

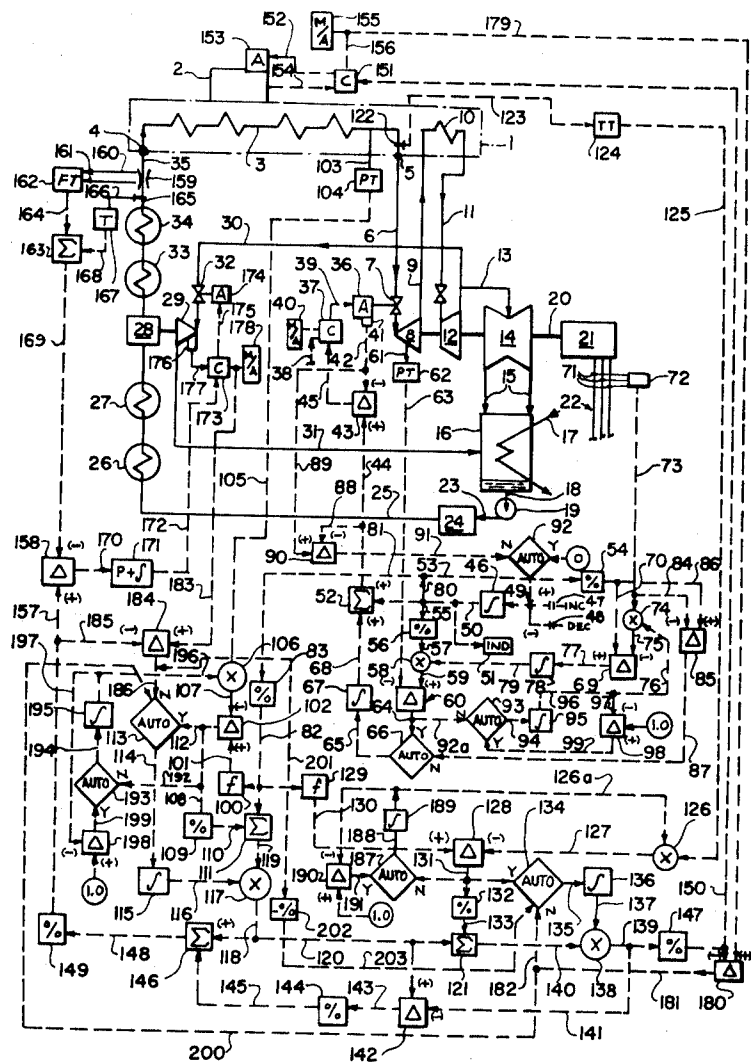
[72] Inventor Charles Strohmeier, Jr.
Reading, Pa.
[21] Appl. No. 65,886
[22] Filed Aug. 21, 1970
[45] Patented Nov. 9, 1971
[73] Assignee Electrodyne Research Corporation
Reading, Pa.

[56] References Cited
UNITED STATES PATENTS
3,422,457 1/1969 Koppel..... 318/591
3,546,472 12/1970 Hoffman..... 290/40
Primary Examiner—Oris L. Rader
Assistant Examiner—W. E. Duncanson, Jr.
Attorney—William J. Ruano

[54] TRACKING MEANS FOR A STEAM ELECTRIC
GENERATING PLANT AUTOMATIC CONTROL
SYSTEM
6 Claims, 2 Drawing Figs.

[52] U.S. Cl..... 290/40 R,
318/591
[51] Int. Cl..... G05b 7/00
[50] Field of Search..... 290/2, 40,
43, 51, 52, 54; 318/591

ABSTRACT: The invention provides a means for balancing a complex steam electric generating plant automatic control system when in the manual tracking mode before transfer to automatic. The tracking system utilizes the normal automatic integral functions to set demands for generation, governor valve position, feedwater flow and heat input to the steam generator equal to actual conditions prior to transfer. Thus, after transfer the system is immediately ready to perform its normal control functions without having to reposition normal working integrals from generation, pressure or temperature errors to satisfy unbalances internally within the system which existed at time of transfer.



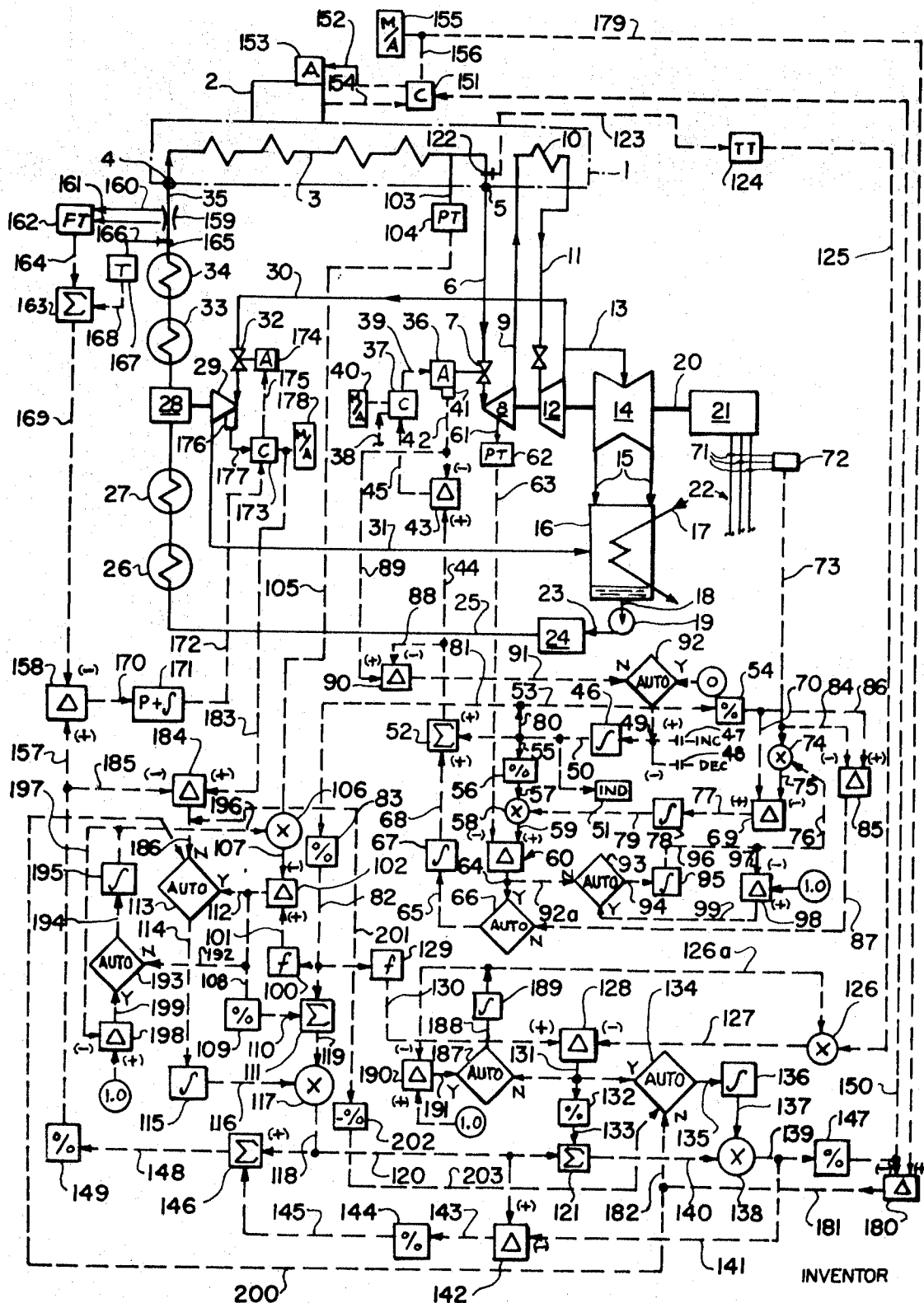


Fig. 1

CHARLES STROHMEYER, JR.

BY

William J. Ruano
ATTORNEY

TRACKING MEANS FOR A STEAM ELECTRIC GENERATING PLANT AUTOMATIC CONTROL SYSTEM

This invention relates to a coordinated control system for a steam electric generating unit having a steam generator and turbine generator. It is customary to provide such a control system with a means for operating both in the manual and automatic modes. The automatic mode is the normal condition. The manual mode is used for back up when the automatic mode fails and to ready the unit preparatory to placing the unit in the automatic mode.

It is desirable to have a smooth transfer when going from the manual to automatic modes. In the past such practice has been called "bumpless transfer." In a system which is predominately of the feedback error type it has been reasonably easy to achieve a stable bumpless transfer. Such systems are, however, slow in their response to changing load conditions. Where strong "feed forward" characteristics are added to stabilize and speed up the response of an integrated steam generator-turbine generator control system to changing load conditions, provisions for bumpless transfer in the past have not provided for internal balancing of working automode integrals to precisely match actual conditions and offsets at time of transfer.

While there may have been little movement of variables as feedwater flow, heat input, governor valve position at time of transfer as a result of special tracking integrals offsetting system unbalances in past systems, the system itself nevertheless was not in equilibrium so as to permit significant load fluctuations immediately after transfer without developing serious steam pressure and temperature errors from such fluctuations. After transfer it was necessary to hold the unit at constant load for a period of time until the system balanced itself internally from pressure and temperature feedback errors.

The present invention overcomes past difficulties in that turbine stage pressure, main steam pressure and temperature integral outputs are coordinated at time of transfer from manual to auto to reflect actual conditions. Thus, since the system is in balance at such time the load of the unit may be varied immediately after transfer to auto up to the maximum capability of the system to withstand load change without excessive deviation occurring from the steam pressure and temperature conditions at time of transfer.

Control system configurations may vary widely and still have equivalent functions and results. For the purpose of this invention where separate integrators are used for each of the tracking and automatic modes of operation and where one integrator is directly related to the output of another integrator at time of transfer from the manual to automatic mode, the integrators shall be considered to be equivalent or the same.

The objects of this invention are related to the tracking mode of an integrated steam generator-turbine generator control system for a steam electric generating unit wherein a common load reference is developed for required output of the steam generator and turbine generator.

A specific object of this invention is to provide a means of balancing the load reference with actual megawatt output of the unit when in the manual mode through use of the turbine stage pressure error integral.

A further object is to amplify said specific object by reducing turbine stage pressure error to zero through use of the megawatt error correction integral when in the manual mode.

As an alternative to the above when in the manual mode, the turbine stage pressure error integrator output may be blocked at a neutral value representing zero error.

A still further object when in the manual mode is to use the turbine stage pressure error integral to set the load reference at a value representative of actual megawatt output of the unit, to use either the main steam pressure or temperature error correction integral to balance feedwater flow demand with actual F.W. flow and to use the remaining error integral of the latter two to balance demand for heat input to the boiler with actual heat input.

The invention will be described in detail with reference to the accompanying drawings wherein:

FIG. 1 is a schematic diagram of the steam and water cycle for a steam electric generating plant and the associated control system incorporating the various objectives of this invention, and

FIG. 2 is an alternative arrangement of the control systems in accordance with said alternative objective. Only those parts of the system which are required to distinguish from FIG. 1 are shown on FIG. 2. Where elements are missing on FIG. 2 they can be assumed to be like FIG. 1.

The invention is illustrated in FIG. 1. Steam generator 1 receives heat from source 2 which may be either from combustion of fossil fuel or from nuclear fuel reaction. In the latter case an intervening medium (not shown) may convey the heat of nuclear reaction to absorption circuits 3 of steam generator 1. Absorption circuits 3 are located between feedwater inlet 4 and superheater outlet 5. Steam lead 6 conveys the working fluid to turbine steam admission control valves 7 which regulate the flow of steam to high-pressure turbine 8.

Turbine 8 exhausts through conduit 9 to reheater 10 in steam generator 1. Reheated steam is conveyed through conduit 11 to intermediate pressure turbine 12. After expansion, the steam passes through conduit 13 to low-pressure turbine 14. Exhaust steam passes through conduits 15 to steam condenser 16. Cooling water passing through conduits 17 condenses the vapor. Condensate collects in the bottom of condenser 16 and is drawn through conduit 18 to the inlet of condensate pump 19.

Shaft 20 connects turbines 8, 12 and 14 to electric generator 21. Generator 21 is provided with a rotating DC field (not shown). Three phase AC output current passes through isolated phase bus duct 22 to the distribution system (not shown).

Condensate pump 19 discharges through conduit 23 to water purification equipment 24 from whence it passes through conduit 25 to and through feedwater heaters 26 and 27 which are of the tube and shell type.

Heaters 26 and 27 receive extraction steam from the low-pressure turbine in their shells (not shown). The drains cascade from the 27 to 26 heater and to the condenser through conduit and flow control means not shown. The boiler feed pump 28 takes suction from the discharge of heater 27 and raises the fluid pressure to the working pressure of the steam generator. Pump 28 is driven by auxiliary turbine 29 which receives steam from turbine 12 through conduit 30 and exhausts to condenser 16 through conduit 31.

Steam flow to turbine drive 29 is regulated by control valve 32. Speed of turbine drive 29 and pump 28 regulates flow of feedwater discharging from pump 28 to and through high-pressure feedwater heaters 33 and 34 and conduit 35 to feedwater inlet 4 of steam generator 1.

High-pressure heater shells receive extraction steam from the exhaust of main turbine 8 and the intermediate turbine 12, not shown. The drains cascade from heater 34 to heater 33 and are then returned to the feedwater cycle, also not shown.

Valves 7 are power operated by means of actuator 36. Controller 37 regulates actuator position through control of the power supply from circuit 38 to actuator 36 through circuit 39. Pushbuttons in manual/autostation 40 increase or decrease valve 7 opening when in the manual mode. Transfer from manual to auto and from auto to manual is accomplished through pushbuttons in station 40. Conventional practice is employed. Valve 7 position is measured and ranged in unit 41 and is transmitted through circuit 42 to difference unit 43 where actual valve position is compared with demand for valve position in circuit 44. The generated error in circuit 45 feeds to controller 37. When in the automatic mode controller 37 regulates the opening of valves 7 in response to the error in circuit 45.

Integral unit 46 generates a load reference or demand signal in circuit 50 dependent upon closure of increase or decrease contacts 47 and 48 when in the automode and from circuit 49 when in the manual mode. Indicator 51 visually displays load reference 50. Circuit 50 connects to summer 52, the output of which is circuit 44. The circuit 50 increment in circuit 44 is the feedforward demand for valves 7 position.

Reference 50 through circuit 55 feeds to proportional unit 56 ranging the signal for comparison with turbine stage pressure and from thence passes through circuit 57, ratio relay 58, and circuit 59 to difference unit 60 generating a set point for turbine stage pressure. Turbine stage pressure in conduit 61 is measured and ranged in unit 62 and is transmitted through circuit 63 to difference unit 60. The output in circuit 64 is turbine stage pressure error.

When in the automode, circuit 64 is connected to integral unit 67 through transfer function 66 and circuit 65. The output of integral 67 in circuit 68 when added to reference 50 in summer 52 increases or decreases demand in circuit 44 opening or closing valves 7 to increase or decrease stage pressure until the output of difference unit 60 becomes zero.

Reference 50 also connects to proportional unit 54 through circuit 53. Unit 54 ranges the signal for comparison with MW. Unit 54 connects to difference unit 69 through circuit 70 which establishes a set point for MW error in the automode of operation.

Current transformers 71 on generator 21 output bus duct 22 connect to measuring and ranging unit 72 which transmits generator MW output through circuit 73 to ratio unit 74 and through circuit 75 to difference unit 69. In the automode of control the input to ratio unit 74 from circuit 76 is one and the values in circuits 73 and 75 are the same. Thus, load reference provides a set point and the difference between circuits 70 and 75 in circuit 77 is MW error.

Integral 78 increases or decreases the output in circuit 79 in response to MW error to increase or decrease the output of ratio unit 58 which in turn increases or decreases set point for stage pressure to correct MW error until the output of difference unit 69 becomes zero.

Load demand in circuit 50 is conveyed through circuit 80 and 81 to proportional unit 83 where the signal is ranged for use in the boiler control segment of the system.

Prior to transfer to automatic control and when in the manual mode, it is highly desirable for the system to be in a balanced condition. The outputs from integrals 46, 67 and 78 should be positioned properly so that such values will be representative of actual requirements for the system at time of transfer. If this can be accomplished, then no upset to the system will occur after transfer as integrals 46, 67 and 78 will be representative of actual MW, turbine stage pressure and zero MW error respectively at time of transfer from manual to auto.

The present invention relates specifically to such special balancing systems and devices for proper alignment of cascading and/or related integrals prior to transfer from manual to auto.

Known systems in the past which calculate demand for governor valve position as a relative value representative of actual valve position, as is the case in circuit 44 of FIG. 1, have given little attention to the proper alignment of load reference, turbine stage pressure and MW integrals prior to transfer from manual to auto. Rather they have relied upon using the measure of error between demand for and actual valve position to drive a special tracking integral to balance actual and demand positions. In such case the tracking integral in turn drove related online integrals against high or low-output limits, narrowing the effective band in which such online integrals could be successfully applied. To avoid upsets after transfer, the tracking integrals had to be slowly restored to some neutral value giving first stage pressure and MW correction integral and load reference values time for readjustment from online feedback errors. Thus, after transfer it was good practice to hold load steady until the control system integrals came to equilibrium.

In the present invention all effective related errors are zero or close thereto at time of transfer and the entire coordinated and/or related system is balanced accordingly. The present invention overcomes past difficulties in utilizing online working integrals for tracking service instead of using special tracking integrals to compensate for offsets in the outputs of normal online integrals when in the manual mode.

The philosophy of the present invention permits the alignment of cascading integrals prior to transfer from manual to auto. To achieve this, the turbine stage pressure error correction integral is used to align the reference or MW demand signal with actual MW and the MW error correction integral is used to align the demand for stage pressure with actual stage pressure.

Proper alignment of cascading integrals at time of transfer permits changes to be made in set points immediately after transfer without the need for a period of stabilization. This is particularly significant when it is desired to change load immediately following transfer. Working online integrals in the present invention after transfer respond quickly and accurately to accommodate set point changes without first having to find a new equilibrium condition to satisfy unbalanced condition which existed at time of transfer. The latter situation has the effect of compounding the magnitude of the error signal when set point is changed after transfer in a dynamic operating situation.

In accord with the present invention when the system is in a tracking mode the measure of actual generation from circuit 73 passes through circuit 84 to difference unit 85. Output from proportional unit 54 also feeds the ranged load reference signal 50 to unit 85 through circuit 86. The error signal in circuit 87 passes through transfer function 66 to circuit 65 when in the tracking mode. Circuit 64 is isolated from circuit 65 at such time.

The error from unit 85 is integrated in unit 67. The output in circuit 68 is summed with load reference 50 in summer 52. The output of summer 52 passes through circuit 88 and is differenced with the circuit 89 measure of governor valve position in unit 90. The output of unit 90 in circuit 91 is the error between actual and demand for governor valve position.

In the tracking mode transfer function 92 passes error in circuit 91 through circuit 49 to integrator 46 which increases or decreases the output in circuit 50 to increase or decrease the output of summer 52 in circuit 88 to reduce the error in circuit 91 to zero. In turn the error in circuit 87 is integrated in unit 67 to force opposite change in the circuit 50 output of integrator 46.

If ranged load reference in circuit 86 is greater than actual MW output in circuit 84, the output of unit 85 is plus which increases the output of integrator 67. This in turn increases the output of summer 52 and decreases the output of difference unit 90 to a negative or equivalent value which in turn decreases the output of integrator 46 in circuit 50 which decreases the value in circuit 86 to make the output in circuit 87 less positive. Equally, a decrease in the value of circuit 50, results in a decrease in the output of summer 52. This makes the value of circuit 91 more positive. The action continues until the output of integrators 46 and 67 are representative of zero error.

In reality, governor valve position in circuit 89 less integrator 67 output in circuit 68 becomes set point for load reference in circuit 50. When the value in circuit 50 is in excess of such set point, the output of unit 90 in circuit 91 is a negative error which after integration in unit 46 decreases the value of circuit 50 until an equivalency is reached between the value of circuit 50 and set point.

When in the tracking mode, the stage pressure error in circuit 64 is transmitted through circuit 92A to and through transfer function 93 to circuit 94 and integrator 95. Integrator 95 output in circuit 96 feeds to ratio unit 74. Ratio unit 74 increases or decreases the value in circuit 75 above or below the reference value in circuit 73 changing the differential relationship in unit 69 and output in circuit 77 to integrator 78. The integrator 78 output in circuit 79 to ratio unit 58 changes the differential relationship in unit 60 to produce a zero value in output circuit 64.

For example, when in the tracking mode, if stage pressure set point from load reference 50 in circuit 59 is greater in value than actual stage pressure in circuit 63, the output in circuit 92A to integrator 95 is positive. This increases the value

in circuits 96 and 75 which in turn makes the output of difference unit 69 in circuit 77 less positive or negative reducing the output of integrator 78 in circuit 79 to a lower value. This in turn reduces the output of ratio unit 58 until the values in circuits 59 and 63 are equivalent.

When an equivalency is reached to produce a zero error at the output of units 85, 90, 60 and 69, integrals 67, 46, and 78 are in a balanced condition and are representative of actual stage pressure and MW conditions at such time. The system is now balanced and ready to transfer to the automatic control mode.

Integrator 46 which generates load reference in circuit 50 has been driven to a value equal to actual MW. After transfer to auto, its output will not change until either increase contact 47 or decrease contact 48 is closed. These contacts supply a positive or negative value respectively to integrator 46. After transfer, transfer function 92 is switched and the circuit 91 value no longer feeds to integrator 46 through circuit 49.

In the tracking mode integrator 95 has offset the difference between demand for stage pressure in circuit 57 and actual stage pressure in circuit 63. After transfer to auto, transfer function 93 switches and blocks circuit 92A from outputting to integral 95. Instead, the output of integral 95 in circuit 96 and through circuit 97 is compared with a value equivalent to one in difference unit 98. The error output in circuit 99 passes through transfer function 93, through circuit 94 to integral 95 and the output of integral 95 is slowly returned to the neutral value of one.

This latter function is not a necessity to the objectives of the present invention. In reality, when in the tracking mode, integral 95 compensates for calibration errors between demand for and actual turbine stage pressure, demand for and actual MW. In such case, even in the tracking mode the output of integrator 95 will deviate little from the value of one when the system is in a balanced condition. Integrator 95 could maintain the offset developed in the tracking mode permanently in the normal automatic mode of control. In such case its output would become a locked value which could not be changed by input error. In essence, integral 95 permits integrator 78 to be set while in the tracking mode within close tolerance of actual requirements of what will be required immediately after transfer to the automatic mode of control.

In FIG. 1, when in the automatic mode of operation, the signal in circuit 77 can be considered a first operating error, unit 69 producing one differential relationship between demand for and actual generation. The signal in circuit 64 can be considered a second operating error, unit 60 producing the differential relationship.

When in the tracking mode, unit 85 produces another differential relationship between demand for and actual generation and the signal in circuit 87 can be considered to be a first tracking error. The signal in circuit 92A can be considered to be a second tracking error generated by the differential relationship in unit 60. The signal in circuit 77 is a third tracking error generated by the one difference in unit 69.

Ratio units 58 and 74 vary the differential relationship in units 60 and 69 respectively. In the automatic mode circuit 64 through transfer function 66 to circuit 65 and integrator 67 produces a trim signal. In the tracking mode circuit 87 through transfer function 66 to circuit 65 and integrator 67 produces an alternative trim signal.

Unit 67 integrates both the first tracking error and the second operating error and assures an equivalency of integrator outputs immediately before and after transfer. Unit 78 integrates both the third tracking error and first after error and assures an equivalency of integrator outputs immediately before and after transfer.

The configuration of FIG. 1 could be modified considerably to produce equivalent results. Ratio units could be applied in the other inputs to difference units from what is shown and signs of difference units could be changed to compensate accordingly. Parallel difference units and integrating units could be used. Parallel integration units could be forced to track

each other in the alternative operating modes. The difference between circuits 89 and 68 could be used as a set point for developing a load reference error to be used in integrator 46 after subtraction of load reference 50 from such a generated set point. Such alternative arrangements are not distinguishing from the intent of the present invention.

Alternatively, the configuration shown in FIG. 1 can be modified as is shown in FIG. 2. Circuits 92A, 94, 96, 97, 99 and 76, transfer function 93, integrator 95 and ratio unit 74 are omitted. Difference unit 85 and circuits 84 and 86 are combined with difference unit 69 and circuits 70 and 73. Circuit 87 originates from the output of difference unit 69. FIG. 2 otherwise functions similarly to FIG. 1 except that in the tracking mode the output of integrator 78 is locked in at a value of one and is not responsive to error in circuit 77. In such a manner the error in circuit 64 will approximate zero. After transfer to autointegrator 78 is free to function normally.

Returning again to FIG. 1, load reference ranged in proportional unit 83 passes through circuit 82 for correction from steam generator pressure error. Circuit 82 feeds to function generator 100 which characterizes set point for steam pressure as a function of load. Output setpoint in circuit 101 is compared with actual steam pressure in difference unit 102.

Steam pressure in conduit 5 is transmitted through conduit 103 and is measured and ranged in unit 104 and transmitted through circuit 105, ratio unit 106 and circuit 107 to unit 102. The output error from unit 102 passes through circuit 108 to proportional unit 109 where it is ranged and conducted through circuit 110 to summer 111 where the error is combined with the ranged load reference in circuit 82.

The output error from unit 102 feeds through circuit 112, transfer function 113, circuit 114 in the normal automatic control mode to integrator 115. Integrator output in circuit 116 increases or decreases the ratio unit 117 output in circuit 118 above or below the summer 111 output in circuit 119.

The circuit 118 value is the pressure corrected boiler demand which feeds through circuit 120 to summer 121 for steam temperature correction of demand for feedwater flow and heat input.

Steam temperature in conduit 5 is measured by thermocouple 122 and transmitted through circuit 123 to measuring and ranging unit 124. The ranged measure of temperature is transmitted through circuit 125 to ratio unit 126 and circuit 127 to difference unit 128 where the measure of actual temperature is differenced with set point developed from the ranged load reference in circuit 82 and as modified by function generator 129 which outputs to unit 128 through circuit 130. In the normal automatic control mode the input to ratio unit 126 from circuit 126A is one so that the values across unit 126 from circuit 125 to circuit 127 are equal.

The temperature error in circuit 131 feeds to proportional ranging unit 132, through conduit 133 to summer 121 where the error is combined with pressure corrected boiler demand from circuit 120. When in the normal automatic control mode the circuit 131 error also feeds through transfer function 134 and circuit 135 to integrator 136, circuit 137 to ratio relay 138. Ratio relay 138 increases or decreases the output in circuit 139 above or below the output of summer 121 in circuit 140.

The output in circuit 139 and as transmitted through circuit 141 is differenced with the circuit 120 value in unit 142. Unit 142 reverses the sign of the correction in circuit 143 which is ranged by proportional unit 144 and conveyed through circuit 145 to summer 146 where temperature compensation is summed with the pressure corrected boiler demand of circuit 118.

As actual temperature rises above set point the value in circuit 131 becomes negative. This decreases the output in circuit 139 below the input value to summer 121 from circuit 120. Temperature above set point lowers demand for heat input in circuit 139 which is further ranged in proportional unit 147. The same high-temperature increases the output of

difference unit 142 which in turn increases the output from summer 146 in circuit 148. This increases the demand for feedwater flow in response to high-steam temperature. Circuit 148 feeds to ranging proportional unit 149.

Demand for heat input to steam generator 1 from unit 147 feeds through circuit 150 to heat input controller 151. Controller 151 feeds through circuit 152 to actuator 153 which regulates heat input to steam generator 1. A measure of heat input feeds back to controller 151 through circuit 154 for balancing purposes.

When in the manual control mode controller 151 output in circuit 152 is regulated from manual/autostation 155 and through circuits 156. Controller 151 is not responsive to the input from circuit 150 at such time.

When in the normal automatic mode of control, the output from proportional unit 149 in circuit 157 is demand for feedwater flow. This demand is compared with a measure of actual feedwater flow in difference unit 158. Flow meter orifice 159 is located in conduit 35 supplying feedwater to steam generator 1. Conduits 160 and 161 convey a measure of differential pressure across flow orifice 159 to measuring and ranging unit 162. The output of 162 feeds to summer 163 through circuit 164. Temperature in conduit 35 is sensed by thermocouple 165 and the impulse is conveyed through circuit 166 to measuring characterizing and ranging unit 167. The output in circuit 168 feeds to summer 163 and provides temperature compensation for the feedwater flow measurement in circuit 169. Circuit 169 feeds to difference unit 158, the output of which in circuit 170 is feedwater flow error. When actual flow is in excess of set point the output of unit 158 in circuit 170 is negative.

Proportional and integral unit 171 receives the error from circuit 170 and transmits the converted output through circuit 172 to controller 173. Controller 173 regulates power supply to actuator 174 through circuit 175 to open or close valve 32 to control turbine 29 speed. Flow from pump 28 at a given discharge pressure is a function of pump speed. Turbine 29 speed is sensed and ranged in unit 176 and transmitted through circuit 177 to controller 173. Speed as a measure of flow serves as a feedback for comparison with demand for feedwater flow in circuit 172.

Thus, if feedwater flow is greater than set point, circuit 170 is negative. Integrator 171 decreases the demand in circuit 172. Controller 173 partially closes valve 32 which in turn reduces turbine 29 and pump 28 speed. This decreases the measure of feedwater flow in circuit 169 until the output in circuit 170 becomes zero.

When in the manual mode increase and decrease pushbuttons in manual/autostation 178 regulate controller 173 and power supply to actuator 174. Input from circuit 172 to controller 173 is ineffective at such time. Standard systems are used.

In the past there has been considerable difficulty in aligning the integrals 136 and 115 when in the tracking mode before transfer to the automatic mode. They have been held at certain values by forcing means but they have not been responsive to feedwater and heat input demand errors when comparing such demands to actual conditions. As a result while special tracking integrals were used to balance feedwater demand with actual feedwater flow and demand for heat input with actual heat input at time of transfer, unbalances existed internally within the system requiring correction from feedback errors after transfer.

The present invention overcomes past difficulties by using the pressure and temperature integrals as working units when the system is in the tracking mode. In fact, feedwater flow and heat input demands are a direct function of pressure error and an inverse function of temperature error. Accordingly, such a relationship permits the use of the pressure integral to track one demand and the use of the temperature integral to track the other demand. When in such a mode, the system will track actual operating conditions so that at time of transfer from manual to automatic no internal upsets exist. This can be done

without forcing such integrals to any neutral position prior to transfer and is therefore a definite advantage since as a result of free movement of integrals in the tracking mode the system retains its self calibrating features in both modes of operation. Smooth operation, thus, does not depend upon precise calibration of the feed forward aspects of the system.

When in the manual mode, manual demand for heat input is conveyed through circuit 156 to controller 151. The same demand is conveyed through circuit 179 to difference unit 180 where manual demand is compared with the coordinated system demand for heat input in circuit 150. The output in circuit 181 feeds through circuit 182 to transfer function 134, circuit 135 to integrator 136. The output of 136 to ratio unit 138 changes the output in circuit 139 which in turn alters the demand for heat input and feedwater flow in inverse relationship.

When manual demand in circuit 179 is greater than integrated system demand in circuit 150, output of difference unit 180 in circuit 181 to integrator 136 is positive. This increases the output of unit 138 until the values of circuits 150 and 179 are equal. At the same time the values in circuits 143 and 148 are decreased.

When in the manual mode, manual demand for feedwater flow feeds through circuit 183 to difference unit 184 where it is compared with coordinated system demand from circuits 157 and 185. The output from unit 184 in circuit 186 is coordinated system error for feedwater demand compared with actual feedwater flow as set-point. Tracking error in circuit 186 passes through transfer function 113 and circuit 114 to integrator 115 which varies the output of ratio unit 117 to correct the error. If the value in circuit 185 is low with respect to the value in circuit 183, the value in circuit 186 increases. This increases the output of integrator 115 until the values in circuits 185 and 183 are equal. The increase in circuit 118 also increases demand for firing rate. The interaction between integrals 115 and 136 will quickly produce a balanced system as a result of the plus-minus relationship that integral 136 output has upon demand for heat input and feedwater flow.

A further refinement when in the tracking mode is to reduce steam temperature and pressure errors to zero and after transfer to auto to slowly restore such errors to permit pressure and temperature to go to predetermined setpoints. When in the manual tracking mode, temperature error in circuit 131 passes through transfer function 187, circuit 188 to integrator 189 which outputs through circuit 126A to ratio unit 126. If temperature error is plus, integrator 189 increases its output and that of ratio unit 126. This decreases error to zero. After transfer to auto, integrator 189 output in circuit 126A is compared with a set point value of one in difference unit 190. The output of unit 190 passes through circuit 191, transfer function 187, and circuit 188 to integrator 189 which in turn restores the output in circuit 126A to one.

When in the tracking mode, steam pressure error from difference unit 102 passes through circuit 192, through transfer function 193, circuit 194 to integrator 195. Integrator 195 outputs to circuit 196 and ratio unit 106. When a measure of actual pressure in circuit 107 is less than set point in circuit 101, the output from unit 102 in circuit 192 is plus which increases the output of integrator 195 and relay unit 106 until the values in circuits 107 and 101 are equal. After transfer to auto, the output of integrator 195 is restored to one. The integrator 195 output passes through circuit 197 to difference unit 198. The circuit 197 value is differenced with a value of one. The output of unit 198 passes through circuit 199, transfer function 193, circuit 194 to integrator 195. When the value in circuits 196 and 197 are greater than one, the output of 198 is minus which reduces the output of integrator 195 until it is one.

There is an alternative arrangement to the above description as is also shown on FIG. 1. When in the tracking mode, the temperature integral may be used to balance demand for with actual feedwater flow and the pressure integral may be used to balance demand for with actual heat input to steam generator 1.

In such case the demand error from difference unit 180 passes through circuit 200 to transfer function 113 instead of through circuit 182 to transfer function 134. When demand for heat input to steam generator 1 in circuit 150 is less than the actual measure of heat input in circuit 179, output of unit 180 is plus. This makes circuit 200 value plus increasing the output of both integrator 115 and ratio unit 117. The values in circuits 120, 140 and 139 increase until the values in circuits 150 and 179 are equal. At the same time the values in circuits 145, 148 and 157 decrease.

Also, for the alternative arrangement, the error from difference unit 184 passes through circuit 201, proportional unit 202, circuit 203 to transfer function 134, circuit 135 to integrator 136 instead of through circuit 186, transfer function 113, circuit 114 to integrator 115. Proportional unit 202 reverses the sign of the input. If the input to unit 202 is plus, its output is negative. When the value in circuit 185 is less than the value in circuit 183, difference unit 184 output in circuit 201 is plus. The output from unit 202 to circuit 203, transfer function 134, circuit 135 to integrator 136 is minus. This decreases the value in circuit 137 which in turn decreases the value outputted from ratio unit 138 in circuits 139 and 141. This increases the output of difference unit 142 through circuits 143, 145, 148, 157 and 185 until the value in circuits 185 and 183 are equal.

The plus and minus effect that the output from integrator 136 has upon the demand for feedwater flow and heat input combined with the direct effect that the output from integrator 115 has upon the two variables provides the balancing means for the integrated system.

Thus, it will be seen that I have provided an efficient embodiment of my invention, whereby a means is provided to internally balance an integrated or coordinated steam generator-turbine generator control system when in the manual mode to achieve a balance state at time of transfer from the manual to automatic mode of operation. Specifically a means is provided utilizing the turbine stage pressure error correction integral to balance the load reference with actual megawatt output of the unit at time of transfer from manual to auto, to neutralize stage pressure error at time of transfer and to balance demands for feedwater flow and heat input to the steam generator through use of the steam pressure and temperature error correction integrals.

While I have illustrated and described several embodiments of my invention, it will be understood that these are by way of illustration only, and that various changes and modifications may be made within the contemplation of my invention and within the scope of the following claims.

I claim:

1. In a steam electric generating plant comprising a steam generator, a turbine generator having power operated governor valves controlling steam admission, interconnecting steam conduits between said steam generator and said governor valves, automatic control means for said steam generator and said turbine generator comprising means to generate a load reference, to measure actual generation, to generate an automatic mode first operating error from one difference between a function of said load reference as set point and a function of said measure of actual generation, to develop a feedforward demand for said governor valve position as a function of said load reference, to generate a set point or demand for said turbine stage pressure as a function of said load reference, to measure actual turbine stage pressure, to generate an automatic mode second operating error from the difference between said stage pressure set point and said actual measure of stage pressure, for integrating said automatic mode second operating error as a trim signal and combining said trim signal with said feedforward demand, for converting said combined demand to turbine governor valve position, said means being characterized to close said governor valves as said actual stage pressure increases above said set point and vice versa, further means for integrating said automatic mode first operating error, for modifying the differential relationship between said set point and said actual measure of turbine stage pressure as a

function of said automatic mode first operating error integration and characterized to increase or decrease said automatic mode second operating error to open or close said governor valves until said first operating error is zero, the invention comprising tracking means for said control means when said turbine governor valve positioning means is in the manual mode including means to measure governor valve position, to develop a first tracking error from another difference between a function of said measure of actual generation as set point and a function of said load reference, to integrate said first tracking error as an alternative tracking trim signal, to vary said load reference as a function of the difference between said governor valve position and said alternative tracking trim signal, said difference being a measure of the required value for said load reference, said first tracking error integration being adapted to develop equivalence between said load reference and said measure of actual generation, further means to develop a second tracking error from the difference between said measure of actual stage pressure as set point and said demand for stage pressure, to integrate said second tracking error, for modifying said one differential relationship between said load reference and said measure of actual generation as a function of said second tracking error integration and characterized to increase or decrease the working values of said differential relationship, said differential relationship generating a third tracking error, means to integrate said third tracking error and for modifying the differential relationship between said measure of actual stage pressure and demand for stage pressure as a function of said third tracking error integration, said third tracking error integration being adapted to develop equivalence between said measure of actual stage pressure and said demand for stage pressure, and finally means for establishing an equivalence between said first tracking error and said automatic mode second operating error integrator outputs and between said third tracking error and said automatic mode first operating error integrator outputs at time of transfer from said tracking to said automatic control mode.

2. In a steam electric generating plant having control means as recited in claim 1, the invention also including control means after transfer from said tracking to said automatic control mode to slowly restore said second tracking error integrator output to a neutral value to diminish the modifying effect that said integrator has upon said one differential relationship between said load reference and said measure of actual generation.

3. In a steam electric generating plant having a steam generator, a turbine generator, and an automatic control system for said steam generator and said turbine generator, the invention comprising tracking means for said control system when in the manual mode before transfer to the normal automatic mode, said tracking means being adapted to utilize the normal turbine stage pressure correction integrator to balance said control system load reference with a measure of actual generation and to utilize the normal generation correction integrator to drive normal stage pressure error to zero, said integrator outputs from said tracking mode being retained after transfer to said automatic mode as base starting values.

4. In a steam electric generating plant having a steam generator, turbine generator, and an automatic control system for said steam generator and said turbine generator, the invention comprising tracking means for said control system when in the manual mode before transfer to the normal automatic mode, said tracking means being adapted to utilize the normal turbine stage pressure correction integrator to balance said control system load reference with a measure of actual generation and to set the output of the normal generation correction integrator to maintain stage pressure error in a range approaching zero, said integrator outputs from said tracking mode being retained after transfer to said automatic mode as base starting values.

5. In a steam electric generating plant having a steam generator, a turbine generator, and a coordinated automatic

control system for said steam generator and said turbine generator, in which a common load reference is developed for both said steam generator and said turbine generator demand, the invention comprising tracking means for said coordinated control system for use in the manual mode before transfer of the system to the normal automatic mode, said means being adapted to use the normal related turbine stage pressure correction integrator to balance said control system load reference with a measure of actual generation, to use the normal related steam generator steam pressure correction integrator to balance said control system demand for feedwater flow with actual feedwater flow and to use the normal related steam generator steam temperature correction integrator to balance said control system demand for heat input to said steam generator with actual heat input to said steam generator, said related and interacting integrator outputs from said tracking mode being retained after transfer to said normal automatic mode as base starting values for said integrator outputs.

6. In a steam electric generating plant having a steam

generator, a turbine generator, and a coordinated automatic control system for said steam generator and said turbine generator, in which a common load reference is developed for both said steam generator and said turbine generator demand, the invention comprising tracking means for said control system for use in the manual mode before transfer of the system to the normal automatic mode, said means being adapted to use the normal related turbine stage pressure correction integrator to balance said control load reference with a measure of actual generation, to use the normal related steam generator steam pressure correction integrator to balance said control system demand for heat input to said steam generator with actual heat input to said steam generator, and to use the normal related steam generator steam temperature correction integrator to balance said control system demand for feedwater flow with actual feedwater flow, said integrator outputs from said tracking mode being retained after transfer to said normal automatic mode as basic starting values for said integrator outputs.

* * * * *

25

30

35

40

45

50

55

60

65

70

75