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EMERGENCY POWER UNIT

BACKGROUND OF THE PRESENT INVENTION

Modern aircraft conventionally have secondary power systems as backup systems for both emergency electrical power as well as emergency hydraulic power. In today's aircraft the emergency electrical power system and emergency hydraulic power system are completely separate. These emergency hydraulic power systems are employed in case of loss of one or more of the main hydraulic pumps that supply hydraulic fluid to the aircraft hydraulic system. In addition to the emergency power function of the emergency hydraulic system, the latter is used for hydraulic circuit check out as well as during peak hydraulic loads. The emergency electrical power systems, which include motor driven generators, are employed in the event of a loss of the primary generating system. Both the emergency electrical power units as well as the emergency hydraulic power units have been found to employ hydraulic units of practically the same hydraulic capacity.

Moreover, there is no practical requirement for both the emergency electrical unit and the emergency hydraulic unit to be employed at the same time.

Thus, there is the possibility of combining the emergency hydraulic electrical unit and the emergency hydraulic unit into a single system and possibly halving the required weight as well as the required envelope for both systems.

SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, a dual mode unit is provided that effects the functions of both an emergency electrical unit as well as an emergency hydraulic unit in a single power assembly. An AC generator-motor is provided that may be selectively connected to the electrical system bus of the aircraft driven as a generator, or supplied electrical power from an external source so that it acts as a motor driving the same hydraulic unit that drives the AC unit when acting as a generator. The hydraulic unit is of the reversible variable displacement type and is drivingly connected to the AC generator-motor. The hydraulic unit itself is of conventional construction having high and low pressure main conduits connected thereto. In the present system, only one of the conduits acts as the high pressure conduit, eliminating the requirement for the heavy-duty crossover valves. The high-pressure conduit is connected to selectively supply hydraulic fluid to the aircraft hydraulic support system during the emergency hydraulic power mode, or selectively receive fluid from the hydraulic system during the emergency electrical power mode. The feature of employing only a single one of the main conduits as the high pressure conduit is accomplished by a displacement control circuit for the hydraulic unit that reverses the displacement of the unit on changing mode, so that the hydraulic unit can continue in the same direction of rotation and either deliver or receive hydraulic fluid through the same conduit regardless of the mode selected.

The present emergency power unit is controlled during the emergency electrical power mode by a rotary governor and hydraulic valve that delivers fluid to a displacement control motor in a manner to shift the swashplate of the hydraulic unit on one side of neutral and to control the displacement to thereby maintain a substantially constant speed of the AC unit acting as a generator. To control the displacement of the hydraulic unit in the emergency hydraulic power mode, a pressure compensator valve is provided, responsive to outlet pressure from the hydraulic unit, that varies the displacement of the hydraulic unit on the other side of neutral to maintain a substantially constant outlet pressure from the hydraulic unit when acting as a pump supplying fluid to the hydraulic support system.

A further feature of the present invention is the provision of a mode control circuit that provides the necessary interconnections with the AC generator-motor, as well as provides control for a mode selector valve that selectively places in cir-

cuit with the hydraulic unit displacement control, either the governor during the electrical power mode, or the pressure compensator during the hydraulic power mode.

To minimize the load on the AC generator-motor during the hydraulic power mode as it is coming up to speed, the pump is depressurized by delaying the activation of the pressure compensator valve, which is effected by a suitable time delay circuit in the mode control circuit.

Other features will appear below in the detailed description of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of one embodiment of the present invention;

FIG. 2 is a somewhat amplified schematic illustration of an emergency power unit according to the present invention shown in the generating mode; and

FIG. 3 is a schematic illustration of the emergency power unit shown in FIG. 2, but in the hydraulic power mode rather than the electrical power mode.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and particularly FIG. 1, wherein a block diagram schematic is illustrated for the present auxiliary power unit 10, the unit is seen to consist generally of an AC generator-motor 12 drivingly connected to a reversible displacement hydraulic motor-pump unit 14. The hydraulic unit 14 has a high pressure main conduit 16 and a low-pressure conduit 18 with the high-pressure conduit 16 being connected to the hydraulic support system of the aircraft through a main system valve 20.

During the generating mode, a mode selection switch 22 is placed in the emergency electrical power position energizing a solenoid valve 23 which couples a generator driven governor 26 to a fluid operable displacement control piston 28 which places the hydraulic unit 14 in its maximum displacement motoring position. At the same time the main system valve 20 is opened permitting hydraulic fluid to be supplied from the hydraulic support system through conduit 16 to the hydraulic unit 14 rotating it as a motor. With the hydraulic motor in maximum displacement it accelerates the AC unit 12 to its rated generating speed, e.g., 13,000 r.p.m., and at that time an electrical control unit 31 energizes a generator control relay which connects a voltage regulator circuit to the generator 12 so that the generator builds up voltage. When the generator output is within preset values, the generator control unit 31 provides a signal to a contactor 30 which connects the generator output to the main electrical bus of the aircraft. The governor 26 responsive to generator speed, serves to maintain a constant generator speed by varying the displacement of the hydraulic unit 14 in its motoring mode.

To place the emergency power unit 10 in the emergency hydraulic power mode, mode switch 22 is placed in its hydraulic power position which actuates electrical control circuit 31 to apply power to the AC generator-motor 12. After a suitable time delay to effect depressurization of the hydraulic unit 14, the solenoid valve 23 is actuated to connect compensator 32 to the control piston 28 permitting movement of the control piston into a pumping position, and controlling the piston to maintain a substantially constant pressure in pressure line 16 to the main hydraulic system through valve 20 which is then again open. Compensator 32, however, does not take over control until the AC generator-motor 12 assumes its synchronous speed, e.g., 12,000 r.p.m., so that it can come up to speed unloaded. In this mode the hydraulic unit 14 may, for example, be designed to achieve discharge pressures of three thousand p.s.i. with continuous flow of 5½ gallons per minute.

Reference will now be made to FIGS. 2 and 3 wherein the present emergency power unit 10 is shown in somewhat more detail.

AC generator-motor 12 may, for example, have a rated output of 10 kva., with overload capabilities of 15 kva. The hydraulic unit 14 is drivingly interconnected with the generator through shaft 34 which is adapted to transmit torque in either direction between AC generator-motor 12 and hydraulic unit 14.

The hydraulic unit 14 is an axial piston swashplate hydraulic unit and may take the form of the hydraulic unit disclosed in more detail in the patent to Iseman entitled "Fluid Translating Device," U.S. Pat. No. 3,366,968, assigned to the assignee of the present invention. Shaft 34 is drivingly connected to a cylinder block 36 in the hydraulic unit which slidably receives pistons 37 reciprocable in the cylinder block by a cam or swashplate member 38 as the block rotates. The cam or swashplate member 38 is biased toward its maximum displacement position clockwise from neutral by spring bias assembly 40.

Swashplate 38 is movable from a neutral or zero stroke position to maximum stroke positions on either side of neutral.

For the purpose of controlling the displacement of hydraulic unit 14, the control piston 28 is slidably received in a cylinder 29 and interconnected with the cam by a link or rod 42. By the application or relief of fluid pressure relative to the cylinder 29, the displacement of the cam 38 may be varied against the bias of spring assembly 40 from its maximum displacement position clockwise from neutral (pumping) to its maximum displacement position counterclockwise from neutral (motoring). In FIG. 2, the cam 38 is shown in its motoring mode in position, pivoted counterclockwise from its neutral position. As will appear hereinbelow, the control system is operative to place the cam 38 in a clockwise direction from neutral during the pumping mode and to place it on the counterclockwise side of neutral in the motoring mode as shown in FIG. 2 so that with a unidirectional rotation of shaft 34, main conduit 16 will always be the high-pressure conduit regardless of whether the unit 14 is acting as a pump or a motor.

When the hydraulic unit 14 is acting as a pump during the emergency hydraulic power mode, fluid is supplied through passage 16 to the main aircraft hydraulic support system 44, and conversely when the hydraulic unit 14 is acting as a motor during the emergency electric power mode, fluid under pressure is supplied from the hydraulic support system 44 through conduit 16 to drive the hydraulic unit 14.

The governor 26 is provided for controlling the displacement of hydraulic unit 14 in the emergency electric power mode and generally serves to control fluid pressure to control cylinder 29 in a manner to vary the displacement of the hydraulic unit 14 to maintain the speed of shaft 34 substantially constant at the rated speed of the AC unit 12. Governor 26 is a rotary governor driven by shaft 34 through a mechanical interconnection indicated at 49 so that it is driven at speed proportional to the AC unit 12. By itself, the governor 26 is conventional in construction and is seen to include pivotal flyweights 52 which position spool valve 54 against the bias of spring 56 which has an adjustable spring seat 55. Spool 54 has spaced lands 57 and 58 separated by a reduced stem portion 59. Fluid is supplied to valve 54 from high pressure conduit 16 through line 60 and passage 61. Valve bore 62 associated with valve 54 has an outlet port 63 controlled by land 58, and in this manner land 58 controls the flow of fluid under pressure from passage 61 to outlet port 63 and passage 65. Fluid from passage 65 is delivered across mode selector valve 67 through passage 68 to the control cylinder 29 of the hydraulic unit 14. It is readily seen that as the speed of the governor 26 increases that the flyweights 52 will move outwardly urging valve 54 upwardly from the position shown to a position blocking the outlet 63. Land 58 blocks outlet port 63 approximately at the design speed of AC unit 12 and as the speed at shaft 34 and governor 26 goes above that rated speed, land 58 will move upwardly permitting flow from the outlet 63 to a tank port 69 and thus permitting the control cylinder 29 to depressurize, reducing the displacement of hydraulic unit 14. Conversely,

when shaft 34 falls below rated speed, land 58 will shift downwardly permitting flow from passage 61 to port 63 increasing the displacement of hydraulic unit 14.

For the purpose of controlling the displacement of the hydraulic unit 14 during the emergency hydraulic power mode, the pressure compensator 32 is seen to consist of a spool valve 70 slidable in a valve bore 71 and having land portions 72 and 73 separated by a reduced stem portion 74. Valve member 70 is continuously urged to the right by an adjustable biasing spring assembly 76. Supply fluid from passage 60 is ported to the right end of the bore through inlet port 77, and outlet port 78 is controlled by the position of land 73. With mode selector valve 67 shifted downwardly to its position shown in FIG. 3, supply fluid pressure in passage 60 acts on the right end of valve member 70 urging it leftwardly and porting fluid to the displacement control cylinder 29 through passage 79, across valve 67 and through passage 68.

The compensator valve 32 is constructed so that upon an increase in fluid pressure in passage 16 above a predetermined value, valve land 73 will shift to the left permitting supply fluid in passage 16 to be ported to the control cylinder 29, reducing the displacement of the cam 38, (from the clockwise pivoted position shown in FIG. 3) which in turn reduces the pressure in passage 16 to the desired value. Of the pressure in passage 16 falls below the predetermined compensated value, land 73 will be urged rightwardly by spring assembly 76, and fluid in the control cylinder 29 will be drained across compensator valve drain passage 82, permitting the displacement of the cam 38 and hydraulic unit 14 to increase, raising the pressure in passage 16 back to the desired value. In this manner compensator valve 32 controls the fluid pressure in the control cylinder 29 to maintain a constant outlet pressure in main conduit 16 when the emergency power unit 19 is in the emergency hydraulic power mode.

The mode selector valve 67 serves the basic function of selecting either the electric power mode or the hydraulic power mode by selectively connecting either the governor 26 or the compensator 32 to the control cylinder 29. Toward this end the selector valve 67 includes a slidable spool valve 83 in bore 84 having land portions 85 and 86 separated by reduced stem portion 87. The valve member 83 is biased by spring 86' to its hydraulic mode position connecting passages 79 and 68, and is shiftable to its upper position shown in FIG. 2 connecting passages 65 and 68 by the energization of a solenoid coil 88 through mode control circuit 89.

For the purpose of controlling the mode selector valve, solenoid coil 88, and the AC generator-motor 12, the mode control circuit 89 is provided which includes the mode switch 22 and the electrical control unit 28 shown in FIG. 1. Switch 22 is seen to have an upper electric generating mode contact 91 and a lower hydraulic mode contact 92.

When switch 22 is placed in its upper position closing contact 91 solenoid coil 88 is energized through line 92' across diode 93 shifting the spool 83 to its upper position shown. At the same time, solenoid valve 20 is opened supplying the motive fluid to the hydraulic unit 14 through conduit 16 and control fluid through passage 60 and 61 to the governor spool valve 54. Governor valve 54 ports fluid to the control cylinder 29 pivoting cam 38 in counterclockwise direction against the force of spring assembly 40 and placing it in its maximum motoring displacement position shown in FIG. 2. Hydraulic unit 14, acting as a motor, begins to accelerate the AC unit 12 through shaft 34. Moreover, when switch 22 is closed on contact 91, relay coil 93' will be energized connecting voltage regulator 95 to the AC generator-motor 12. When rated speed is approached, a centrifugal switch (not shown) or the equivalent, contained within AC generator-motor 12, opens permitting the voltage regulator to regulate the output of the unit 12 acting as a generator at some fixed level. The centrifugal switch, if the electrical unit 12 is of the brushless rotating rectifier type, is used to short circuit the rotor field winding in the unit. When rated speed is attained, the governor 26 modulates flow to the control cylinder 29 to maintain the speed of AC unit 12 at substantially its rated value.

When it is desired that the emergency power unit act to provide hydraulic fluid to the aircraft hydraulic system 44, the pilot actuates switch 22 to its lower position engaging contacts 92. Since time delay relay 98 has normally closed contacts 99, current will, upon closure of switch 22 in this mode, energize coil 88 and shift mode selector valve 67 to its upper position shown in FIG. 2. Noting that the cam 38 would be in its maximum displacement clockwise position under the influence of spring bias assembly 40 prior to actuation of the switch 22, the shifting of valve 67 upwardly temporarily has the effect of depressurizing the hydraulic unit 14 by permitting full control fluid pressure to be applied to cylinder 29 across governor valve 26. This shifts cam 38 counterclockwise toward neutral. The purpose of this is to take the load off the AC generator-motor 12 as it accelerates toward synchronous speed, acting as a motor. The AC unit 12, when acting as a motor, accelerates rapidly to its synchronous speed as an induction motor. When operating as an induction motor, the damper bars in the motor serve as a squirrel cage rotor. The main generator field is short-circuited by the centrifugal switch (not shown) to protect the windings, and any rectifiers from the high induced E.M.F.'s attainable at low speed. As synchronous speed is approached, the centrifugal switch opens and the time delay relay 98 is timed to open contacts 99 shortly before this permitting the valve member mode selector valve 67 to shift downwardly to its position shown in FIG. 3, connecting passage 79 with passage 68 and thereby activating the pressure compensator valve 32.

The compensator valve 32 then permits the displacement of the hydraulic unit 14 to increase in a clockwise direction toward the position shown in FIG. 3 delivering fluid through passage 16 to the hydraulic support system 44 at a regulated constant pressure as described above. At the same time that time delay relay 98 opens contacts 99, contacts 105 of the same relay close, energizing relay 97, closing its contacts 98' and connecting the reactive current control 100 to the field winding of AC unit 12. This circuit minimizes the reactive current supplied to the motor by suitably adjusting the field current, and so insures that the unit 12 operates as a synchronous motor at near unity power factor.

I claim:

1. An emergency power unit for an aircraft or the like, comprising; a hydraulic motor-pump unit, means for varying the displacement of the unit, a generator-motor electrical unit drivingly connected to said hydraulic unit, means for driving said electrical unit as a generator to supply the electric power including means for supplying fluid under pressure to said hydraulic unit and means for maintaining said electrical unit as substantially constant speed, and means for providing hydraulic power under load to an associated hydraulic system including means for supplying electrical power to said electrical unit and means for maintaining substantially constant outlet pressure from said hydraulic unit.

2. An electrical-hydraulic power supply assembly, comprising; an electric unit having a generating mode a motoring mode, a hydraulic unit having a motoring mode and a pumping mode, means drivingly interconnecting the electric unit and the hydraulic unit, means for varying the displacement of the hydraulic unit, governor means responsive to the speed of said electric unit for varying the displacement of said hydraulic unit to maintain a substantially constant speed of the electrical unit, compensator means for varying the displacement of the hydraulic unit to maintain a substantially constant outlet pressure under load from said hydraulic unit, and mode selection means for selectively rendering operable said governor means or said compensator means.

3. An emergency power unit, comprising; an electric generator-motor unit, a hydraulic motor-pump unit drivingly connected to said electric unit, high pressure conduit means connected to deliver hydraulic fluid to and from the hydraulic circuit, low-pressure conduit means connected to deliver hydraulic fluid to and from the hydraulic unit, reversible means for varying the displacement of said hydraulic unit in both directions from neutral, governor means responsive to

the speed of the electric unit for controlling the displacement varying means on one side of neutral to maintain the electric unit at a substantially constant speed, and compensator means responsive to pressure in said high-pressure conduit means for controlling said displacement varying means on the other side of neutral to maintain substantially constant pressure in said high-pressure conduit means.

4. An emergency power unit as defined in claim 3, including control means for said governor means and said compensator means to selectively activate either.

5. An emergency power unit defined in claim 4, wherein said control means includes valve means between said governor means, said compensator means and said displacement varying means, and a mode selection switch for said valve means.

6. An emergency power unit as defined claim 3, including control means for said governor means and said compensator means, and mode selection means for the electric power mode or the hydraulic power mode.

7. An emergency power unit as defined in claim 6, including means responsive to the mode selection means for reducing the displacement of the hydraulic unit in the hydraulic power mode to permit the electric unit to come up to speed unloaded.

8. An emergency power unit as defined in claim 7, including control valve means for selectively connecting said governor means or said compensator means to control said displacement varying means, said means for depressurizing the hydraulic unit in the hydraulic power mode including means for temporarily maintaining the control valve means to connect the governor means to the displacement varying means in response to the mode selection means selecting the hydraulic power mode.

9. An emergency power unit as defined in claim 3, wherein said governor means includes a rotary governor and a governor control valve, passage means communicating said high-pressure conduit means to said governor control valve, said displacement varying means including fluid operable means, and conduit means connecting the control valve to deliver fluid to the fluid operable means.

10. An emergency power unit as defined in claim 9, wherein said compensator means includes a pressure compensator valve, means biasing said valve in a first direction including passage means connecting said high-pressure conduit means to supply fluid to one end of said compensator valve, conduit means connecting said compensator valve to supply fluid to said control valve means, and means biasing said compensator valve in a second direction.

11. An emergency power unit, comprising; an electric generator-motor unit, a hydraulic motor-pump unit drivingly connected to said electric unit, high pressure conduit means connected to deliver hydraulic fluid to and from the hydraulic circuit, low pressure conduit means connected to deliver hydraulic fluid to and from the hydraulic unit, reversible means for varying the displacement of said hydraulic unit in both directions from neutral, governor means responsive to the speed of the electric unit for controlling the displacement varying means on one side of neutral to maintain the electric unit at a substantially constant speed, compensator means responsive to pressure in said high-pressure conduit means for controlling said displacement varying means on the other side of neutral to maintain substantially constant pressure in said high-pressure conduit means, control means for said governor means and said compensator means, mode selection means for the electric power mode or the hydraulic power mode, means responsive to the mode selection means for reducing the displacement of the hydraulic unit and depressurizing the same in the hydraulic power mode to permit the electric unit to come up to speed unloaded, control valve means for selectively connecting said governor means or said compensator means to control said displacement varying means, said means for depressurizing the hydraulic unit in the hydraulic power mode including means temporarily maintaining the control valve

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means to connect the governor means to the displacement varying means in response to the mode selection means selecting the hydraulic power mode, said governor means including a rotary governor and a governor control valve, passage means communicating said high-pressure conduit means to said governor control valve, said displacement varying means including fluid operable means, conduit means connecting the governor control valve to deliver fluid to the fluid operable

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means, said compensator means including a pressure compensator valve, means biasing said valve in a first direction including passage means connecting said high pressure conduit means to supply fluid to one end of said compensator valve to supply fluid to said control valve means and means biasing said compensator valve in a second direction.

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