A steam turbine operating system includes at least a high pressure turbine section and a low pressure section; one or more control valves arranged to admit steam from a boiler to the high pressure turbine section; a condenser arranged to receive steam exhausted from the low pressure section and to convert the steam to a liquid; a top heater arranged to receive liquid from the condenser and to heat the liquid via heat exchange with steam from the high pressure section, and to return the heated liquid to the boiler; and an overload bypass valve arranged to supply steam bypassed around the one or more control valves directly to the top heater.
STEAM TURBINE OVERLOAD VALVE AND RELATED METHOD

[0001] This invention relates to the operation of a steam turbine using turbine reserve capacity for operation at elevated loads.

BACKGROUND OF THE INVENTION

[0002] Large steam turbines of the type used in the electrical power generating industry are liberally designed to provide some additional load capability beyond the nominal rated capacity, an operating point commonly referred to as the “guarantee point.” The nominal rated capacity is stated in terms of power output, and conventionally, this condition is achieved with one or more control valves less than fully open so that the additional capability is obtained by opening the control valves fully. If the turbine design is such that the nominal rated capacity occurs with the steam admission valves fully open, the turbine efficiency at that point will be improved significantly in terms of energy utilization or heat rate. However, with the control valves fully open, there are limited means by which reserve capacity of a steam turbine can be achieved.

[0003] One known method of achieving excess capacity in a turbine when the nominal rated capacity occurs with the control valves fully open, is to provide a bypass valve and thereby pass extra steam around the control valves to a lower pressure stage of the turbine. This method (as used in the past) has three disadvantages. First, it has been considered necessary to integrate the bypass valve into the turbine control system, in effect making the bypass valve an additional control valve which is throttled in a controlled and coordinated manner with the admission control valves. This adds significantly to the complexity of the control system. Second, to meet industry incremental regulation requirements with a throttling type bypass valve, it has been necessary to provide some overlap between the control valves and the bypass valve. In other words, it becomes necessary to begin opening the bypass valve before the control valves are fully open. This degrades the efficiency of the turbine at its nominal rated capacity. Third, because of the small capacity of such a bypass valve, considerable valve stroking motion is required to have the turbine participate in frequency control in the power system to which it is connected. This large motion may cause heavy wear and lead to early failure of the valve.

[0004] In another method, a bypass overload valve is employed to achieve reserve capacity of the turbine with no substantial change to the turbine control system, with the diverted or bypass steam reintroduced into a downstream turbine stage. This method is described in commonly-owned U.S. Pat. No. 4,403,476.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In the exemplary but non-limiting embodiment disclosed herein, the steam supplied by the boiler and diverted toward the overload valve upstream of the steam turbine inlet is redirected to the top heater rather than to a downstream turbine stage.

[0006] Accordingly, in one aspect, the present invention relates to a steam turbine operating system comprising at least a high pressure turbine section and a low pressure section; one or more control valves arranged to admit steam from a boiler to the high pressure turbine section; a condenser arranged to receive steam exhausted from the low pressure section and to convert the steam to a liquid; a top heater arranged to receive liquid from the condenser and to heat the liquid via heat exchange with steam from the high pressure section, and to return the heated liquid to the boiler; and an overload bypass valve arranged to supply steam bypassed around the one or more control valves directly to the top heater.

[0007] In still another aspect, the invention relates to a method of operating a steam turbine delivering power to a connected load and adapted to receive steam from a steam generating source; the turbine having one or more control valves for controlling the admission of steam to higher pressure stages of the turbine and having a bypass overload valve connected to receive steam from the steam source, the method comprising the steps of: (a) maintaining the bypass overload valve closed while controllably positioning the control valves to admit steam to the turbine to sustain a preselected power load; (b) at least partially opening the bypass overload valve; and (c) returning steam passing through the bypass overload valve to the top heater.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a simplified schematic illustration of a steam turbine generator power plant in which the turbine utilizes a bypass overload valve in accordance with a known arrangement; and

[0009] FIG. 2 is a supplied schematic illustration similar to FIG. 1, but modified to incorporate the subject matter of the exemplary but non-limiting embodiment disclosed herein.

DETAILED DESCRIPTION OF THE INVENTION

[0010] In the electrical power generating plant of FIG. 1, a boiler 10 serves as the source of high pressure steam, providing the motive fluid to drive a reheat steam turbine 12 which includes high pressure (HP) section 14, intermediate pressure (IP) section 16, and a low pressure (LP) section 18. Although the turbine sections 14, 16 and 18 are illustrated to be tandemly coupled to each other and to generator 20 by shaft 22, other coupling arrangements may be used. It will also be appreciated that the invention disclosed further herein applies equally well to non-reheat turbines which do not have an IP section.

[0011] The steam flow path from boiler 10 is through steam conduit 24 from which steam may be taken to HP turbine 14 through one or more admission control valves (plural valves are shown at 25-28). Each control valve 25-28 is connected to discharge steam to the HP section 14 either through circumferentially arranged nozzle arcs in a partial admission configuration or to a single space ahead of the first stage nozzles in a single admission configuration. Both of these configurations are well known in the art. Further, the control valves of a turbine with the partial admission arrangement may be operated either simultaneously, in the full arc mode in which case steam is admitted to the HP section 14 in an assembly uniform circumferential pattern so that the turbine operates like a single admission turbine, or they may be operated sequentially, in the partial arc mode, in which case steam is admitted first to one or more nozzle arcs and then to the others in sequence as the turbine load is increased.

[0012] Steam exhausted from the IP section 14 passes through reheater 30 wherein the temperature of the steam is increased. Subsequently, steam from the reheater is passed to
IP section 16, then, through crossover conduit 32, to LP section 18. Steam exhausted from the LP section 18 flows to the condenser 34 which changes the state of the fluid from a vapor, i.e., steam, to a liquid, i.e., water. The water is then returned to the boiler where it is changed back to steam and returned to the turbine through the one or more control valves.

[0013] Although control of a steam turbine is a very complex and complicated process, with the turbine operating at essentially steady state the principal considerations are to maintain the turbine’s speed and load. With reference to FIG. 1, these variables are controlled by feedback control system 38 which positions (i.e., determines the degree of opening of) control valves 25-28 to admit more or less steam to the turbine 12. Such control systems are well known and control system 38, for example, may be of the type disclosed by U.S. Pat. No. 3,097,488.

[0014] Virtually every turbine is designed to provide reserve capacity for producing power over the nominal rated capacity. For gaining additional power from the turbine after the control valves have reached their limit or fully open position, a bypass overload valve 40 is connected between the steam supply conduit 24 and the reheat point ahead of reheater 30. For control of the bypass overload valve 40, a simple open-closed (manual or automatic) control 42 is provided that actuates valve 40 to be opened whenever the load demand is greater than the nominal rated capacity. For manual operation of the overload valve 40, a simple switching arrangement may be used and the valve 40 opened at the discretion of operating personnel whenever the control valves 25-28 are fully open.

[0015] For example, with the control valves 25-28 fully open and the turbine 12 operating at its nominal rated capacity, additional power is attained by subsequently opening the overload bypass valve 40. This allows a quantity of steam to bypass the higher pressure sections of the turbine and enter the low temperature side of the reheater 30. Alternatively, however, the bypassed steam through overload 40 may be admitted to a lower pressure stage of the high pressure section 14 as indicated by the dashed line 44. In either case, there is an increase in total steam flow into the turbine which, if maintained, enables the turbine 12 to produce a greater output.

[0016] With reference now to FIG. 2, where similar reference numerals are utilized, but with a prefix 1 added, to indicate corresponding components, the steam diverted from the boiler 110 toward the overload valve 140 is not redirected to a downstream turbine stage as in the FIG. 1 arrangement, but rather, is redirected via line 46 to the turbine top heater 48. Thus, steam input to the top heater 48 from the HP section 114 (or steam extracted from a location part way through the HP turbine expansion), and the bypass steam entering the top heater via line 46 combine to heat the liquid condensate from the condenser 134. The heated condensate returns to the boiler 110 where it is converted back to steam and recycled to the turbine, while the now-cooled steam from the HP section 114 and line 46 are simply drained from the top heater. It will also be appreciated that the overload valve may be opened and/or closed incrementally (as opposed to simple on/off operation) by any suitable known control arrangement, i.e., used in a throttling manner and thus be more responsive to cycle conditions.

[0017] The exemplary but non-limiting arrangement solves problems associated with the more conventional arrangements. For example, this arrangement eliminates the need for another control stage within the steam turbine which is normally very costly. Bypassing the steam to the top heater directly also prevents the steam path from being disrupted. The arrangement also eliminates problems associated with temperature mis-match in the turbine structure which causes thermal distortion at the point where the bypass flow enters the steampath. Thermal distortions can result in larger clearances between rotating and stationary components leading to increased steam leakage and lower efficiency.

[0018] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

1. A steam turbine operating system comprising at least a high pressure turbine section and a low pressure section; one or more control valves arranged to admit steam from a boiler to a high pressure turbine section; a condenser arranged to receive steam exhausted from the low pressure section and to convert the steam to a liquid; a top heater arranged to receive liquid from the condenser and to heat said liquid via heat exchange with steam from the high pressure section, and to return the heated liquid to the boiler; and an overload bypass valve arranged to supply steam bypassed around said one or more control valves directly to said top heater.

2. The operating system of claim 1 wherein bypass steam from the overload valve and steam from the high pressure turbine section are drained from said top heater.

3. The operating system of claim 1 wherein said overload bypass valve is moveable between open and closed positions.

4. The operating system of claim 3 wherein said overload bypass valve is moveable incrementally in a throttling manner.

5. The operating system of claim 3 wherein said bypass overload valve is moveable manually at the discretion of operating personnel.

6. The combination of claim 3 wherein said bypass overload valve is moveable automatically in response to a signal indicative of turbine load.

7. A method of operating a steam turbine delivering power to a connected load and adapted to receive steam from a steam generating source, the turbine having one or more control valves for controlling the admission of steam to higher pressure stages of the turbine; a condenser arranged to receive steam exhausted from said turbine and convert the steam to a liquid; and a bypass overload valve connected to receive steam from the steam source, the method comprising the steps of:

(a) maintaining said bypass overload valve closed while controllably positioning said control valves to admit steam to the turbine to sustain a preselected power load;
(b) at least partially opening said bypass overload valve; and
(c) returning steam passing through said bypass overload valve to said top heater.

8. The method of claim 7 wherein said bypass overload valve is manually caused to be opened and closed at an operator's discretion.

9. The method of claim 7 wherein said bypass overload valve is automatically caused to be opened and closed in response to a signal indicative of turbine load.

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