STEAM REHEATER CONTROL FOR TURBINE POWER PLANT

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ABSTRACT

A moisture separator and reheater for a steam turbine power plant which uses a portion of the inlet steam in tube bundles to reheat lower pressure power plant cycle steam has a valve which controls the pressure of the reheating steam in the bundles as a proportional function of the lower pressure cycle steam.

4 Claims, 3 Drawing Figures
STEAM REHEATER CONTROL FOR TURBINE POWER PLANT

BACKGROUND OF THE INVENTION

This invention relates generally to steam turbine power plants having reheaters which use a portion of the steam supplied to the cycle to reheat the cycle steam in the reheat sections of the turbine at a lower pressure. More particularly, the invention relates to a means for controlling the supply of heating steam to the reheat sections of the turbine to reduce stresses due to temperature differences and rapid temperature changes.

Steam turbine power plants operating from an essentially saturated steam supply, as in the case of plants supplied by boiling water or pressurized water nuclear reactors, commonly employ moisture separating and reheating devices to remove moisture from the steam and to reheat it between a high-pressure turbine section and a lower pressure turbine section. The reheaters, which may either be combined with moisture separating elements in a single pressure vessel, or disposed in a separate pressure vessel, commonly withdraw a portion of the inlet steam supply to the steam turbine to serve as heating fluid for the cycle steam which is at a lower pressure and temperature. More than one stage of reheating may be employed.

In the reheater, the highest temperature stage uses inlet steam as the heating fluid and the temperature on the "tube-side" of the reheater tube bundles does not change greatly with load. On the other hand, the "shell-side" temperature of the cycle steam being reheated varies over a wide range during load as does the pressure of the steam. At partial loads, significant temperature differences between shell-side and tube-side can give rise to stresses in and around the reheater tube bundles and tube sheets which are undesirable.

Accordingly, one object of the present invention is to provide a reheater control which reduces stresses in the reheater caused by temperature differences between the heating and the heated fluid.

Another object of the invention is to provide a generally improved control for a reheater using supply steam as the reheating fluid, thereby minimizing rates of temperature change in the reheater as the plant is loaded.

SUMMARY OF THE INVENTION

Briefly stated, the invention is practiced by providing a controller which varies the pressure of the inlet steam supplied to the reheater as a function of the pressure of the reheated cycle steam over selected load ranges according to the mode of operation of the reheater.

DRAWING

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. The invention, however, both as to organization and method of practice, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

FIG. 1 is a simplified schematic diagram of a steam turbine power plant with reheater, illustrating the preferred controller of the invention in block diagram form, and

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 of the drawing, a steam turbine power plant includes a high-pressure steam turbine section 1 and low-pressure turbine sections 2, with a combined moisture separator and reheater vessel 3, only one of several such units being shown for purposes of clarity. Steam entering the supply line 4 expands through the high-pressure turbine 1 to a wet condition, leaving via line 5. The cycle steam then enters moisture separator and reheater 3 and flows through a number of inlets 6 on the bottom of the pressure shell and leaves by way of outlets 7 at the top of the pressure shell. From there it flows through line 19 to the low-pressure turbine and then to condensers (not shown).

The interior of the moisture separator and reheater 3 contains moisture separating elements (not shown) for removing moisture from the cycle steam which is drained off through pipes 8. Cycle steam is then guided via internal baffles (not shown) over a first stage 9 of reheater tubes (shown schematically) and a second stage 10 of similar tubes. The tube bundles of stages 9, 10 are supplied from internal headers 11, 12, respectively, which connect to the tube bundles via tube sheets. Supply and drain pipes for the headers pass through the pressure vessel wall and comprise a first stage reheater inlet 13, a first stage condensate drain 14, a second stage inlet 15 and a second stage drain 16. The first stage inlet 13 is supplied by an extraction line 17 from high-pressure turbine 1. The pressure of this extraction steam varies proportionately with turbine load as does the cycle steam discharged through line 5 from the high-pressure turbine.

The second stage reheater inlet 15 is supplied by a branch line 18 connected to the main steam supply line 4. The steam pressure and temperature in this line is substantially constant over the load range.

It remains to note that the moisture separator and reheater 3 is constructed to give a very low pressure drop in the cycle steam entering from line 5, perhaps of the order of 7 psi. Therefore, the pressure in the discharge line 19 from the moisture separator and reheater is comparable to that in line 5.

In accordance with the present invention, a control system, shown generally at 20, is provided to control the pressure of the steam flowing to the second stage reheater inlet 15 so that it is a linear function (proportional to) the cycle steam pressure in line 19 (or line 5). Control of the pressure in the preferred embodiment is effected by means of a pneumatically operated steam control valve 21 connected in parallel with a motor-operated check valve 22.

The control system 20 includes a pressure transducer 23 connected to sense steam pressure in line 19 (or, alternatively, line 5 ahead of the reheater) and to convert it to a "controlling" variable. A multiplying relay 24 serves to multiply the signal from transducer 23 by a selected factor K. A bypass 25 is connected to shunt relay 24 under selected modes of operation.

Reheater steam inlet pressure downstream of valves 21, 22 in line 18a is sensed by transducer 26 and similarly converted to a "controlled" variable. The controlling and the controlled signals are combined in a com-
parator 27 with proportional plus reset characteristics, the signal in the output 28 being used to adjust the opening of control valve 21 so as to reduce the error to zero.

In order to reduce the flow requirements and size of the control valve 21, the parallel-connected check valve 22 is operated to assume either open or closed condition by a signal in line 29. The connections are such that the check valve 22 opens when the pressure drop across control valve 21 is less than about 30 psi, so that the valve 21 controls over only a portion of the turbine load range.

In some installations, it may be desirable to allow control valve 21 to control the inlet pressure to a pair of moisture separators and reheaters, and in this case there may be a check valve 22 for each of the reheaters connected in parallel with a single control valve such as 21.

The components and operating medium for the control system 20 may take many different forms, such as electronic, fluidic, hydraulic, etc. The elements shown in the figure are conventional pneumatic and hence are only shown in block diagram form. By way of example, and not limitation, transducer 23 may be a Fisher Type 4157 pressure transmitter ranged 6-30 psig (air) output for 0-175 psig (steam) input. Transducer 26 may be a Fisher Type 4157 pressure transmitter ranged 6-30 psig (air) output for 0-885 psig (steam) input. Multiplier 24 may be a Moore Type 68-2 2/1 multiplying relay which provides a pneumatic output pressure which is twice the input pressure. Comparator 27 may conveniently be a Fisher Type 4164 differential pressure controller with proportional plug reset response.

The moisture separator and reheater 3 shown in FIG. 1 is arranged by means of appropriate valving, such as valve 30, so that it can be used either with or without the first stage of reheating. With both the first stage 9 and the second stage 10 of reheating in service, valve 30 is open. This is the normal mode of operation and in this case, bypass 25 in the control system 20 is positioned and the multiplying relay in FIG. 2 is in operation. In the other mode of reheater operation, valve 30 is closed and only the second stage reheater 10 is then supplied with steam. In this mode, bypass 25 is positioned so as to shunt multiplier 24.

Referring now to FIGS. 2 and 3 of the drawing, FIG. 2 illustrates pressure and temperature conditions obtained during normal two stage operation of the reheater over the load range of the turbine. FIG. 3 is a similar graph but with only the second stage reheater in operation. The abscissa of both graphs is scaled to show the percent of steam flow to high-pressure turbine 1 (which is proportional to load on the turbine). Identical reference numerals are used on both graphs for purposes of comparison.

Variation of the controlling steam pressure in steam line 19 measured by transducer 23 is indicated by curve 30, while the controlled steam pressure in steam line 18a measured by transducer 26 is shown by curves 31, 31a. Curve 31 on FIG. 2 is at twice the slope of curve 31 on FIG. 3, because the multiplying relay 24 is in operation. The controlled steam pressure cannot exceed that in steam supply line 4 which is indicated by the flat portion of curve 31a in the FIG. 2 mode. Variation of temperature of the cycle steam on the shell-side at the inlet to the second stage reheater is indicated by curve 32. In the FIG. 3 mode (since the first stage reheater is not in service) curve 32 is simply the saturation temperature corresponding to the steam pressure shown in line 30. In the FIG. 2 mode (since some first stage reheating takes place) curve 32 is the shell-side outlet temperature from the first stage reheater.

Similarly, the temperature of the heating steam inside the tubes of the second stage reheater is indicated by curves 33, 33a. These correspond to saturation temperatures at the steam pressures of curves 31, 31a. The maximum temperature differential between the second stage reheater shell-side and tube-side are shown as T. This temperature difference is a contributing factor to reheater thermal stress and is held at a minimum value by the present invention.

For purposes of comparison, the pressures and corresponding temperatures which would be supplied to the reheater without the control system of the present invention are shown by the dashed line portions 34, 35, respectively. Without the present invention, the maximum tube-side versus shell-side temperature differential would be represented by a temperature difference T'.

OPERATION

The operation of the invention in normal (or two stage) operation is as follows. From no-load up to approximately one-half load, the steam control valve 21 is controlled to cause the steam pressure entering the second stage reheater from line 18a through inlet 15 to vary in proportion to the reheater cycle steam pressure. With multiplier 24 in operation, valve 21 is fully open at approximately one-half load. From approximately one-half load to full load, the temperature differential is limited by the system characteristics, because the reheater shell-side inlet temperature continues to increase, while the tube-side temperature is limited to turbine inlet temperature. Thus, the control system only operates from no load to one-half load.

Single stage operation takes place when the first stage reheater tubes 9 are shut off using valve 30 and the bypass 25 is repositioned to shunt multiplier 24. In this case, as seen on FIG. 3, valve 21 serves to control the inlet pressure in line 18a to the second stage reheater inlet over the full load range in proportion to the reheater cycle steam pressure. Because of the similar characteristics of the steam temperature with respect to pressure in various parts of the reheater, controlling the second stage reheater steam inlet pressure linearly with reheater cycle steam pressure causes the temperature curves to generally follow one another. This limits the maximum temperature differential T between tube-side and shell-side in the reheater.

Thus, it can be seen that the invention offers a very simple means of controlling steam serving as the heating fluid in the reheater in a manner which limits its temperature over certain load ranges in certain modes of operation. The invention makes use of the fact that the characteristic temperature curves of heating and heated fluids are caused to be similar. This serves to reduce temperature differentials within and around the reheater tube bundle thereby holding thermal stresses to a minimum.

The invention also offers a very simple means of controlling the heating steam to the reheater as load is built up on the turbine. The automatic control ensures that as the turbine is loaded, so the second stage reheater heating steam pressure is gradually built up in accor-
dance with the turbine loading routine, thus minimizing rates of temperature change in the second stage reheater, so improving reliability. Such control could only be effected manually with the most careful and time-consuming operational procedures.

Although the invention has been shown in its preferred and simplest form as using reheat cycle steam as the controlling variable to control the pressure of the reheater supply steam, other methods of obtaining the same linearly increasing pressure characteristic with respect to load will be apparent to those skilled in the art. It is desired to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed:

1. In a steam turbine power plant of the type having a high-pressure turbine supplied from a steam source, reheater means with tube bundles adapted to reheat cycle steam from the high-pressure turbine using a portion of said source steam in said tube bundles as the reheating fluid, the improvement comprising: control means arranged to vary the pressure of said reheating fluid as a function of the pressure of said cycle steam from said high-pressure turbine.

2. The combination according to claim 1, wherein said control means comprises a control valve interposed between said steam source and said reheater means and further including comparator means controlling said control valve in response to a difference between a first signal representing steam pressure at said control valve outlet and a second signal representing a selected multiple of cycle steam pressure.

3. The combination according to claim 2 and further including check valve means connected in parallel with said control valve means and arranged to open at a third signal representing a selected pressure of cycle steam from the high-pressure turbine, whereby said control valve means controls over only a portion of the turbine load range.

4. The combination according to claim 2, further including selectable signal bypass means to change the multiple of said controlling cycle steam pressure second signal supplied to said comparator.

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