pipe connection to the casing may enter directly between the gate valve and guide vanes in which case the gate valve need only be closed, or the pipe may enter directly into the runner passage on the inside of the guide vanes thus necessitating only their closure without the necessity of unwatering the casing itself. The pump 10 is driven preferably by an electric motor 15 although if desired a small water wheel could be used instead. This pump is a relatively small high pressure type adapted when operated over an appreciable period of time to build up a relatively high pressure in the receiver 11. Due to my improved arrangement the volumetric capacity of the receiver 11 is not necessarily as large as the volume of water to be expelled from the draft tube. This is because the high pressure is sufficient not only to effect a relatively rapid expulsion of the water, but in addition as it discharges into the draft tube the pressure drops with a corresponding expansion of volume thereby satisfying the volumetric requirement of the draft tube and accordingly maintaining the water depressed. In this way any desired speed of operation is possible without sacrifice of volumetric requirements. As a result of this arrangement wherein the pump 10 and receiver 11 are of relatively small size, the smallness in size is compensated for by operating the pump over a relatively long period of time, this being preferably during the period of turbine operation. It is thus seen that when the turbine is operating the air pressure mechanism is also operating instead of having the air pressure mechanism operated only when the turbine is shut down and the water ready to be expelled. This simultaneous operation of the air pressure mechanism and turbine not only provides economical advantages but also has the further advantage that a complete potential source of air pressure is present when it is desired to expel the water when the turbine is shut down. When the turbine is shut down the valve 14 is opened and air pressure admitted to the turbine casing to expel water therefrom. The pump 8 can thus be operated to pump water from the tailrace 5 to any suitable higher point of elevation diagrammatically indicated at 5'.

To ensure that air will not escape from the turbine casing and leak along the top of the horizontal passage 4 over into the pump 8 and thus reduce the efficiency of the latter, a pipe 16 is connected into the outlet 3 at a point slightly above the top of passage 4, this pipe acting as an atmospheric vent. As the air pressure in outlet 3 is vented the pressure will drop and the water will rise to cover the openings of pipe 16 and accordingly seal the same. If the air pressure should again accumulate to depress the level below the opening for pipe 16, this pressure will be again immediately reduced until the turbine is again closed by the water.

When the turbine is operating a suitable hand valve 17 will close the atmospheric vent. It will of course be understood that the motor for air pump 10 is controlled preferably by a pressure switch of any suitable type so that when the pressure in receiver 11 has reached a point which will give a sufficient volume of air at the reduced pressure in the pump casing the pump will stop.

In the modification shown in Fig. 2 the pump 8 is adapted to be supplied with compressed air in the same manner as the turbine is supplied in the preferred form, it being desirable in this modification to unwater the pump runner to reduce the hydraulic friction during turbine operation. The receiver 11 is connected to the pump casing by a valve controlled pipe 18. It may be desirable under certain circumstances where the change-over from turbine to pump operation or vice versa will occur at fairly regular but not too frequent intervals, to use a main motor driven air compressor 19, one high pressure tank 11, and one auxiliary air compressor 19 connected preferably directly to the pump and turbine casings. There is disposed in each of the air pipes, valves A, B, C and D operated so that when the turbine is driving the generator, valves A, C and D are closed. While the turbine is driving the generator, valves A, C and D are closed, but valve B is open so that the auxiliary air compressor will be operated to replenish leakage air, thus maintaining the depressed water level in the pump casing. The main air compressor will operate as long as necessary to build up the desired pressure in the high pressure air tank, being shut off automatically by a pressure switch.

When it is desired to use the generator as a motor to drive the pump and turbine the turbine penstock valve is closed, the valves 10, 13, and 14 opened and the valve B is closed (valve D remaining closed). When the high pressure air from the air tank has fully depressed the level of the water in the turbine casing the valve C is closed but valve A remains open so the auxiliary air compressor will operate to replenish leakage air from the turbine casing, thus maintaining the depressed water level in the turbine casing. Meanwhile the main air compressor has been started by the pressure switch to once more build up a high pressure in the air tank, and the air has been expelled from the pump casing so that the pump will function normally on opening the main valve in the pump discharge line.

When it is desired to again generate power by normal use of the turbine, the pump discharge valve is closed, the valves B and D are opened, the valve A is closed and the turbine penstock valve is opened forcing the air out of the casing through the draft tube. As the water level in the pump is fully depressed the valve D is closed, the valve B remaining open to replace air that may leak out of the pump casing. The pressure switch automatically starts the main air compressor to build up the necessary high pressure in the air tank ready for the next change-over. It is seen from this arrangement of valves and pipes that the pump of either an independent pump unit or of a pump turbine unit and whose rotor is connected through a releasable clutch to a synchronous motor, may be easily started by first starting and synchronizing the motor with the clutch disengaged, and then, with the pump rotor unwatered, to engage the clutch after which the pump is primed. This reduces wear and tear on the clutch and improves the operating efficiency and maintenance. It is also seen that in case the pump rotor is revolved with the motor during starting thereof, the pump can be unwatered to advantage prior to starting and then primed after the motor is synchronized although the advantages of my improved system are still maintained.
are equally applicable even where induction or direct current motors are used.

The invention described hereinbefore is also applicable for use in depressing the level of the water in the casing of a hydro-electric unit where the unit is designed both for operation as a prime mover to drive the motor-generator and for operation as a pump to be driven by the motor generator. In such a combined pump-turbine unit, my invention would be useful in eliminating the hydraulic friction on the pump-turbine impeller when starting the pump in operation or when operating the unit as a synchronous condenser.

It is thus seen from the foregoing that I have provided an extremely simple arrangement whereby the water expulsion means may be relatively small and hence of relatively low initial cost and maintenance and in addition is adapted to provide not only a potential source of air supply immediately available upon stopping of the turbine operation but an arrangement which will function during a period of turbine operation and be available for use in a manner not immediately desired, thus insuring that in case the air pressure mechanism is out of order such will be known to the operator of the plant in advance of the time when its ultimate use is desired, thereby giving the plant an opportunity to repair the equipment without probable delay of the change-over operation.

It will of course be understood that various changes may be made in the construction and arrangement of parts without departing from the spirit of the invention as set forth in the appended claims.

I claim:

1. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a pump, a motor-generator commonly connected to the pump and turbine runners, and means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver to receive fluid from the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein.

2. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a hydraulic pump, a motor-generator commonly connected to the pump and turbine runners, means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver to receive fluid from the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein, and means for controlling the level of the expelled water.

3. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a hydraulic pump, a motor-generator commonly connected to the pump and turbine runners, means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver connected to the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein, and means for controlling the level of the expelled water.

4. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a hydraulic pump, a motor-generator commonly connected to the pump and turbine runners, means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver connected to the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein, and means for controlling the level of the expelled water.

5. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a hydraulic pump, a motor-generator commonly connected to the pump and turbine runners, means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver connected to the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein, and means for controlling the level of the expelled water.

6. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a hydraulic pump, a motor-generator commonly connected to the pump and turbine runners, means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver connected to the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein, and means for controlling the level of the expelled water.

7. A power-accumulation system comprising, in combination, a turbine having gates and a runner passage connected to tailwater with the turbine runner normally disposed below the tailwater level, a hydraulic pump, a motor-generator commonly connected to the pump and turbine runners, means adapted upon closure of said gates for expelling water from the turbine runner passage during pump operation, including a pressure fluid receiver connected to the turbine runner passage and a high pressure air pump connected to said receiver for creating therein a source of pressure fluid adapted to be discharged into the turbine runner passage to expel the water therein, and means for controlling the water in the turbine runner passage during pump operation including a receiver and an air pump therefor.

8. A power-accumulation system comprising,
in combination, a turbine having gates and a
runner passage connected to tailwater with the
turbine runner normally disposed below the tail-
water level, a hydraulic pump, a motor-genera-
tor commonly connected to the pump and tur-
bine runners, means adapted upon closure of
said gates for expelling water from the turbine
runner passage during pump operation, includ-
ing a pressure fluid receiver connected to the
turbine runner passage and a high pressure air
pump connected to said receiver for creating
therein a source of pressure fluid adapted to be
discharged into the turbine runner passage to
expel the water therein, and means for expel-
lng or controlling the water in the turbine pas-
sages during hydraulic pump operation and in
the hydraulic pump passages during turbine
operation including a receiver, an air pump
therefor and an auxiliary air pump.
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