

Sept. 25, 1962

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3,056,036

PARALLEL ALTERNATOR SYSTEM

Filed May 16, 1960

3 Sheets-Sheet 1

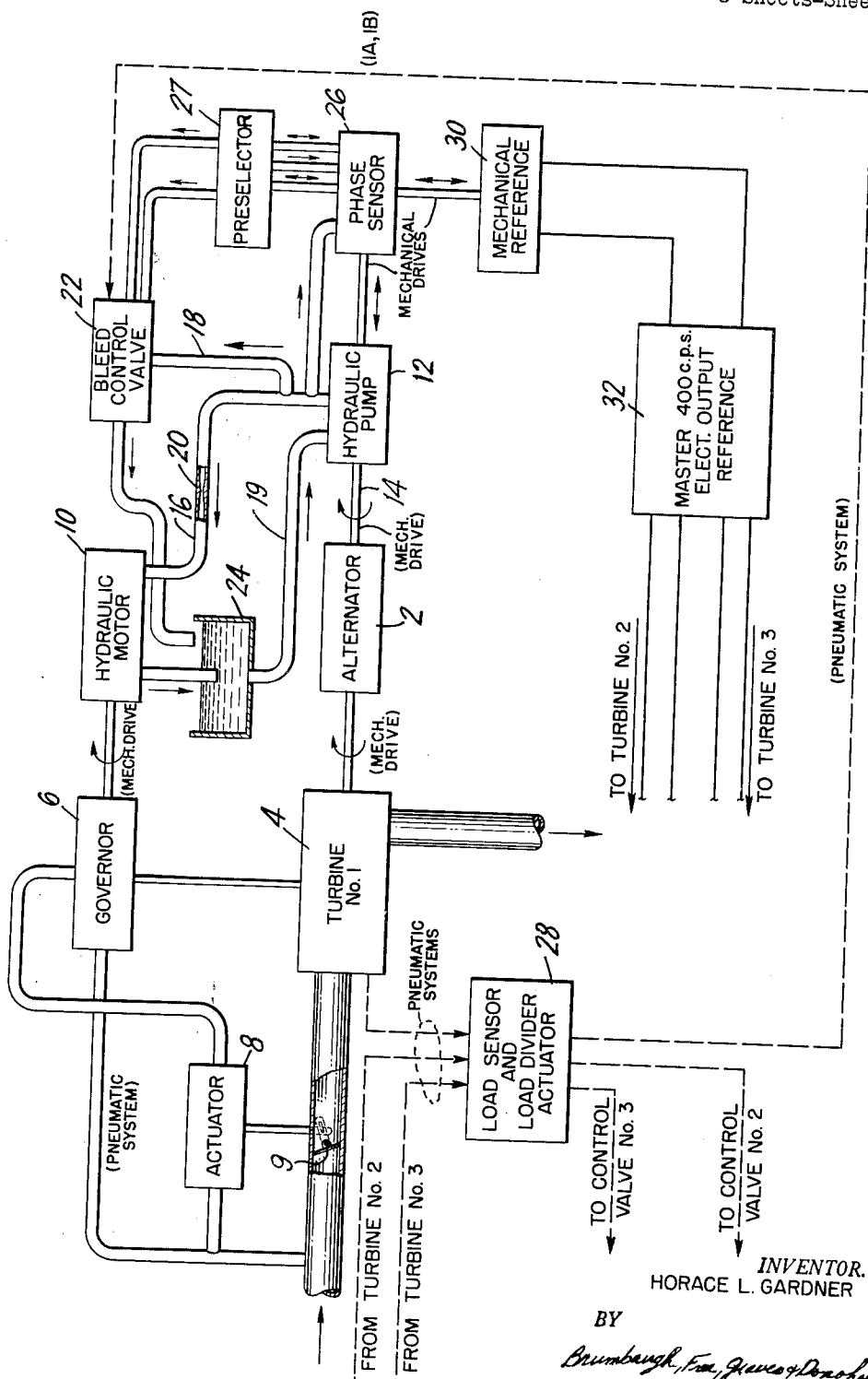


FIG. 1

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PARALLEL ALTERNATOR SYSTEM

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3 Sheets-Sheet 2

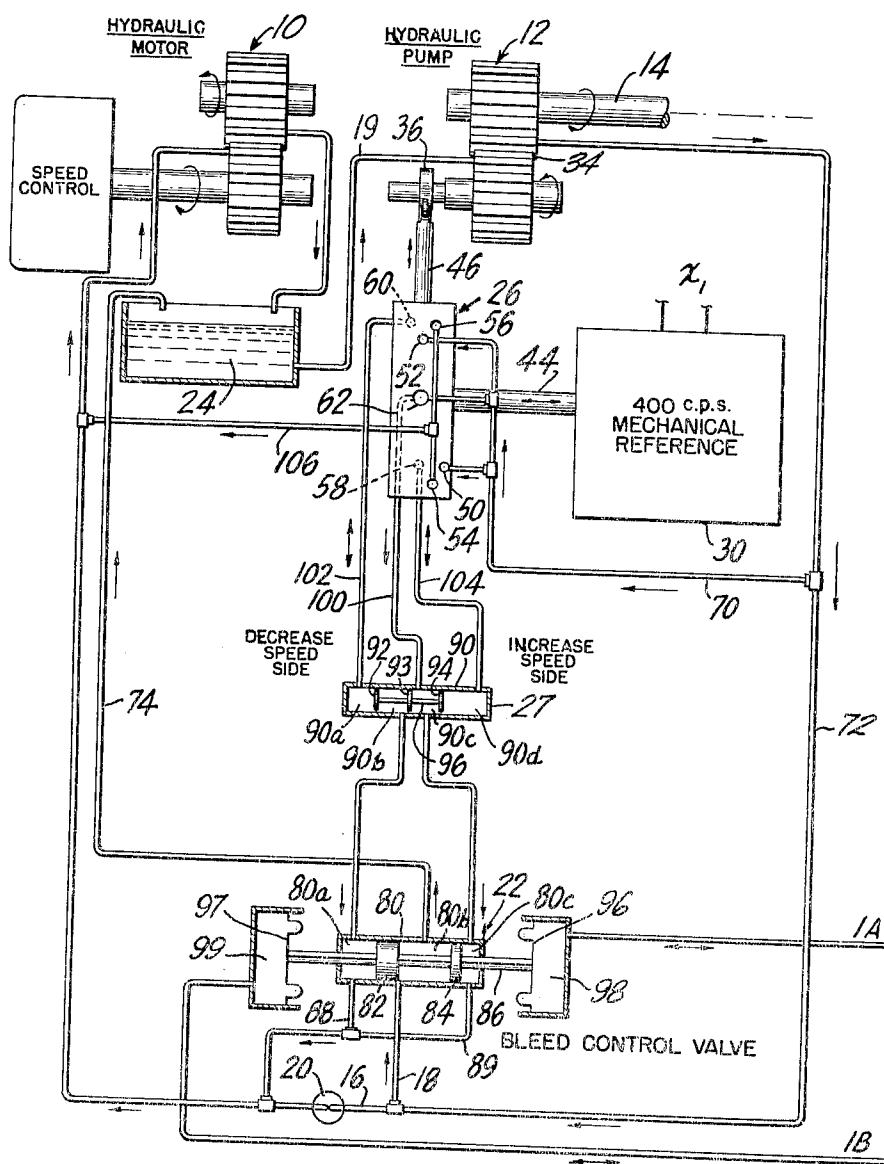


FIG. 2

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Sept. 25, 1962

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3 Sheets-Sheet 3

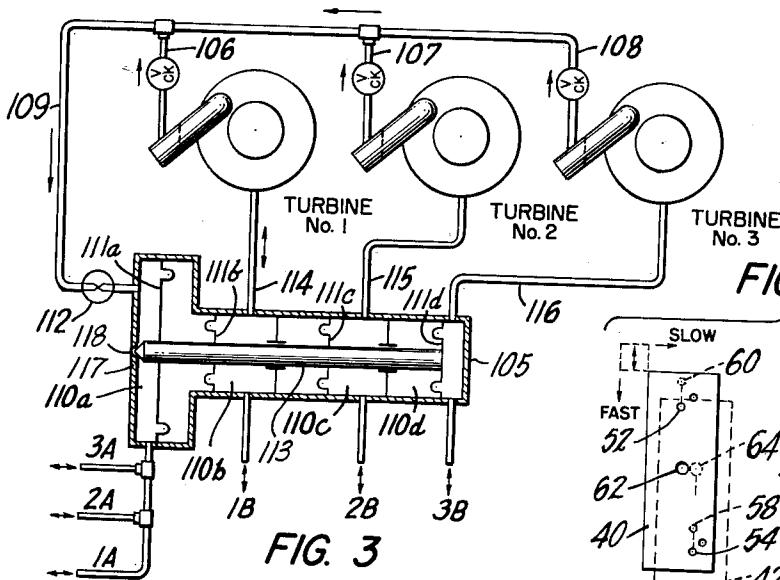


FIG. 3

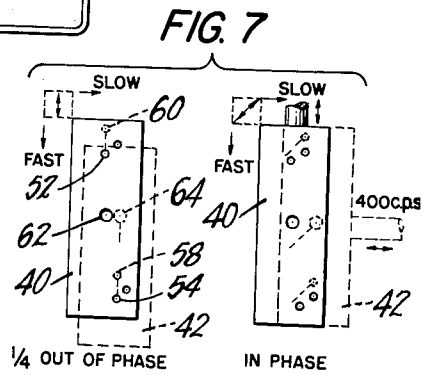


FIG. 7

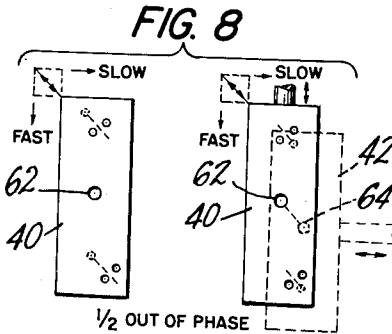


FIG. 8

FIG. 6

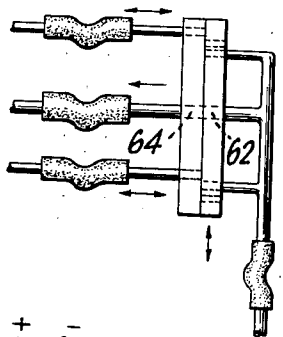


FIG. 4

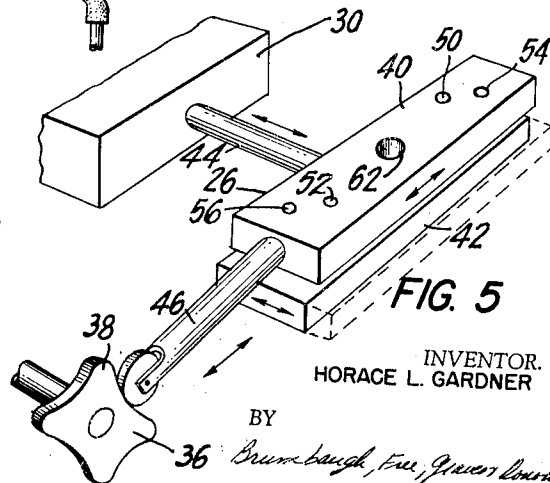
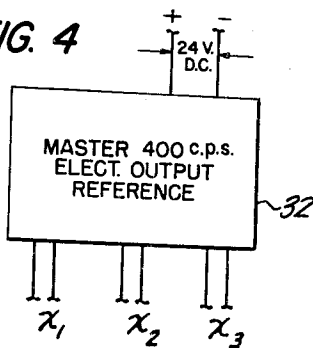


FIG. 5

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PARALLEL ALTERNATOR SYSTEM

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Filed May 16, 1960, Ser. No. 29,435
13 Claims. (Cl. 290-4)

This invention relates to a control system for parallel operation of alternator drives, and specifically to a system for bringing into phase a multiple number of turbine driven alternators, and for maintaining equal load distribution between the turbines subsequent to locking the alternators in phase and the application of a load.

When more than one alternator is operated in parallel, it becomes necessary to bring the alternators into phase before tying them in with a bus bar. When this preliminary requirement has been fulfilled and the alternators have been locked in phase, the load must then be equally divided between the driving turbines to prevent any of the alternators from functioning as a motor rather than as a generator. The present invention provides a simplified system for accomplishing both functions.

Thus, in accordance with the principles of the present invention, there is provided a multiple number of turbines and alternators operating in parallel with each other, and individual speed control systems therefor.

These control systems may be comprised of a hydraulic motor for each turbine adapted to actuate a speed governor for that turbine, the latter adjusting the turbine speed through an inlet throttle valve in a well known manner. An example of a suitable control unit of this type is illustrated in U.S. Patent No. 2,840,094. In these units each hydraulic motor is provided with a pressure source in the form of a hydraulic pump, connected to and driven by the turbine, so that the flow is proportioned to the turbine speed. The system is designed so that a decrease or increase in turbine speed will cause a proportional decrease or increase in the hydraulic flow, and a corresponding change in motor and governor speed. This results in a reaction by the governor in the form of a demand for increased or decreased turbine inlet pressure and corresponding adjustment of the turbine throttle valve.

The speed control system may comprise a bleed control valve adapted to modify the flow supplied to the hydraulic motor for the governor, the bleed valve being actuated by a regulating system including a novel phase sensing means and a load sensing device. The phase sensing means and load sensing device effectively actuate the bleed control valve at separate and independent times in a non-conflicting manner.

In one embodiment of the invention, the phase sensing function and bleed control valve actuation is accomplished by a novel "hydraulic" system wherein the speed of an alternator is compared to that of a master reference signal, and a demand for lesser or greater turbine input is called for. This system is so arranged that when an alternator is in phase with the master reference signal, no change in input is called for. It is further arranged to produce a different response depending on whether the alternator is one-half out of phase or one-quarter out of phase, and also whether the alternator is leading or lagging the master phase reference means.

The load sensing device on the other hand is a novel "pneumatic" system adapted to compare the nozzle pressure of each of the individual turbines with the inlet nozzle pressure of the turbines having the highest value, and to transmit a resultant pressure differential to the bleed control valve in a manner to actuate it for an increase or decrease in governor speed, and for a corresponding movement of the turbine throttle valve. Prior to applying the load, the turbines have been locked in phase with

each other, so that modifying the turbine inlet pressure affects only the load carrying capability of the turbine without affecting the turbine speed.

The control valve may be of the spool valve type, and is adapted to be sensitive to actuation by both the "hydraulic" actuating pressure of the phase sensing means and the "pneumatic" actuating pressure of the load sensing device. However, the effect of the phase and load sensing means is experienced at separate times or in a manner to prevent conflict between the two. For example, by using a pneumatic pressure for the load sensor, the influence of the load sensor on the positioning of the control valve during the hydraulic "phasing in" stage is negligible. Also, by so separating the control devices in this manner, it is apparent that an additional turbine may be phased in parallel with the turbine or turbines already under load without affecting their operation. Further, if desired, the phase sensor may be effectively and automatically disengaged from control once the turbines are in parallel.

Other advantages will become apparent upon further consideration of the specification and accompanying drawings, in which:

FIGURE 1 illustrates schematically an exemplary turbine and alternator control system in accordance with the present invention;

FIG. 2 illustrates schematically the hydraulic portion of the control system which brings the alternators into phase with a mechanical reference, in accordance with the principles of the invention;

FIG. 3 illustrates schematically the pneumatic portion of the system which provides for equal load division between the turbines, in accordance with the invention;

FIG. 4 illustrates schematically the master phase reference means for phasing in the alternators;

FIG. 5 illustrates the mechanical connection and drive between the phase sensing means and individual alternators;

FIG. 6 is a side view of the phase sensor means; and
FIGS. 7 and 8 are schematic views of the phase sensing means, illustrating its mode of operation in accordance with the invention.

Referring to FIG. 1, there is illustrated the combination of a single mechanically driven alternator 2 and a turbine prime mover 4 having a suitable inlet and an outlet. The turbine, designated as turbine No. 1, and alternator are adapted to be locked in parallel at the same speed with other similar units, broadly designated as turbine No. 2 and turbine No. 3. This locking in phase is accomplished by a common bus bar (not shown) in a conventional manner. The turbine speed is controlled by a pneumatic speed control system including a governor 6 and a throttle actuator 8, which system is similar to the speed control system disclosed in U.S. Patent No. 2,840,094, and is adapted to automatically compensate for variations in load and supply pressure conditions.

A hydraulic motor 10 is hydraulically driven by a hydraulic pump 12, the pump 12 being adapted to provide a hydraulic flow proportionate to the turbine and alternator speed. This pressure actuates the hydraulic motor 10, which drives the governor 6 through a suitable mechanical drive in a manner such that a decrease in turbine speed will cause a reaction in the form of a demand for an increase in turbine input flow, which is accomplished by means of a turbine throttle valve 9 controlled by the actuator 8. Similarly, an increase in turbine speed will cause an increase in the output pressure from the pump 12, to result in a decrease in flow input to turbine No. 1.

The output of the pump 12 is supplied to two hydraulic lines 16 and 18, the line 16 extending to the motor 10 and having a restriction 20 therein, and the line 18 being provided with a bleed control valve 22, leading to a reser-

voir 24 and having a normal flow rate or bleed function. Thus a variable hydraulic rate of flow is produced in line 16 through the restriction 20 to the hydraulic motor 10. Fluid by-passing the restriction 20 through the control valve 22, plus fluid from the motor 10 passing to the reservoir 24, is recycled to the pump 12 by means of a line 19 in a conventional manner. In normal operation when the alternator is phased in, the control valve is in a partly open position permitting a normal bleed rate of about 1% of the capacity of the hydraulic pump. This bleed rate may be varied depending on the arrangement and design of the component parts but has a finite and substantial value.

It is apparent that actuation of the control valve 22 to a closed position, cuts off the normal bleed of fluid and increases the flow of fluid supplied to the motor 10. This causes the motor 10 and governor 6 to increase in speed, and results in a demand for a decrease in the turbine input. Similarly actuating the control valve 22 to a full open position causes a maximum bleed rate (which may be about 2%) and thereby a reduction in flow, resulting in a decrease in motor and governor speed and calling for an increase in turbine input.

In actual practice the hydraulic pump 12 is provided with a capacity greater than that of the hydraulic motor 10 to accommodate for line, pump and motor losses, and the bleed rate.

The control valve 22 is responsive to signals from a phase sensing means and from a load sensing device 28, the former comprising a phase sensor 26 and a preselector servomechanism 27, both described in greater detail in reference to FIG. 2. The phase sensor 26 itself is comprised of two reciprocating components, one actuated through a mechanical linkage or drive by the alternator 2, and/or pump 12, the other by a mechanical reference device 30. The mechanical reference device 30, which may be of any suitable conventional form capable of providing a reciprocating motion, operates in response to and in phase with an electrical signal output of a suitable master electrical output reference means 32. A similar electrical signal output is also supplied to the mechanical reference means (not shown) for each of turbines Nos. 2 and 3, as shown. The reciprocation of one of the reciprocating components corresponds to the phase and speed of the alternator 2 and the reciprocation of the other component is proportional to the phase and frequency of the master reference. The phase sensor 26 is adapted to compare the two phases and to actuate the control valve 22 in a manner to permit a lesser or greater amount of fluid to be bled from the hydraulic motor input line 16 to thereby cause acceleration or deceleration of the turbine 4 and the alternator 2 to bring the latter two into phase with the master reference. The same system is used for turbines Nos. 2 and 3 which, after being brought into phase, are locked in phase at the same speed by a common bus bar in a known manner.

When the units are locked in at the same speed and phase, the phase sensor 26 of each of the units is essentially disengaged in a manner to be described, and the control valve 22 is actuated in response to the load sensor 28 only. However, the system is appropriately designed, as will be described, to make it possible to phase-in an unloaded alternator while other alternators in the system are operating under load.

The load sensor 28 is designed to ascertain the load placed on the individual turbines, to compare that load with the average load placed on all the turbines, and to appropriately actuate the control valve 22 and similar control valves for turbines Nos. 2 and 3 for increasing or decreasing the intake pressures of the respective turbines. Since the turbines are locked in at the same speed, the effect of a change in intake pressure is to change the load assumed by the turbine.

FIGS. 2, 3 and 4 disclose the above system in greater detail. It is to be understood, with reference to FIG. 2

that the system here is duplicated for each individual alternator and turbine, but with respect to FIGS. 3 and 4, the single load divider unit and single master electrical output reference unit are operable simultaneously with all the turbine-alternator units to be paralleled.

Phase Control

The phase control portion of the system including the pump 12, the phase sensor 26, the control valve 22, the hydraulic motor 10, reservoir 24, and mechanical reference device 30 is illustrated in FIG. 2. The hydraulic pressure from the pump 12, as described with reference to FIG. 1, is conducted to hydraulic lines 16 and 18, containing the restriction 20 and control valve 22, respectively, and from there to the motor 10 and reservoir 24, respectively. In FIG. 2, the initial pressure line leading from the pump 12 to lines 16 and 18 is designated by the numeral 72, and the line leading from the control valve 22 to the reservoir 24 is designated by the numeral 74. An additional pressure line 70 extends from the pump pressure line 72 to the phase sensor 26, tying the latter into the hydraulic pressure system in that way. The phase sensor 26 in turn is appropriately adapted to transmit this pressure to an increase or decrease speed side of a preselector servomechanism 27, the latter being actuated by this pressure to direct the actuating pressure to an appropriate increase or decrease speed side of the control valve 22. The control valve 22 is thus actuated to a normal bleed rate position, a no bleed rate position, or a maximum bleed rate position, depending on the relative position of the components of the phase sensor 26.

As illustrated in detail in FIG. 5, the phase sensor 26 is comprised of two superimposed cooperating plates 40 and 42 adapted to reciprocate at right angles to each other, actuated by reciprocating mechanical drive means or linkage arms 46 and 44, respectively. The arm 44 is linked to a 400 cycle per second mechanical reference means 30 (FIG. 2), phased in by an electrical signal X_1 (FIG. 4) received from a master electrical output reference 32. This frequency may be varied depending on the application. The arm 46 is linked (FIG. 2) to the alternator 2 through a shaft 14, the pump 12 including a gear train 34, and a cam 36. As shown in FIG. 5, the cam 36 is provided with four (4) lobes 38 on its periphery to provide the reciprocating action of arm 46. The number of lobes may be varied depending on the application. In the exemplary embodiment, the alternator is designed to be rotated normally at a speed of about 100 revolutions per second, which provides a frequency of 400 cycles per second for linkage arm 46 and the upper phase sensor plate 40, equal to that of the master electrical output reference 32 and the lower sensor plate 42. Both members 40 and 42 of the phase sensing means are equipped with ports, designated by the numerals 50 to 64, so positioned that any variance between the phase and/or frequency of the alternator with respect to the master phase reference will produce an alignment of certain specific ports in the members 40 and 42 and the transmission of pressure to either the aforementioned increase side or the decrease side of the hydraulic system, in a manner to be described.

The bleed control valve 22 (FIG. 2) is of the conventional spool-valve type comprised of an elongated closed cylinder 80, divided into three separate sub-chambers 80a, 80b, and 80c, separated by pistons 82 and 84. The pistons 82 and 84 are mounted on a reciprocating shaft 86 longitudinally mounted in the cylinder 80, and are so positioned to permit the flow from hydraulic line 18 entering subchamber 80b to be bled partially at about a 1% rate to line 74 leading to the reservoir. This is accomplished by having piston 82 occupy a normal position half covering the entrance port of line 18 leading into the subchamber. However, when pressure is supplied on the "decrease speed side" to subchamber 80a, the piston

82 is shifted to cover line 18, thus interrupting the flow into the bleed line 74. This increases the flow through restriction 20 of line 16, increasing the motor speed, and calling for a demand of less input into the turbine. When pressure is applied on the "increase speed side" to subchamber 80c, the piston 82 is moved in the opposite direction to expose the line 18 and permit maximum 2% bleed of the pump output. This reduces the flow rate through restriction 20 and calls for a greater turbine input. Lines 88 and 89 leading from pressure subchambers 80a and 80c are provided with minimum bleed restrictions to permit a minimum flow of fluid from the subchambers 80a and 80c as these chambers are restricted in volume by movement of the pistons 82 and 84. The flow here is sufficiently slight to not affect motor speed.

The preselector servomechanism 27 is also of the spool-valve type comprised of a cylindrical chamber 90 containing pistons 92, 93 and 94 connected by a common shaft 96 and dividing the chamber 90 into four subchambers, 90a, 90b, 90c, and 90d. Fluid is supplied to subchambers 90a and 90d by primary flow lines 102 and 104, respectively, and to either of subchambers 90b and 90c by secondary flow line 100, depending on the position of piston 93. When pressure is supplied from the phase sensor 26 via line 102 to subchamber 90a on the "decrease speed side" of the servomechanism, the pistons 92 and 93 are moved to the right to permit fluid provided by flow line 102 to be transmitted to subchamber 90a of the bleed control valve 22, thus causing a "no-bleed" response. Similarly, when the pressure is supplied on the "increase speed side" to subchamber 90d via line 104, the piston 94 is appropriately moved to the left to permit fluid from line 104 to be directed to subchamber 80c of the bleed control valve 22, causing a maximum bleed line flow. When fluid is supplied through secondary flow line 100 (as a result of a $\frac{1}{2}$ out of phase condition, as will be described) the fluid may be transmitted through either of subchambers 90b or 90c depending on the position previously assumed by piston 93. Accordingly, it is apparent that the fluid pressure may be transmitted to either the "increase speed side" or "decrease speed side" of the bleed control valve. The function of the preselector servomechanism 27 is now apparent. When the alternator is $\frac{1}{2}$ out of phase, it is unimportant whether the turbine is increased in speed or decreased in speed. However, in a $\frac{1}{4}$ out of phase condition, it is important that the turbine be increased in speed or decreased in speed depending on whether it is lagging or leading the reference signal.

The flow in lines 102 and 104 leading to the bleed control valve 22 shall hereafter be referred to as the "primary flow," while that in line 100 shall hereafter be referred to as the "secondary flow." The former, as indicated by the arrows is unidirectional, while the latter, as indicated by the arrows, is bi-directional. In other words the secondary flow line serves only as a supply line, whereas the primary flow lines may be either supply or escape lines. The need for this arrangement will become apparent.

The phase sensing and frequency control system operates as follows:

As mentioned, the reciprocating plates 40 and 42 of the phase sensor are each provided with ports. Depending on the relative phases and speeds of these plates, respective ports are either intermittently aligned or not aligned. Referring to FIG. 7, when the mechanical reference and alternator are in phase with each other, the members 40 and 42 have a relative movement with respect to each other such that there is no alignment of any of the ports 50-64 of the upper and lower members. The dotted lines in the "In Phase" figure of FIG. 7 represent the travel of the ports in member 42 (connected to the mechanical reference) relative to those of member 40 (connected to the alternator) and clearly indicate that no alignment results. Thus no actuating fluid pressure,

either primary or secondary flow, is transmitted to the preselector servomechanism 27 and bleed control valve 22, and the latter assumes a normal bleed function of 1%.

No primary oil flow, through line 100 to the preselector servomechanism 27, occurs until the alternator 2 approaches a $\frac{1}{4}$ out-of-phase relationship, illustrated in the " $\frac{1}{4}$ Out of Phase" portion of FIG. 7. Here, as shown by the dotted lines, representing a situation where the alternator 2 is leading the mechanical reference 30, the ports 52 and 54 of the super sensor member 40 become aligned with ports 60 and 58 of the lower member 42, respectively. Referring to FIG. 2 it is apparent that the fluid pressure will follow a secondary flow path from line 70 to subchamber 90a on the decrease speed side of the preselector servomechanism 27 via ports 52 and 60, and line 102. It is also apparent that fluid will escape from subchamber 90d via lines 104 and 106 to line 16, in that order, due to alignment of ports 54 and 58 in the phase sensor 26. Also, line 106 is connected to line 16 at a point, in the latter, past the restriction 20 so that the pressure in line 106 will be less than that in subchamber 90d, to induce this escape flow. It might be noted that this restriction also permits the bleed in lines 88 and 89 leading from the control valve to be operable with respect to flow through subchambers 80a and 80c, for the same reason. The resultant pressure difference between subchambers 90a and 90d causes piston 93 to be shifted to the right, which after a number of cycles will be shifted far enough to the right to permit the fluid pressure from line 102 to be transmitted to subchamber 80a of the bleed control valve 22, causing the latter to disrupt its normal bleed function. The resultant speed-up in the motor and governor causes a decrease in speed in the turbine in a well known manner.

When the alternator 2 is in a lagging relationship with the mechanical reference 30, ports 50 and 56 of the upper member become aligned with ports 58 and 60 of the lower member causing a reversal of the above-mentioned secondary supply and escape paths and a shift of piston 93 to the left. Fluid is thereby transmitted to subchamber 80c of the bleed control valve 22 which is actuated to a full bleed function. This causes a maximum bleed through line 74 and a slow up in governor speed, resulting in a demand for greater turbine input.

The alignment of the respective ports is caused by the fact that when the sensor members are a $\frac{1}{4}$ out of phase, the ports assume relative elliptical paths and consequently meet at periodic intervals. It is noted that, in each of these instances, the ports 62 and 64 for secondary flow do not interrupt each other.

FIG. 8 illustrates the action of the members 40 and 42 when the alternator 2 is 180° out of phase with the mechanical reference 30. In this instance, the members 40 and 42 shift from a relative exactly superimposed relationship shown, to a fully displaced relationship illustrated at the right in FIG. 8. There will be no alignment of primary ports, nor transmission of supply pressure into or escape pressure out of servo subchambers 90a and 90d. Rather, the servomechanism in this instance will assume a static function. The secondary ports 62 and 64 on the other hand, will be aligned completely at intermittent times, and the pressure in line 70 will be transmitted directly via line 100 to the bleed control valve subchambers 80a and 80c. The subchambers to which the pressure is transmitted, depends on the position which the piston 93 previously assumed. Since the alternator is 180° out of phase, it is satisfactory to cause either an increase or decrease in turbine input pressure.

FIG. 6 illustrates the use of flexible tubular connectors by which the movable members 40 and 42 of the phase sensor 26 are connected to rigidly held pressure lines. FIG. 4 illustrates schematically the master electrical output reference 32 and signal lines X_1 , X_2 , X_3 , directed to mechanical reference means 30 for the respective turbines.

The present invention provides a novel and simplified

phase sensing arrangement for phasing in a multiple number of turbines and alternators operating in parallel, wherein, once the turbines and alternators have been phased in, the phasing-in control means may be effectively disengaged to avoid conflict with subsequent load control devices. This is accomplished by having no alignment of ports of the phase sensor 26 when the alternators are operating in phase. By having separate phasing-in units for the individual turbines, linked to a master phase reference signal, which units are separate from a load controlling arrangement, there is provided a system which permits the phasing-in of a turbine having no load, with turbines operating under load without disturbing the latter. There is also provided a simplified arrangement whereby actuation of the bleed control valve 22 is readily and accurately obtained and related to the particular phase position of the alternator relative to the phase of the master phase reference signal.

Pneumatic Load Distribution Control

In order to maintain equal load distribution between the turbines, after they are locked in at the same speed, the following pneumatic system illustrated in FIGS. 2 and 3 is provided.

Attached to opposing ends of the bleed control valve shaft 86 (FIG. 2), are diaphragms 96 and 97 positioned in pressure chambers 98 and 99, respectively, and adapted to actuate the shaft 86 in opposite directions to either cause a slow-up or speed-up of the hydraulic motor 10 and corresponding speed-up or slow-up of the turbine 4 and alternator 2. The chambers 98 and 99 are connected to pressure lines 1A and 1B leading to a balancing means designated generally by the numeral 105 in FIG. 3. The balancing means 105 is additionally provided with paired lines 2A and 2B, and 3A and 3B, leading to corresponding control valves for turbines Nos. 2 and 3.

Referring to FIG. 3, each turbine is provided with a line (106, 107 or 108) leading from the turbine intake at a point before the turbine throttle valve to transmit the turbine inlet pressure to the balancing means 105. The take-off lines 106, 107 and 108 feed into a common line 109 having a restriction 112 therein, which line leads to a first chamber 110a of the balancing means 105. Each of the lines 106, 107 and 108 are provided with check valves to prevent a flow of gas from a turbine inlet having a high pressure to one at low pressure. It is apparent that a pressure proportional to the highest inlet pressure of the turbines will be transmitted to chamber 110a. The chamber 110a is provided with a diaphragm 111a mounted on a reciprocating shaft 113. On the opposite side of chamber 110a, the shaft 113 is provided with a valve element 117 adapted to cooperate with a bleed orifice 118 to provide a controlled bleed rate from chamber 110a. The pressure lines 1A, 2A and 3A lead from the chamber 110a to the respective pneumatic chambers 98 positioned at one end of the respective turbine bleed control valve shafts 86.

The balancing means 105 is divided into three additional smaller subchambers 110b, 110c and 110d by small diaphragms 111b, 111c and 111d, respectively, of preferably equal area. In the disclosed embodiment where three turbines are paralleled, the area of diaphragm 111a is three times that of each of diaphragms 111b, 111c and 111d. If n number of turbines are employed, the area of the diaphragm 111a would be n times as large as that of n diaphragms 111b, 111c and 111d. The smaller chambers 110b, c, and d are provided with feed lines 114, 115, and 116 connected to the respective turbine nozzles, and are adapted to transmit the nozzle pressures to the respective turbine control valve chambers of the respective bleed control valves 22 via lines 1B, 2B, and 3B respectively. This nozzle pressure is indicative of the load assumed by the turbines.

As indicated above the highest turbine inlet pressure signal is fed through the restriction 112 to the chamber

110a in which is produced a control pressure that is varied in response to the bleed rate through orifice 118. When the turbine inlet pressures are all equal and the loads assumed by the turbines are equal, the opposing forces exerted on shaft 113 are equal and the orifice 118 is closed, so that the control pressure in chamber 110a is equal to the pressures in each of chambers 110b, 110c and 110d. When this condition obtains, the loads are in balance and the pneumatic forces exerted by the pressure signals on the diaphragms 96 and 97 of the respective bleed control valves 22 are equal and opposite. Thus no demand is made for a change in the individual turbine inputs.

If the load of one of the turbines is greater than the others even the alternators are locked in phase, the load of the turbine can be decreased by closing the throttle valve a certain amount thereby limiting the airflow to the turbine and reducing its load carrying ability. This is possible since the turbines are operating at the same speed regardless of the load being carried once the alternators are locked in phase. In this condition of load unbalance the control pressure in chamber 110a of the balancing means 105 is reduced by bleed flow through the orifice 118 since the average force exerted on the shaft 113 to close the orifice 118 is less than that exerted by the highest inlet nozzle pressure fed through the restriction 112. Thus the force exerted on diaphragm 96 of the bleed control valve 22 of overloaded turbine is less than the force exerted on diaphragm 97. Accordingly, the piston 80 is moved to the right to restrict the bleed through hydraulic line 18, speeding up the hydraulic motor 10, and causing the throttle valve of the turbine to be closed a certain amount.

On the other hand, if one of the turbines is underloaded, the control pressure in chamber 110a of the balancing means 105 and chamber 98 of the respective control valve 22, while reduced from the value of the highest intake nozzle pressure by the balancing action described above, is greater than the pressure in chamber 99 of the control valve 22 of the underloaded turbine, and the bleed rate through the hydraulic line 18 is increased, reducing the speed of the respective hydraulic motor 10, and causing the respective throttle valve to be opened a certain amount to enable the load to be shared equally.

Since the pneumatic forces are much less than the hydraulic forces exerted on bleed control valve 22 during the phasing of the alternators, an additional alternator can first be phased in without regard to load balance, and then after being locked in phase the load carrying capability of the turbine is automatically adjusted.

It is thus evident that there is provided a mechanism for comparing the nozzle pressures of the individual turbines, and correspondingly adjusting the turbine throttle valves to obtain equal load divisions between all of the turbines. Also, since the alternators are locked in phase with each other, the phase sensing valve 22 will not affect the operation of the load distribution mechanism. It is thus apparent that there is provided in combination an extremely efficient and successful system for bringing alternators operated in parallel into phase, for tying them in with the bus bar, and for then subsequently equally dividing the load between them to prevent any of the alternators from functioning as a motor rather than as a generator.

It will be apparent to those skilled in the art that the disclosed embodiment is merely exemplary and that suitable modifications may be made without departing from the spirit and scope of the invention. For example, although the preselector servomechanism has been described as hydraulically actuated by pressure supplied by the pump and fed to the phase sensor, suitable electrical and mechanical systems may be used to accomplish the function of appropriately directing fluid to the control valve. Further, it will be apparent that the number of turbine driven alternators may be varied, as well as the

source of motive power. Therefore, it is intended that the invention is to be limited in scope only in the manner set forth in the appended claims.

I claim:

1. A control system for a turbine driven alternator operating in parallel with other alternators, comprising a speed controller and hydraulic actuator for said controller, a fluid pressure source for supplying fluid to said hydraulic actuator, a bleed control valve positioned between said source and said actuator adapted to modify the flow of fluid supplied to said actuator, a phase sensing means, and a load sensing means, said bleed control valve being responsive to both said means whereby the alternator may be first set in phase with other alternators in parallel with it and the turbine then controlled to have the alternator assume a load equal to that of the other alternators.

2. A control system for turbine driven alternators operating in parallel comprising a control unit for each turbine, which unit includes a hydraulic fluid responsive means, a pressure source of hydraulic fluid, a flow line leading from said source to said fluid responsive means including a restriction therein and a bypass about said restriction, a flow control valve in said bypass adapted to bleed the flow from said line, and a regulating means to actuate said flow control valve, said regulating means comprising a phase sensing means responsive to both the phase of the alternator and the phase of a master reference signal, and a load sensing means responsive to the load of each turbine and to the highest load of all the turbines, said phase sensing means and said load sensing means being operated at predetermined and separate times to actuate said flow control valve.

3. A control system for turbine driven alternators operating in parallel, each turbine-alternator combination comprising a speed controller, a hydraulic fluid responsive actuator therefor, and a pressure source of hydraulic fluid for said actuator; a bleed control valve positioned between said source and said actuator adapted to modify the flow of fluid supplied to the actuator by maintaining a particular bleed rate of the fluid supplied by said source; a phase sensing means comprising first means to compare the phase of each alternator with that of a standard reference, and second means for enabling said bleed control valve to control the turbine speed in a manner to phase in the alternator; each alternator then being capable of being locked in at the same speed with a bus bar; said system further comprising a pneumatic load sensing means responsive to the load of each turbine and to the highest load of all the turbines for positioning each of the bleed control valves for the respective actuators and speed controllers whereby equal load division is obtained.

4. A control system for turbine driven alternators operating in parallel according to claim 3, wherein said bleed control valve is of the spool valve type having a shaft and a piston mounted on said shaft adapted to provide a no-bleed rate, a maximum bleed rate, or a normal bleed rate depending on its position, said shaft further comprising at one end thereof a first pressure responsive means adapted to actuate the shaft and piston to a maximum bleed rate to increase turbine speed and at the other end thereof a second pressure responsive means adapted to actuate the shaft and piston to a no-bleed rate to decrease turbine speed, said piston further being adapted to assume the normal bleed rate position when not actuated, said phase sensing first means comprising means for transmitting at independent times a fluid pressure to first, second or third ducts, depending on whether the alternator is leading the standard phase reference by $\frac{1}{4}$ phase, lagging it by $\frac{1}{4}$ phase, or $\frac{1}{2}$ out of phase, respectively, said phase sensing second means comprising means for transmitting hydraulic pressure from said first duct to said second pressure responsive means of said bleed valve, from said second duct to said first pressure responsive means of said bleed valve, and from said third duct to

either one of said first or second pressure responsive means.

5. A control system according to claim 4 wherein said bleed control valve is additionally provided with pressure responsive piston actuating and opposing means to increase speed and to decrease speed responsive to pressures provided by said load sensing means, said load sensing means being adapted to provide pneumatic actuating pressures of a value substantially less than the hydraulic actuating pressures to said piston actuating and opposing means to avoid conflict with the hydraulic actuating pressures of the phase sensing means.

6. A control system according to claim 5 wherein the load sensing means comprises a balancing means for comparing the highest supply pressure of all the turbines with the average nozzle pressure of all the turbines to produce control pressures, and to transmit control pressures to said respective pneumatic actuating and opposing means of said bleed control valve, said balancing means being provided with means for modifying one of said transmitted pressures depending on the difference between the highest supply pressure and the average nozzle pressure.

7. A phase sensing device for a turbine driven alternator operating in parallel with at least one additional turbine driven alternator wherein the phase sensing device is adapted to compare the phase of the alternator with a reference phase signal and to appropriately modify the positioning of a pressure responsive speed control system to bring the alternator in phase with said signal, the latter comprising a pressure source for the speed control system, and means for modifying the pressure, said phase sensing device comprising a first means mechanically reciprocated at a desired frequency, and a second means mechanically reciprocated in phase with the alternator but in cooperation with and at right angles to said first means, said first and second means being provided with ports adapted to be intermittently aligned depending on the phases of the respective means wherein the ports of said first means are connected to the pressure source and wherein the ports of the second means are connected to the speed control system means for modifying the pressure output of the pressure source, whereby depending on which ports are aligned, the speed control system pressure modifying means is appropriately actuated.

8. A phase sensing device according to claim 7 wherein said first and second reciprocating means comprise two respectively sliding superimposed plates with ports positioned therein adapted to be appropriately aligned depending on the phase of reciprocation of the respective plates, said ports being so positioned and reciprocated such that the relative motion of ports in one plate with respect to ports on the other plate is in the form of an ellipse.

9. A phase sensing device according to claim 7 wherein said first and second reciprocating means comprise first, second and third sets of ports so positioned that no fluid pressure is transmitted through the phase sensing device when the alternator is in phase with the reference signal, but positioned so that pressure is transmitted through the first set of ports when the alternator is leading by a $\frac{1}{4}$ phase, through the second set of ports when lagging by a $\frac{1}{4}$ phase, and through the third set of ports when $\frac{1}{2}$ out of phase.

10. A phase sensing device according to claim 9 further comprising a preselector servo means interposed in the fluid path between said first and second reciprocating means and the speed control system pressure modifying means including means for increasing speed and means for decreasing speed, said preselector servo means comprising a means adapted to selectively transmit pressure from said first and second sets of ports to said speed increasing means and said speed decreasing means respectively, said preselector servo means further being adapted to transmit the pressure from said third set of ports to either of said means for increasing or decreasing speed.

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11. A load sensing device for n number of turbine driven alternators operating in parallel wherein the load sensing device is adapted to compare the load assumed by one turbine relative to loads assumed by the other turbines and to appropriately modify the positioning of a pressure responsive turbine throttle control system for bringing the turbines into equal load division, said throttle control system including a pressure source and means to modify the pressure from said source, the latter being actuated by opposing pneumatic first and second means adapted to cause an increase-load response and a decrease-load response, respectively, said load sensing device comprising a balancing means for comparing the highest turbine supply pressure with the average nozzle pressure of all the turbines, and to transmit the highest supply pressure and the individual nozzle pressures of each turbine to said pneumatic first and second means of said control system pressure modifying means, and said balancing means being adapted to modify at least one of said respectively transmitted pressures depending on the difference between the highest supply pressure and the average nozzle pressure.

12. A load sensing device according to claim 11 wherein said balancing means is comprised of a chamber and a reciprocating shaft within said chamber, said chamber being divided into $n+1$ subchambers by a series of diaphragms mounted on said shaft, said balancing means having means whereby the highest turbine supply pressure is directed into the first of said subchambers against a first of said diaphragms, the nozzle pressure of each of the n turbines being directed individually into the n remaining subchambers, each of the diaphragms of the n subchambers being mounted on said shaft in such manner as to act in opposition to said first diaphragm, the cross-sectional area of said first diaphragm being equal to the combined cross-sectional areas of said n di-

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aphragms, said shaft further being adapted to actuate a bleed valve in said first subchamber to modify the pressure transmitted by said first subchamber.

13. A control system for turbine driven alternators operating in parallel comprising a flow control valve for each turbine, each said flow control valve comprising a chamber, at least one reciprocating piston within said chamber, and ports appropriately positioned in said chamber whereby the bleed rate through the control valve is adjusted by the position of said piston; regulating means adapted to actuate each said flow control valve, said regulating means comprising a phase sensing means responsive to the phase of each alternator and to a master phase reference signal for bringing each alternator into phase with said reference signal; and a load sensing means responsive to the load assumed by each turbine as compared to the input to all the turbines for obtaining equal load division among the turbines when the latter are operating at the same speed and phase; said reciprocating piston comprising means responsive to both said phase sensing means and said load sensing means; and said regulating means further comprising means adapted to automatically disengage said phase sensing means from actuating connection with said control valve after the alternators are locked in at the same speed, and means for selectively controlling said control valve by said load sensing means and said phase sensing means, said phase sensing means being part of a hydraulic system and said load sensing means being part of a pneumatic system whereby conflict is avoided with respect to response by said flow control valve.

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