SAFETY DEVICE FOR PREVENTING THE EXCESSIVE SPEED OF WATER TURBINES

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ABSTRACT

A safety-valve for preventing the overspeed of an hydraulic-turbine runner has passages communicating between the servo-control valve and the servomotor which varies the position of the pivotal vanes of the runner. The safety-valve member leaves the passages unobstructed in its normal position and is hydraulically biased into this position by a substantially constant pressure which is relieved upon the development of overspeed and a slight displacement of the valve member under the hydraulic pressure resulting therefrom to substantially instantaneously drive the valve member into an opposite position in which the flow paths are blocked and fluid displacement to or from the servomotor is made independent of the control valve and such that the blades pivot into an open position.

4 Claims, 2 Drawing Figures
SAFETY DEVICE FOR PREVENTING THE EXCESSIVE SPEED OF WATER TURBINES

The present invention relates to a safety device for preventing the excessive speed of water turbines.

Water turbines, particularly Kaplan turbines, can attain on overspeeding, rotational speeds of three times greater than their rated speeds. The rotating parts, e.g., the turbine runner and the rotor of the alternator are loaded by forces which increase approximately with the square of the speed. In designing Kaplan turbines and corresponding alternators, particularly with great units, complicated problems thus arise.

For reducing the rotational speed and the duration of operation at this maximum speed, various devices are used, such as weirs placed before or behind the turbine, special oil pressure devices for closing the turbine guide wheel, special servomotors allotted to single vanes of the turbine guide wheel, and the like.

All these solutions have the common imperfection that it is difficult, due to great flows of water, to reduce the operational speed of the turbine by weirs. When the weir is placed behind the turbine in the suction pipe it has a smaller size than when it is placed before the turbine, nevertheless its closing speed is limited due to the comparatively big weir and to unfavourable dynamic events in the discharge system of the turbine, and this is the reason why in such a manner the rate of overspeeding revolutions cannot be substantially reduced. Practically, only a reduction of the duration of turbine operation at maximum speed can be obtained by the weirs.

Additional pressure devices can fulfil their task only when the controlling organs and the installations from the turbine to the valve which isolate the pressure device from the turbine governor are in good order. Moreover, such devices complicate the system of control, protection and automation.

The embodiment with separate servomotors for each vane of the turbine guide wheel has failed because of unfavorable dynamic phenomena occurring when the vanes are not closed synchronously and the flow through the turbine runner becomes nonuniform during closing.

Attempts have been made to improve the reliability of closing the turbine guide wheel by designing guide vanes for self-closing. In this case, of course, servomotors are necessary on each guide vane in order to remove friction in the governing mechanism of usual design. In this case, the servomotors are hydraulically synchronized. This solution has the disadvantage that a great number of connections is needed, whereby the reliability of the arrangement is reduced and is influenced also by faults in the system for hydraulic synchronization. Therefore non-uniform openings may occur between the vanes, resulting in undesirable dynamic influences on the system of flow.

The main inconvenience of all these devices lies in the fact that the rotating parts cannot be designed for speeds which would be essentially lower than the maximum possible speed.

It is also known to utilize the centrifugal force for opening the blades of the runner. With this arrangement, the runner blades are closed at increased rotational speed of the turbine, independently of the pressure oil from the pressure device. The connection between the closing and the opening spaces of the servomotor is realized through a centrifugal distributor mounted in the head of the runner. At an increase of the rotational speed of the turbine, the centrifugal distributor connects the said two spaces of the servomotor thereby rendering possible the opening of runner blades. The disadvantage of this arrangement lies in the difficult adjustment of the centrifugal distributor because the whole space of the turbine runner must be provided with draining equipment for rendering possible the access to the centrifugal distributor. Furthermore, the centrifugal distributor cannot warrant the opening of runner blades with a favourable time dependence but the opening changes permanently in accordance with variations of the rotational speed, since the oil can flow only from the closing space into the opening space.

It is the object of the present invention to remove these disadvantages and to provide a safety device which will operate independently of rotating parts and other auxiliary devices and will, in accordance with the turbine speed, control the opening or closing of the runner blades.

This object is attained according to the present invention by a safety device for preventing the excessive speeds of water turbines, equipped with a runner with swivelling vanes moved by a sole servomotor connected with the oil supply and with the main distributor slide valve, safety distributor valve is inserted between the oil supply and the main distributor valve. In a particular embodiment an auxiliary distributor valve is inserted on the constant-pressure side of the safety distributor valve, the auxiliary distributor valve being further connected to the pressure-oil supply from the protecting organs of the turbine. The safety distributor valve is characterized in that it has a casing with preferably six channels for connection of pipelines incoming from the oil supply or the servomotor, respectively, whereby the channels are arranged in such a way that a rapid switch-over of the piston is obtained at increased turbine speed and so the main distributor valve is totally separated by closing the corresponding channels. Other features of the safety device according to the present invention will be evident from the following description.

The invention is illustrated and described in detail with reference to accompanying drawing which:

FIG. 1 a sectional view of the fundamental elements of the safety device,
FIG. 2 a longitudinal cross-section of the safety distributor valve according to the invention.

In FIGS. 1 and 2 the fundamental assemblies of the safety device according to the present invention are designated with the following reference numbers: the turbine 1, the main distributor slide valve 2 of the servomotor of the turbine guide wheel, the safety distributor valve 3, the auxiliary distributor valve 4 and the servomotor 5 with the oil supply.

The turbine shown in FIG. 1 has a runner passage 11, over which and above the helical channel the turbine guide wheel 12 is placed and, overlying it, the bearing of the runner 13, having the shaft 131. The runner blades 132 are swivelled with the aid of servomotor 5. Reference number 14 designates the cover of the alternator, 15 the turbine discharge pipe, 16 the cover of the oil supply 500. The servomotor 5 of the runner comprises a piston 51 built into a corresponding casing. The space above the piston where oil is supplied when
the blades 132 have to be opened is the opening space 52, the space under the piston where oil is supplied when the blades should be closed is the closing space 53. For opening the blades 132 oil is supplied into the opening space 52 and pressed out from the closing space 53, while for closing the blades, oil is supplied into the closing space 53 and pressed out of the opening space 52. Along the axis of the piston there is a channel 531 for supplying or discharging oil, or two channels 521 for supplying or discharging oil, respectively, are connected with the space 52, whereby the corresponding chambers in the cover 16 of the oil supply 500 bear the same reference numbers. The runner blades 132 are closed when the piston 51 is lifted and the closing space 53 increases, while the runner blades are opened when said piston lowers, reducing the closing space. The opening direction is marked by arrow a, the closing direction by arrow z. Closed runner blades have the plane of a blade forming a smaller angle with respect to plane perpendicular to the runner axis, opened runner blades have the plane of a blade forming a greater angle with respect to said plane perpendicular to the runner axis, and thus the blades induce a braking effect.

The main distributor slide valve 2 of the servomotor 5 of the turbine runner comprises a casing 21 containing a movable piston rod 22 with the pistons 23, 24, and 25. The casing 21 has an opening 212 for the connection with the opening 315 of the safety distributor valve 3, further an opening 213 for the connection with the opening 316 of the safety distributor valve 3. On the opposite side of the casing there is an opening 214 for free discharge of oil from the upper part of the valve into the collector, while the constant-pressure oil supply 215 comes from the pressure device not shown in the drawing. The free discharge of oil 216 from the lower part of valve 2 leads to the reservoir, while the connection 211 is connected to the not turbine governor not shown.

The safety distributor valve 3 comprises a casing 31 closed with an upper cover 38 and a lower cover 39, having within it six channels, which are correspondingly arranged along the valve axis. In the casing there is a channel 312 with a three-part piston, having as parts the upper piston 33, the central piston 34, and the lower piston 35. In the valve position shown, corresponding to the position for the normal operation of the set, immediately below the upper piston 33 there is a channel 315 with the opening 315 for the connection with the opening 212 of the distributor slide valve 2, and underneath there is a channel 311 with an opening 311 connected to the chamber or the channel 531 of the oil supply 500 and through it to the closing space 53 of the servomotor.

In the region of the central piston 34, a channel 313 is made, leading through the opening 313 to the throttle 37. Underneath the piston 34 there is a channel 316 with the opening 316 connected to the opening 213 of the distributor slide valve, and further on, below the channel 316 there is a channel 312 with the opening 312, connected to the chamber or channel 521, respectively, of the opening space 52 of the servomotor. Through the elements 213, 316, 316', 312, 312, 521 oil can be supplied from the distributor slide valve 2 into the opening space 52 of the servomotor and in this way provoke opening of the runner blades, while through the elements 212, 315, 315', 311', 311, 531 oil can be discharged from the closing space 53 of the servomotor and so act upon opening of the blades again.

In the region of the lower piston 35, a channel 314' is provided which through opening 314 facilitates a free discharge of oil from the safety valve 3, and the drain from the throttle 37 is also connected to the corresponding discharge pipe. The channel 314' is connected with the bore 351 of the lower piston 35, with the annular groove 354 and the space 357 under the piston 35, so that oil can be drained from this space.

Finally, a control channel 314" is provided in the lower part of the valve, which, through the bore 352, is connected with the space 535 of the piston 35 and during control it prevents oil from entering the space 357 when the piston is moving downwards.

Besides the already described features the lower piston 35 has the following additional characteristics:

It has the shape of a cylindrical body with a hole along the axis of the piston rod, which subsequently will be named constant-pressure space 353. A bore 351 leads from the upper end of said space into the control channel 314". A sleeve 36 is inserted in the lower part of said space 353 and is fixedly connected to the lower cover 39 at its lower end while at its upper end the piston 35 can slide along it. The upper surface of said sleeve has the reference number 36a. Along its axis the sleeve has a bore 361 for the supply of constant-pressure oil, in its lower part a bulge 36b, and in the upper part a sealing edge 36c. In the region of the upper part of sealing sleeve 36 which occupies the lower part of the space 353, an annular groove 354 is provided in the body of the piston, to which groove a connecting bore 351 is provided from the channel 314" for a free oil discharge. The lower surface of the lower piston 35 bears the reference number 35a, the bottom surface of space 353 the number 35c, whereby a small widening of this surface with respect to the mean width of this space is not taken into account as it is made for technologic reasons. The control edge 355 on the outer mantle of the lower piston 35 cooperates with an edge of casing 31 at the bottom of the control channel 314".

The control edge on the inner side of the piston at the bottom of the annular groove 354 bears reference number 356, the space below the piston 35 number 357.

The auxiliary distributor valve 4 comprises a casing with a piston rod and the pistons 4a and 4b, the latter resting on a spring. The constant-pressure connection 41 leads from the annular groove 411 of the casing into constant-pressure space 353 of the safety distributor valve 3, on the opposite side a constant-pressure oil supply 42, coming from the pressure device enters the annular groove 421 of the casing. The discharge connection 43 is connected to the annular groove 431 of the casing. Through this connection oil is discharged from constant-pressure space 353 when valve 3 moves downwards. In this case oil is fed through the supply connection 44 from protection organs of the turbine and moves the piston 4a so that connection 42 is closed, while piston 4b is moved against the force of the spring so far that the connection 353, 41, 411, 431, 43, oil collector (not shown) is established.

The safety device according to the present invention operates in principle as follows:

In determining the torque of runner blades depending upon the rotational speed of the turbine, the analysis of several types of runner blades has shown that oil
3,820,917

pressure in the closing space of the servomotor of the runner varies according to the equation:

\[ p = C \left( \frac{n}{n_0} \right)^2 \]

When, e.g., the maximum possible number of revolutions be \( n = 3 \), then the maximum oil pressure in the closing space equals \( p = 9 \) C. The coefficient \( C \) contains the characteristics of blades and of their crank mechanism. It follows that at an increase of rotational speed of a turbine the runner blades can be opened independently of the pressure oil of the pressure device. It is necessary only to provide for the needed oil discharge from the closing space 53 of the servomotor of the runner into the oil collector. With such an arrangement the runner blades can be fully opened.

When the oil pressure in the closing space 53 of the servomotor of the runner attains the value corresponding to the increased turbining speed, also the force is increased which is needed to move the distributor valve 3 downwards. As soon as the sealing edge 36c is opened and the edge 355 closed, the distributor valve is shifted by its entire stroke, due to the discharge of the lower space 357 having an equal pressure as space 53. The oil from space 53 is drained out through the throttle 37 and the blades are fully opened. When the servomotor piston 51 rests on the bottom of the servomotor casing and ceases to press the oil, the oil pressure in space 336 is reduced and the oil pressure of space 353 lifts the piston 33, 34, 35 again into its upper position. Therewith the full opening of the blades is finished while the remaining control system is separated and the operating conditions are reestablished.

If we wish to start fully opening the runner blades to reduce the speed at unloading or to switch over the safety distributor valve arbitrarily, without regard to increase of speed, oil can be discharged from spaces 353 or 357 through the auxiliary distributor valve 4. In case of increased speed, pressure oil is supplied from protection organs of the turbine to the auxiliary distributor valve 4 through the connection 44 so that the pistons 4a, 4b are shifted establishing the connection 353, 41, 411, 431, 43. In this way oil is drained from the space 357 allowing the closing of runner blades similarly as in the case of operation without an auxiliary distributor valve.

Now the particulars of operation of the safety device according to the invention will be described.

When the rotational speed of the turbine is greater than the rated speed, pressure in the closing space 53 of the servomotor is increased. Through the channel 531 and the groove of the oil distributor, oil under increased pressure passes through the opening 311, the channels 311' and 315' and the channels 331 and 332 of the upper piston 33 into the space 336 above the piston. In this space now there is the same pressure as in the space 53. When the turbine speed rises the servomotor piston 51 is moved downwards and oil pressure in space 53 increases and so does it in the space 336 above the upper piston 33 of the safety valve. When the pressure on the surface 333 of this piston overcomes the force acting upwards on the surface 353a of the constant-pressure space 353, the piston rod 32 with the three pistons is forced to move downwards. In this instance there is still the same pressure acting on surfaces 35a which is the lower surface of the lower piston 35 and 353a of the constant-pressure space because the connection between these two spaces still exists through the bore 352, the control channel 314", and past the control edge 355. When the piston rod moves downwards, the lower piston 35 opens the connection between its control edge 356 and the control edge 36c of the sleeve 36 before it closes the way past the control edge 355. Therefore, through the bore 351, channel 314' and the opening 314 oil passes into the outlet before the connection past the control edge 355 into the control channel 314' is closed. As the force on surface 333 increases, the valve slides quickly downwards. Now, pressure is applied only to the small surface 353a of the constant-pressure space. At this downward movement the moving speed is somewhat braked by the bulge 36b of the sleeve immediately before seating on the bottom. When the piston 35 comes into its lower position, the distributor slide valve is totally separated since the upper piston 33 has closed the opening 315 connected with the opening 212 of the distributor slide valve, and the sleeve 36 has closed the opening 316 connected with the opening 213 of the same valve. At the same time it is rendered possible to drain oil from the servomotor space 53 through the channel 351, the opening 313, the channel 313', and the throttle 37. As it has already been mentioned, it is the task of the throttle 37 to regulate the draining speed of oil from the space 53 below the piston of servomotor 5, therefore by choosing adequate dimensions of this throttle the opening speed of runner blades can be determined.

The hydraulic torque always tends to open the blades and to press the servomotor piston downwards, therefore up to now it has always been a problem how to drain oil from said space. The servomotor piston, namely, moves slowly downwards until it seats on the bottom of the casing of the servomotor 5 and at this instant the pressure in this part of the servomotor drops to zero. Accordingly, the pressure zero is also in the space 336 above the upper piston 33 of the safety valve 3. The pressure exerted on the small surface 353a of the constant-pressure space 353 now suffices for lifting the piston rod 32 with all three pistons up into the operating position. Here it must be particularly noted that oil from the pressure device is not at all needed for opening the runner blades but only the torque of the runner blades, which at increased speed acts in the sense of opening, is utilized.

The speed regulation of the piston movement of the safety distributor valve is rendered possible by an arrangement in the upper piston 33. Its left side contains a channel 331 for draining oil through a single-way ball valve 334. The right side contains a channel 332 which has a throttle 335 fitted next to the upper cover 38. When pressure is applied to the upper side of the upper piston 33, the space is filled, the ball of the single-way valve 334 is lifted, and oil flows quasi primarily through the single-way valve 334 and also through the nozzle 335. When the piston moves back into the working position, the oil contained above the upper piston 33 closes the ball valve 334 and can drain out only very slowly through the nozzle 335.

The upper piston 33 has a threaded bore 381 which serves for the supervision of oil pressure or of piston position of the safety distributor valve and is closed by a locking screw 382.

Now there are to be described the details of the distributor valve 4. This distributor valve serves to switch over the safety valve 3 already at low turbine speeds so that it is not necessary to wait that the pressure on the
upper surface 335 of the upper piston 33 would increase, i.e., till the moment when the number of revolutions of the turbine has increased. Pressure oil is supplied from the pressure device of the governor through connection 44 pressing the piston 4c of the distributor valve so far inwards that the constant-pressure oil supply is closed and the connection 43 opened so that oil pressure is removed from the surface 353a of the safety valve through the annular groove 411 and the connection 41. Since the safety valve moves downwards oil can go to the outlet through the throttle 37.

The actuation of the auxiliary distributor valve 4 can be arranged, e.g., by a frequency relay and a magnet valve which switches over the distributor valve at any desired increase of frequency.

The arrangement according to the present invention has considerable advantages. At an increase of turbine speed determined in advance, this device renders possible a reliable full opening of runner blades and consequently a reduction of speed. For opening the blades thereby it is not necessary to supply pressure oil into space 52 since the hydraulic torque itself opens the blades, therewith forcing the servomotor piston to be shifted downwards, only oil must be drained from the space 53.

A further advantage lies therein that the device may be inserted at any desired place of the power plant, totally separated from the turning parts of the turbine. It can be mounted, dismantled, and adjusted without previous emptying of the turbine bay. The device operates fully independently of the turbine governor or other safety devices. Finally, the economic side is also important as the cost of the complete device amounts to approximately one per cent of the price of the turbine governor. All other systems of protection do not offer an equivalent protection against the increase of rotational turbine speed, but their price considerably exceeds the price of the turbine governor. The complete arrangement does not operate statically but astatically. It is started immediately when the speed is increased to a given amount and it operates until the blades are fully opened.

It remains, of course, in the frame of the invention when the safety distributor valve is of a larger size in order to eliminate friction at control and to prevent sticking on the edges of channels and when it is designed otherwise, e.g., with the help of a sliding sleeve substituting the upper and middle piston and having correspondingly arranged openings. But such an embodiment must still take into account the connection of this valve with the servomotor of the runner and the distributor slide valve which is the object of the present invention and for which protection is claimed.

What I claim is:

1. An hydraulic turbine comprising:
a runner;
a plurality of blades swivelable on said runner;
an hydraulic servomotor on said runner formed with a pair of oppositely pressurizable chambers and a piston between said chambers, said piston being operatively connected to said blades for varying inclination thereof to control the speed of said run-

er;
an hydraulic-fluid source;
a servo-control valve connected to said source and having a pair of ports;
means forming respective flow paths connecting each of said ports with a respective chamber; and
safety-valve means removed from said runner and connected between said servo-control valve and said servomotor, said safety-valve means including:
an elongated valve housing formed with a pair of axially spaced passages respectively forming part of said paths and traversed by hydraulic fluid passing between said servo-control valve and said servomotor,
a valve member axially displacable in said housing and having a first axial position obstrcuting said passages and draining at least one of said chambers and a second axial position in which said passages are substantially unobstructed,
means in said housing defining with said valve mem-
ber a compartment hydraulically pressurizable to bias said valve member from said first position into
said second position, and
valve-seat means formed on said valve member and normally effective to block drainage of said com-
partment but opening to permit such drainage upon the hydraulic biasing of said valve member toward said first position upon the development of an overspeed condition of said runner to sub-
stantially instantaneously shift said valve member from said second position into said first position and drain one of said chambers to enable said blades to swivel into an open condition.

2. The hydraulic turbine defined in claim 1 wherein said valve member has upper, middle and lower piston formations axially spaced apart thereon, said upper and middle formation being respectively interposable in respective passages upon displacement of said valve member from said second position into said first position, said lower formation defining said compartment, said means and said housing including a tubular mem-
ber projecting axially from one end of said housing and slidably received in said lower formation while com-
municating with said other valve, said tubular member defining within said lower formation an axial space, said valve-seat means including cooperative edges on said tubular member and said lower formation separa-
ble upon displacement of said valve member from said second position to said first position, said lower forma-
tion being formed with a bore communicating between said space and the exterior of said lower formation.

3. The hydraulic turbine defined in claim 2 wherein said upper piston is formed with a pair of axial bores, one of said bores being formed with a check valve and the other of said bores being formed with a throttle.

4. The hydraulic turbine defined in claim 3 further comprising at least one throttle for controlling the draining of said compartment and said one of said chambers.