

Dec. 25, 1962

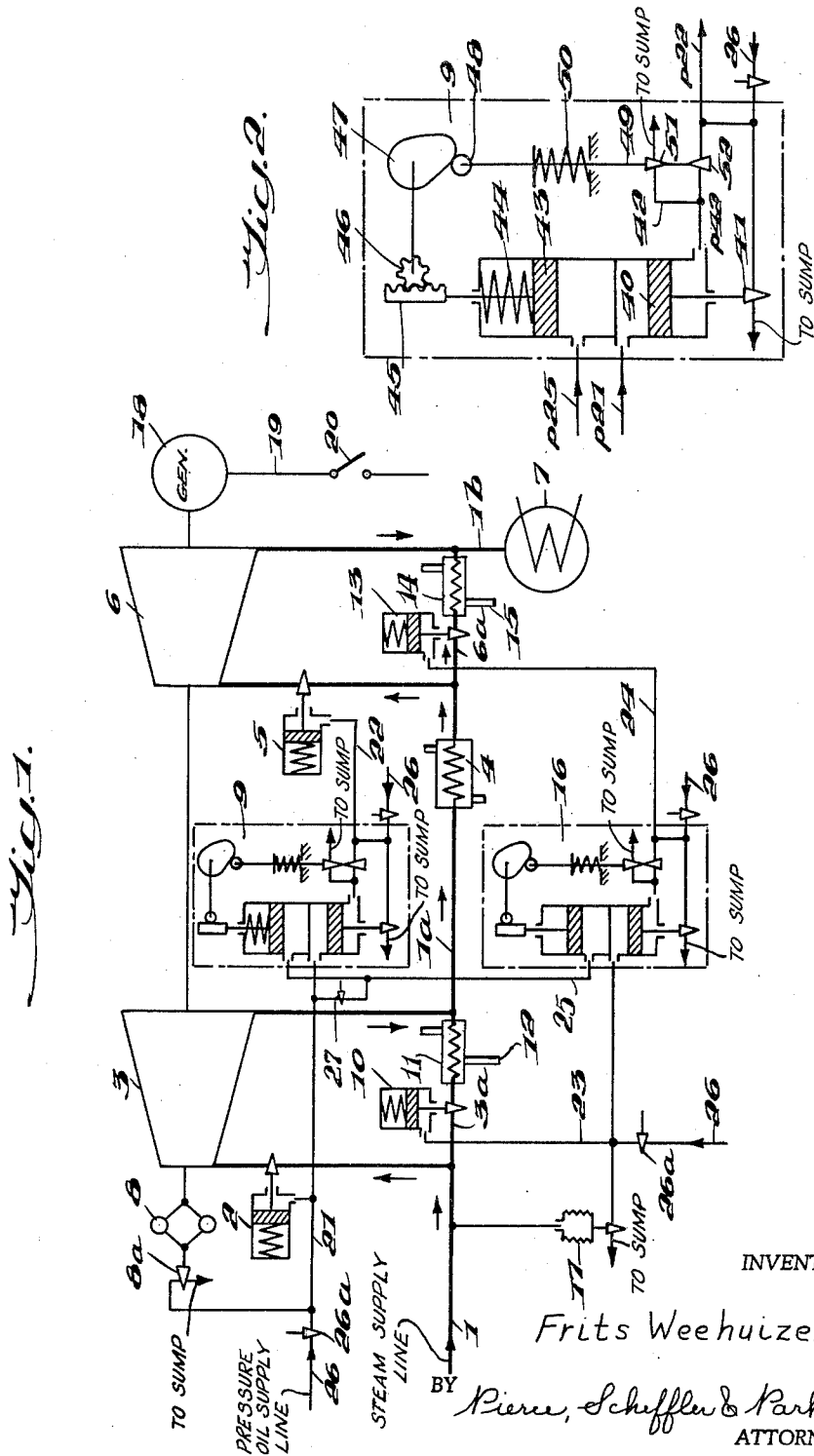
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REGULATING ARRANGEMENT FOR STEAM TURBINE INSTALLATION
WITH INTERMEDIATE SUPERHEATER

Filed June 15, 1960

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 3a.

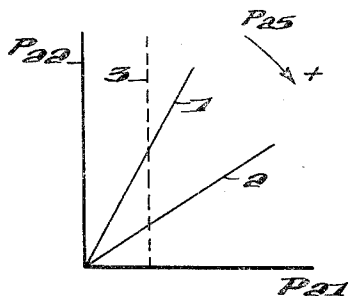


Fig. 3b.

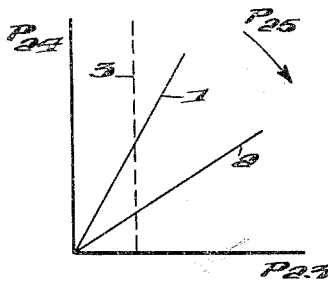


Fig. 4.

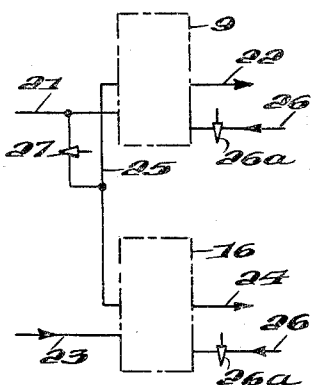
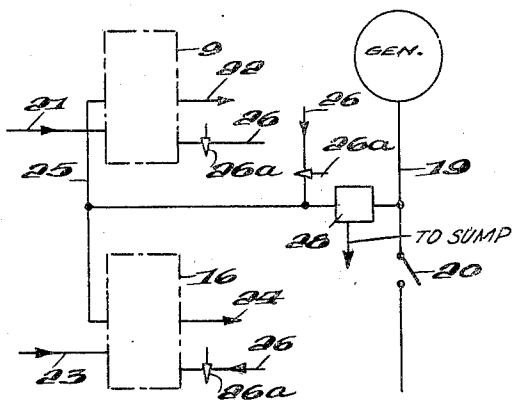


Fig. 5.



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3 Sheets-Sheet 3

Fig. 6.

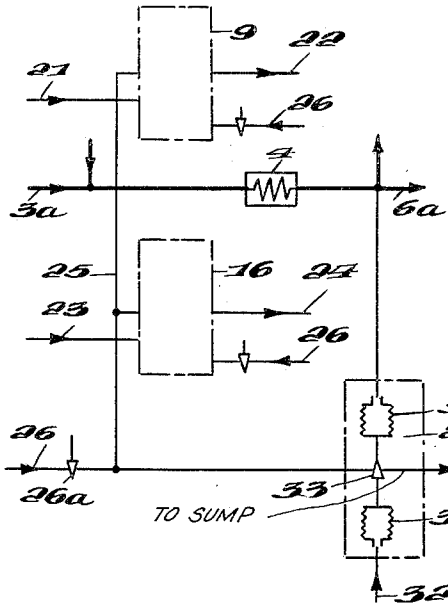


Fig. 7.

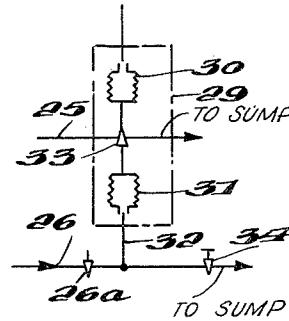
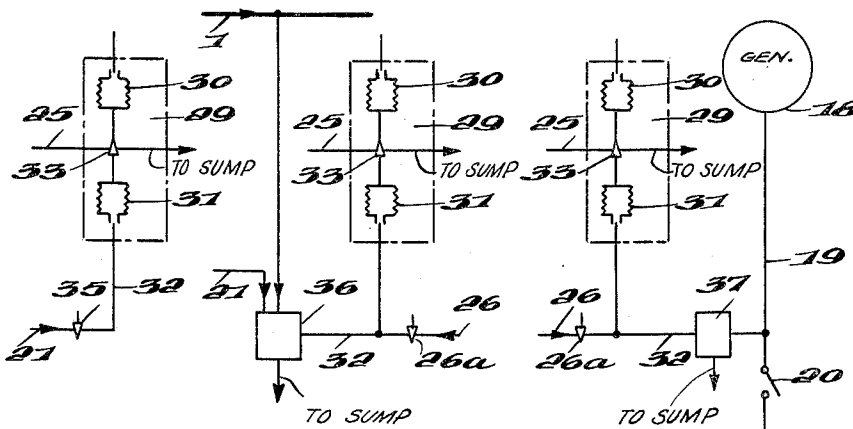


Fig. 8.

Fig. 9.

Fig. 10.



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1

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REGULATING ARRANGEMENT FOR STEAM TURBINE INSTALLATION WITH INTERMEDIATE SUPERHEATER

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8 Claims. (Cl. 60—73)

The present invention relates to steam turbine plants having a high-pressure and a low-pressure turbine and a superheater disposed in the steam line between the turbines, and in particular to an improved arrangement for regulating the steam admitted to the turbines in accordance with a change in load.

Steam turbine plants with intermediate superheating are generally designed together with their steam generators as independent units. It is unavoidable in this case that the turbine can absorb less steam under certain working conditions than the boiler generates. If this overproduction of steam would blow off into the open air over safety valves on the steam generator or on the superheater, valuable water would be lost. Besides, the metal temperature of an intermediate superheater arranged in the boiler would attain inadmissibly high values, due to insufficient cooling. These plants are therefore frequently equipped with by-pass lines parallel to the part turbines, the excess steam being conducted through the intermediate superheater and subsequently into the condenser.

It is also known to provide not only the high-pressure turbine with regulating valves, which are actuated, for example, by a speed regulator, preliminary pressure regulator or a power regulator, but to arrange regulating valves at the inlet of the low-pressure turbine too. In order to achieve an optimum efficiency of the plant, these low-pressure regulating valves are usually wide open above a certain minimum load, which corresponds in most cases approximately to the minimum-load of the steam generator. In order to prevent that the steam stored in the intermediate superheater is discharged by the low-pressure part of the turbine in a sudden reduction of the load of the generator, thus accelerating the turbo group to an unduly high speed, the low-pressure regulating valves are generally temporarily closed completely or partly by a special device, and subsequently returned again into the position of minimum pressure loss. Depending on the extent of the relief, the storage capacity and the thermal inertia of the steam generator, a more or less great overproduction of steam will appear temporarily during the relief, which is eliminated over the above mentioned by-pass lines.

During the starting operation, the steam temperatures after the super-heater and after the intermediate superheater must be brought first to values which are in a certain relation to the metal temperatures of the part-turbines prevailing at the respective moment, before the part-turbines can be admitted again with steam by opening the high-pressure and low-pressure regulating valves. It is customary in this case to eliminate the steam supplied by the steam generator during this period over by-pass lines and through the intermediate superheater into the condenser.

The steam throughput through the by-pass lines is regulated by valves whose regulation can be effected in several ways. Known embodiments comprise: the high-pressure by-pass regulating valve is adjusted by a preliminary pressure regulator connected to the live steam line, the low-pressure by-pass regulating valve by a pressure regulator connected to the steam line after the inter-

2

mediate superheater, either before or after the low-pressure regulating valve; the high-pressure by-pass regulating valve is moved in opposite direction to the high-pressure regulating valve, the low-pressure by-pass regulating valve in opposite direction to the low-pressure regulating valve; a combination of the two systems is also possible. But there is no plant known where the by-pass regulating valves are adjusted in dependence on each other.

According to general practice, the low-pressure regulating valve is coupled mechanically or hydraulically with the high-pressure regulating valve, so that the ratio of the two partial currents remains at least approximately constant. In most cases a constant live steam- and back-pressure after the low-pressure turbine is a prerequisite, which is not always the case, however, in practice. In case the by-pass regulating valves are not adjusted in dependence on each other, there is no assurance that the throughput through the high-pressure and the low-pressure by-pass line is the same. The ratio of the steam throughput through the part-turbines is thus also changed. It can thus happen, for example, that one part turbine receives too little or no steam at all. In this case there is the danger of excessive heating by ventilation.

The present invention concerns a device for regulating a steam turbine plant with intermediate superheater, with at least one regulating valve each before the high-pressure turbine and the low-pressure turbine, with one by-pass each parallel to the high-pressure turbine and parallel to the low-pressure turbine, and with at least one by-pass regulating valve each in these by-pass lines. It is characterized in that the aperture ratio of the regulating valves and the aperture ratio of the by-pass regulating valves is adjusted by known pressure-ratio relays, which are so coupled that the above mentioned aperture ratios are varied simultaneously and in the same sense over a common pressure oil system in dependence on a variable operating quantity.

The above described regulating device combines various advantages: It is suitable for all steam turbines with intermediate superheating, even if they are used for maintaining the frequency in their own network. At all operating conditions occurring in practice, such as starting, rapid relief or great load increase, the constancy of the steam throughput through the high-pressure turbine and low-pressure turbine is maintained, without being impaired by disturbing influences such as variable live steam or back pressure, admissible minimum pressure after the intermediate superheater etc. The entire plant can be operated in a simple manner during the starting, loading and stopping period, the maintenance of a constant steam throughput through the high-pressure turbine and low-pressure turbine being effected automatically. The regulating device can also be used with advantage with two boilers connected in parallel.

The accompanying drawings show schematically in FIG. 1, an embodiment of the regulating device according to the invention; in FIG. 2 a pressure ratio relay on an enlarged scale, in FIGS. 3a and 3b graphs to illustrate the method of operation of the device, and in FIGS. 4 to 10 diagrams of a part of the device for various possibilities of varying the pressure in the common pressure oil-system of the two pressure ratio relays in dependence on an operating quantity. The reference marks for the same parts are identical in all views.

With reference now to FIG. 1, steam is conducted from the superheater (not represented) over the live steam line 1 to the high-pressure turbine 3 and low-pressure turbine 6 and to the respective by-pass lines 3a and 6a. With simultaneous turbine and by-pass operation, a part of the live steam flows through the

high-pressure regulating valve 2 into the high-pressure turbine 3, the balance of the steam flows through the high-pressure by-pass line 3a with the high-pressure by-pass regulating valve 10 and through the cooling device 11, which is fed with injection water over the line 12. Subsequently the two partial steam currents join again at steam line 1a. The steam arrives now in the intermediate superheater 4, traverses it and divides again. One part flows through the low-pressure regulating valve 5 into the low-pressure turbine 6, and the other part flows through the low-pressure by-pass line 6a, with the low-pressure by-pass regulating valve 13 and through the cooling device 14, which is fed with injection water over the line 15. Subsequently, the two partial steam currents join again at steam line 1b and are condensed in the condenser 7. In order to simplify the drawings and particularly the valve element structures since there are so many of them in the system, these valve elements of the various turbine regulating and by-pass regulating valves 2, 5, 10, 13 and other valves to be later described, are symbolized by an arrowhead entering the pressure lines which they control, the convention observed being that the valve opening decreases as the arrowhead moves further into the line, and conversely the valve opening increases as the arrowhead moves in the counter-direction.

The turbines 3 and 6 jointly drive an electrical generator 18 whose outgoing line 19 leads to the main switch 20 of the power plant.

The high-pressure regulating valve 2, is adjusted by the pressure p_{21} of the pressure oil system 21, opening with dropping speed of the turbine and vice versa. The pressure p_{21} is regulated by the oil drain valve 8a in dependence on the speed regulator 8 driven by the turbines. Instead of from the speed regulator, the desired control impulse can also be derived from a pressure regulator connected to the live steam line, from a power regulator, or from a regulator depending on any other operating parameter of the system.

The pressure oil system 21, like the pressure oil systems 22, 23 and 24, is supplied with pressure oil from a central pressure oil system 26 over a calibrated orifice 26a. In FIG. 1, as well as in the other figures to be later described, the pressure oil supply line 26 is applied at various places to various operating components of the system. All of these lines are designated by numeral 26 and it is understood that all such supply lines emanate from the same central pressure source.

The low-pressure regulating valve 5 is actuated by the pressure p_{22} in the system 22, which is controlled by the pressure p_{21} over a pressure ratio relay 9.

The high-pressure by-pass regulating valve 10 is adjusted by the pressure p_{23} in the system 23, which is regulated by a preliminary pressure regulator 17 connected to the live steam line 1. With dropping live steam pressure, the valve 10 moves in a closing sense; with rising pressure it opens. Instead of the pressure regulator 17 or in supplementation thereof, an adjustment by hand of the pressure p_{23} can also be provided.

The low-pressure by-pass regulating valve 13 is actuated by the pressure p_{24} in the system 24, which is controlled by the pressure p_{23} over a pressure ratio relay 16.

The ratio of the pressures p_{21} and p_{22} , and thus the aperture ratio of the regulating valves 2 and 5, is adjusted by the pressure ratio relay 9; the ratio of the pressures p_{23} and p_{24} , and thus the aperture ratio of the by-pass regulating valves 10 and 13, is adjusted by the pressure ratio relay 16. These pressures and aperture ratios respectively can be varied in dependence on the pressure p_{25} in the pressure oil system 25, which acts in the same manner on the relays 9 and 16.

The two pressure ratio relays 9 and 16 are built according to the same principle. By way of an example relay 9 will be described which is represented schematically in FIG. 2.

The input quantity is the pressure p_{21} and the output quantity is the pressure p_{22} . Both pressure oil systems are fed from the central system 26 over calibrated orifices 26a. The pressure p_{22} is controlled by a drain valve 41, which is rigidly connected with the piston 40. The pressure p_{22} exerts its force on this drain valve. On the upper side of the piston 40 acts the pressure p_{21} , on its under side the pressure p_{42} of an intermediate system 42. Since only the forces originating from these two pressures act on the piston, these two forces are equal in the state of equilibrium of the piston.

Pressure oil flows through the valve 52 from the system 22 into the system 42, from where it flows off through the valve 51. The valves 51 and 52 are rigidly connected with each other and with the bar 49. This arrangement has the effect that the ratio of the pressures p_{22} to p_{42} is constant for a certain position of the bar 49, and therefore also of the valves 51 and 52. When the bar 49 moves down, for example, the supply for the intermediate system 42 is increased over the valve 52 and the discharge throttled over the valve 51, the pressure p_{42} rises therefore, and the ratio of the pressures p_{22} and p_{42} drops.

Since the forces on the piston 40 are equal in the state of equilibrium, as already mentioned, the ratio of the pressures p_{42} to p_{21} is constant. For a given position of the bar 49, the pressure ratio p_{22} to p_{21} will therefore also be constant. If the bar 49 moves down, this pressure ratio is therefore reduced.

The position of the bar 49 depends on the pressure p_{25} . If the latter rises, the piston 43 is moved upward against the action of the spring 44. A rack 45 connected with piston 43 turns the pinion 46, and this rotary motion is transferred to the cam disk 47. A cam follower wheel 48 connected with the bar 49 is pressed by the compression spring 50 against the cam disk 47. If the latter is turned, the bar 49 will move up or down, depending on the shape of this disk. In the following description, it is assumed that, when the pressure p_{25} rises, the bar 49 moves down, so that the pressure ratio p_{22} to p_{21} drops, and vice versa. Similar conditions apply to the pressure ratio relay 16.

The above described relations are represented graphically in FIGS. 3a and 3b for the pressure ratio relay 9. The characteristics 1 and 2 each correspond to a constant ratio of the pressures p_{22} to p_{21} , for any two positions of the bar 49 and for two different pressures p_{25} respectively. According to the foregoing considerations, this ratio varies when the pressure p_{25} is varied. If it rises, as it is indicated in the graph by +, the lines of a constant pressure ratio moves clockwise; line 1 is thus displaced toward line 2. The dependence of the pressure p_{22} on p_{21} , and of these two pressures on p_{25} results as follows: If p_{21} is varied, p_{22} is also varied in the same ratio, for example, following line 1. But if the pressure p_{25} is varied, only p_{22} will be influenced, without any effect on p_{21} . The pressure p_{22} will thus vary, for example, along a line 3 for which p_{21} is constant. It assumes a value which lies, for example, on line 2, and follows now this new characteristic when the pressure p_{21} varies again.

The same relations of the pressures p_{23} , p_{24} and p_{25} are represented in graph of FIG. 3b for the pressure ratio relay 16.

For a given value of the live steam pressure, of the back pressure and of the pressure p_{25} , the apertures of the regulating valves 2 and 5 are so associated with the pressures p_{21} and p_{22} , and the apertures of the by-pass regulating valves 10 and 13 are so associated with the pressures p_{23} and p_{24} respectively that the high-pressure turbine 3 has approximately the same steam throughput as the low-pressure turbine 6, and the high-pressure by-pass line 3a has approximately the same steam throughput as the low-pressure by-pass line 6a.

If the live steam pressure or the back pressure vary

5

with constant pressure p_{25} , the aperture ratios of the regulating valves 2 and 5 and of the by-pass regulating valves 10 and 13 respectively remain constant, so that the steam throughput also remains constant.

If the pressure p_{25} varies its value, it varies at the same time and in the same sense the pressures p_{22} and p_{24} over the pressure ratio relays 9 and 16, and thus also the apertures of the low-pressure regulating valve 5 and of the low-pressure by-pass regulating valve 13, without influencing the high-pressure regulating valve 2 and the high-pressure by-pass regulating valve 10. For unvaried apertures of the valves 2 and 10, and for constant live steam pressure and back pressure, only the pressure in the intermediate superheater 4 will therefore vary.

Even with overlapping of the above mentioned possibilities and thus at all operating conditions occurring in practice, the constancy of the steam throughputs is maintained.

The pressure in the system 25 can be regulated in various ways. In FIGS. 4 to 10 a few examples are represented schematically. According to FIG. 4 the pressure oil system 25 is connected with the pressure oil system 21 for the high-pressure regulating valve 2 over a calibrated orifice 27. According to FIG. 5 the pressure oil system 25 is supplied with pressure oil from the central system 26 over the calibrated orifice 26a. The pressure p_{25} is controlled by the power transmitter 28 in dependence on the generator output.

With a rapid reduction of the load, the pressure p_{21} will drop rapidly under the influence of the speed regulator 8, so that the pressure p_{22} also drops. The calibrated orifice 27 (FIG. 4), has the effect that the pressure p_{25} adjusts itself only slowly to the new value of the pressure p_{21} . Likewise, the power transmitter 28 (FIG. 5) has the effect that, when the generator power output diminishes, the pressure p_{25} drops only slowly. The result is that the pressure p_{22} drops first in dependence on p_{21} so that the low-pressure regulating valve 5 closes almost simultaneously with the high-pressure regulating valve 2. When the pressure p_{25} drops, the characteristic of the relay 9, is turned slowly counterclockwise (FIG. 3a) which results in an increase of the pressure p_{22} and thus in a reopening of the valve 5.

When the high-pressure regulating valve 2 closes rapidly, there is a temporary overproduction of steam, because of the inertia of the steam generator. Consequently, the live steam pressure begins to rise, the preliminary pressure regulator 17 responds and opens, by a pressure increase in the system 23, the high-pressure by-pass regulating valve 10. Over the pressure ratio relay 16, the pressure p_{24} rises likewise, opening the low-pressure by-pass regulating valve 13. During the gradual drop of the pressure p_{25} , the low-pressure by-pass regulating valve 13 is opened further to reopen the low-pressure regulating valve 5. The intermediate superheater 4 has thus the possibility of eliminating the stored steam and of adjusting itself to the new load condition. As soon as the steam generator is adjusted to the new load condition, the pressure drops in the live steam line 1, and the by-pass regulating valves 10 and 13 close again.

The pressure p_{25} can also be regulated by a pressure regulator connected to the steam line after the intermediate superheater 4. Its nominal value is adjusted by hand or in dependence on a quantity which is in turn a measure for the turbine load.

The known principle of a regulator with nominal value adjustment is represented in FIG. 6. The regulating quantity is the pressure in the steam line after the intermediate superheater 4, which acts on the diaphragm 30 of the regulator 29. As a guide quantity, the pressure p_{32} in the pressure oil system 32 acts on the diaphragm 31. In this simplified schematic representation, both diaphragms are rigidly connected with the drain valve 33, which regulates the pressure p_{25} in the system 25. The

6

latter is fed from the central system 26 over the calibrated orifice 26a.

When the regulating quantity decreases or when the guide quantity increases, the pressure p_{25} will rise so that the characteristics of the pressure ratio relays 9 and 16 are turned clockwise (FIGS. 3a and 3b), which causes a closing of the low-pressure regulating valve 5 and, if the by-pass device is in operation, also a closing of the low-pressure by-pass regulating valve 13.

FIG. 7 shows the hand control of the pressure p_{32} . By actuating the shutoff element 34 by hand, the pressure p_{32} can be controlled from any desired point, for example, from the central control room.

According to FIG. 8 the system 32 is connected with the system 21 of the high-pressure regulating valve 2 over a calibrated orifice 35. When the turbine is relieved, the pressure p_{32} , and thus the pressure p_{25} , drops slowly, which results, as it was explained above, in a slow reopening of the low-pressure regulating valve 5, and in a further opening of the low-pressure by-pass regulating valve 13, so that the steam pressure after the intermediate superheater adjusts itself to the new pressure level.

In the arrangement according to FIG. 9 the pressure p_{32} is under the influence of a transmitter 36, in which the product of live steam pressure from line 1 and pressure p_{21} , formed in known manner, is proportional to the steam throughput and thus also proportional to the load given off by the generator. The pressure p_{32} is thus directly dependent on the output.

The same problem can also be solved with the arrangement according to FIG. 10. The electric power delivered by generator 18 is measured in the transmitter 37, and the pressure p_{32} is controlled proportionally thereto.

In all the embodiments of the regulating device described above, the stroke of the low-pressure regulating valve 5 and of the steam pressure respectively after the intermediate superheater respectively is so associated with the pressure p_{25} that the valve 5 is completely open at stationary operation and above a certain minimum load of the turbo group.

Steam turbines with intermediate superheating are used mostly for the supply of electricity to the public and run therefore normally in parallel operation in a network of great installed total power. In some cases, these machines are also used for keeping the frequency constant in a network of relatively small total power. To this end the machine must be able to absorb sudden load increases, in addition to rapid load reductions. Various methods are used to meet this problem. The object of all these methods is to utilize temporarily in this case the influence of the storage effect of the intermediate superheater. One of them consists in working in stationary operation with stowed pressure in the intermediate superheater, the low-pressure regulating valve acting as a throttle valve.

The device according to the invention is also suitable for this field. The strokes of the regulating valves 2 and 5 are so associated with the pressure p_{25} that the low-pressure regulating valve 5 is throttled more or less over the entire load range in the stationary state. With a sudden load increase, the pressure p_{21} and thus p_{22} will rise suddenly, in dependence on the speed regulator 8. Since the pressure p_{25} follows only slowly, the low-pressure regulating valve 5 will open wider temporarily (FIG. 3a), and during the subsequent clockwise rotation of the characteristic return slowly into the throttled position.

In the embodiments according to FIGS. 6 to 10, which are best suitable for rapid load increases, the nominal value of the pressure regulator is so set that a higher steam pressure after the intermediate superheater is associated with the turbine power than would correspond to it with the low pressure regulating valve open.

I claim:

1. In a steam turbine plant, the combination compris-

ing a high-pressure turbine and a low-pressure turbine coupled together for driving a common load, a steam line for delivering steam to said turbines in succession, a fluid pressure responsive regulating valve individual to each of said turbines and located in the steam inlet thereto for controlling the amount of steam admitted thereto from said steam line, means controlling the fluid pressure for actuating said regulating valve associated with the steam inlet to said high-pressure turbine in accordance with the load on said turbine plant, a turbine by-pass in the steam line individual to each of said turbines, a fluid pressure responsive regulating valve located in each said by-pass for controlling the amount of steam by-passed from the respective turbines, a superheater located in said steam line intermediate said turbines, a first fluid pressure responsive ratio relay for controlling the ratio of the fluid pressures applied to said regulating valves which control admission of steam to said turbines, a second fluid pressure responsive ratio relay for controlling the ratio of the fluid pressures applied to said regulating valves which control the amount of steam by-passed from said turbines, a fluid pressure control system common to and controlling said fluid pressure responsive ratio relays in accordance with the fluid pressure of said control system, and means controlling said fluid pressure in accordance with an operating parameter of said turbine plant to control said relays and thereby vary said aperture ratios simultaneously and in the same sense.

2. A steam turbine plant as defined in claim 1 and wherein the variation in said aperture ratios for all operating conditions of said plant is such that said high-pressure and low-pressure turbines receive substantially the same steam throughput and said by-passes for said high-pressure and low-pressure turbines receive substantially the same steam throughput.

3. A steam turbine plant as defined in claim 1 wherein said operating parameter for controlling the fluid pressure of said control system which controls said aperture ratio relays is constituted by the fluid pressure which actuates said regulating valve which controls the amount of steam admitted to said high-pressure turbine.

4. A steam turbine plant as defined in claim 1 wherein said common load driven by said turbines is an electrical generator, and said operating parameter for controlling the fluid pressure of said control system which controls

said aperture ratio relays is constituted by the output of said generator.

5. A steam turbine plant as defined in claim 1 wherein said means for controlling said fluid pressure of said control system in accordance with an operating parameter of said turbine plant comprises a pressure regulator having two pressure responsive elements, one of said elements being controlled by the pressure in said steam line after said superheater and the other of said elements being controlled by a pressure which is manually adjustable.

6. A steam turbine plant as defined in claim 1 wherein said means for controlling said fluid pressure of said control system in accordance with an operating parameter of said turbine plant comprises a pressure regulator having two pressure responsive elements, one of said elements being controlled by the pressure in said steam line after said superheater and the other of said elements being controlled by the pressure of the fluid which actuates said regulating valve that controls the amount of steam admitted to said high-pressure turbine.

7. A steam turbine plant as defined in claim 1 wherein said means for controlling said fluid pressure of said control system in accordance with an operating parameter of said turbine plant comprises a pressure regulator having two pressure responsive elements, one of said elements being controlled by the pressure in said steam line after said superheater and the other of said elements being controlled by the product of the live steam pressure and the pressure of the fluid which actuates said regulating valve that controls the amount of steam admitted to said high-pressure turbine.

8. A steam turbine plant as defined in claim 1 wherein said means for controlling said fluid pressure of said control system in accordance with an operating parameter of said turbine plant comprises a pressure regulator having two pressure responsive elements, one of said elements being controlled by the pressure in said steam line after said superheater and the other of said elements being controlled in accordance with the output of an electrical generator which constitutes the common load driven by said turbines.

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