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ENGINE SYNCHRONIZATION MEANS

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This invention relates to an engine speed control and synchronizing system, and more particularly to an engine control and synchronizing system for aircraft engines wherein signal voltages control the engine speed.

An object of the present invention is to provide a speed control and synchronizing system for a plurality of engines whereby the speed of the engines may be controlled at will from a remote point, and the speeds of the engines synchronized with that of one of the engines designated as the master engine without the use of complicated lever, pulley or flexible shafting assemblies.

Another object of our invention is to provide a speed control and synchronizing system for a plurality of engines in which signal voltages are developed for controlling the speeds of the engines, and in which signal voltages are developed responsive to engine speeds to control the synchronization of the engines.

A further object of the invention is to provide a speed control and synchronizing system for engines of the character indicated in which signal voltages responsive to the difference in the speeds of the engines vary the controlling signal voltages for the slave engines to synchronize the speeds thereof with that of the master engine.

Still another object of this invention is to provide a speed control and synchronizing system for engines of the character described which is independent of the fluctuations in the amplitude, or in the frequency of the source of voltage, and which is independent of the variations or characteristics of the engines controlled, or their speed controlling devices.

Yet another object of our invention is to provide a speed control and synchronizing system for engines of the character described which shall be simple to operate with respect to the control of engine speed and automatic with respect to engine synchronization, relatively inexpensive to manufacture, which shall have a large variety of applications, and yet be practical and efficient to a high degree in use.

Other objects of the present invention will in part be obvious and in part hereinafter pointed out.

In the accompanying drawings forming a part of this specification in which two of the various possible illustrative embodiments of this invention are shown, and wherein similar reference characters designate corresponding parts throughout the several views,

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Fig. 1 is a schematic wiring diagram illustrating our system as used in varying the bias of a speeder spring of a propeller pitch governor unit, while

Fig. 2 is a schematic wiring diagram similar to Fig. 1 illustrating another embodiment of our invention.

Referring now in detail to Fig. 1 of the drawings, the numeral 10 designates a circuit interconnecting a control lever 11 with the propeller governors 12 and 13 controlling the pitch of propellers 14 and 15 of the aircraft engines 16 and 17, respectively. The engine 16 will be hereinafter referred to as the master engine, while engine 17 will be referred to as the slave engine, the speed of which is to be synchronized with that of engine 16.

The circuit 10 comprises a synchronous generator or transmitter 18, having a rotor winding 19 and a stator winding 20. The rotor winding 19 is connected across a suitable source of potential 21 and is adapted to be angularly displaced by movement of the control lever 11 through suitable gearing indicated by the dashed line 22. The three phase stator winding 20 is connected by leads 23 to the three phase stator winding 24 of a synchro or receiver 25. The receiver 25 also comprises a single phase rotor winding 26 adapted to be rotated by a two phase induction motor 27 as by gearing 28. The transmitter 18, the receiver 25 and the two phase motor 27 control the speed of the master engine 16.

Control of the slave engine is accomplished by similar units in the circuit 10, and comprising a second synchronous generator or transmitter 29 similar to transmitter 18, having a rotor 30 connected across the source of potential 21 and adapted to be rotated through gearing 31 by the lever 11 and a receiver 35. The transmitter 29 is provided with a three phase stator winding 32 connected as by leads 33, to the three phase stator winding 34 of the receiver 35. The receiver 35 is provided with a single phase rotor 36 adapted to be rotated by a two phase induction motor 37, as by gearing 38. As will hereinafter appear the stator winding 32 of the transmitter 29 is adapted to be angularly displaced by the operation of a gear train, or other coupling devices, shown on the drawings by the dashed line 39.

The receiver rotors 26 and 36 are connected by suitable leads 40 to the input side of amplifiers 41; the output of said amplifiers being connected to the variable phases 42 and 43 of the two phase

induction motors 27 and 37, respectively. The fixed phases 44 and 45 of the motors are connected across the power supply 21.

The movement of the control handle 11 through the gearing 22 and 31 will angularly displace the rotors 19 and 30 of the transmitters 18 and 29, respectively. The position of the rotors will induce a corresponding voltage in the three phase windings of the transmitters which will appear in the stator windings 24 and 34 of the receivers 25 and 35, respectively. The voltage appearing in the stator windings of the receivers will in turn induce a voltage in their associated rotor windings 26 and 36 which, when amplified, is applied to the variable phases of the two phase motors 27 and 37. The voltage appearing in the variable phases 42 and 43 will cause the respective induction motors to operate to position the receiver rotors 26 and 36 to a null position at which no voltage is induced in the rotor windings. With no voltage being applied to the amplifiers 41, the two induction motors 27 and 37 will be brought to a standstill.

The electrical circuit 10 is provided with means for varying the speed setting of the propeller governors 12 and 13. To this end, there is provided for each of the two phase induction motors 27 and 37 a gear train, herein indicated by the dashed line 46 and 47, terminating in pinions 48 and 49, respectively. The pinion 48 is adapted to mesh with a rack 50 of the propeller governor 12, which pinion 49 meshes with a rack 51 of the propeller governor 13.

The propeller governors 12 and 13 are of the type well known in the art, and comprise a speeder spring 52 fixed at its upper end to the lower end of rack 50 (or 51) and at its lower end to a disc 57 fixed to the upper end of a rod 53. The rod 53 is journaled in a sleeve 54 adapted to be rotated by the aircraft engine 16 (or 17). The enlarged portion 55 of the sleeve 54 has pivoted thereto weighted bellcrank members 56 adapted to coast with the disc 57 on the upper end of the rod 53.

In response to the speed of the engine the weighted bellcrank members 56 will fly outwardly, tending to lift the disc 57 and the rod 53 against the bias of the spring 52. Movement of the rod 53 by the weighted members will vary the propeller pitch in the manner well known in the art.

Upon operation of the two phase motors 27 and 37 to position the transmitter rotors 26 and 36 to a new null position as demanded by the angular displacement of the rotors of their respective transmitters, the speeder spring bias of the propeller governors 12 and 13 will be varied by the rotation of the pinions 48 and 49 moving the racks 50 and 51. The movement of the racks will either increase or decrease the bias of the speeder springs, thus affecting the response of the weighted members to the engine speeds. The pitch of the propellers 14 and 15 are thus varied in accordance with the position of the control lever 11.

Means is now provided to match the speed of the engine 17 with that of the master engine 16.

To this end there are provided synchronous transmitters or generators 60 and 61 having single phase rotors 62 and 63, respectively, connected across the source of potential 21 and adapted to be rotated by the engine shafts as indicated by the dashed lines 64 and 65, respectively. The three phase stator winding 66 of the transmitter 60 is connected by suitable leads 67 to a three phase stator winding 68 of a differ-

ential motor 69, while the three phase winding 70 of the transmitter 61 is connected by leads 71 to the three phase rotor winding 72 of the differential motor 69. The differential rotor 72 is coupled by the gear train 39 hereinbefore described, to the stator winding 32 of the transmitter 29.

Rotation of the rotors 62 and 63 by their respective engines will induce in the respective stator windings 66 and 70 a voltage which gives rise to a rotating magnetic field in the stator and rotor windings of the differential motor 69 to which said transmitter stators are connected. When the speeds of the engines 16 and 17 are the same the two rotating magnetic fields in the differential motor 69 will rotate at the same speed. No rotation of the rotor winding 72 will take place under this condition.

When a difference in engine speed exists between the engines 16 and 17, the speed of the rotating field in the rotor 68 will be different than that of the rotating field in the rotor winding 72. The reaction of the two rotating magnetic fields will cause the rotor 72 to be angularly displaced in accordance with the difference in engine speeds. The angular displacement of the rotor 72 will cause an angular displacement of the stator winding 32 of the transmitter 29. A change in the relative positions of the rotor 30 and stator 32 will change the signal voltage induced in the stator. The change in signal voltage is impressed on the rotor 36, amplified and applied to the variable phase of the two phase motor 37. The motor 37 will thus rotate to displace the rotor 36 to a new null position and to reposition the rack 51 in the manner hereinbefore described. The bias of the speeder spring 52 is thus altered, changing the pitch of propeller 15 to bring the speed of the engine 17 in synchronism with that of engine 16.

Referring now to Fig. 2 of the drawings, in which a second embodiment of our invention is illustrated, the control circuit for the slave engine 17 includes therein a source of variable voltage responsive to the speed difference between the slave and master engines.

The control circuit for the slave engine 17 comprises synchronous motor 80 having a three phase stator winding 81 and a single phase rotor winding 82. The rotor 82 is adapted to be angularly displaced with respect to the stator coil 31 by means of the control lever 11 through a gearing, or other coupling indicated by the dashed line 83. The motor 80 is connected by suitable leads 84 to a synchro transmitter 85 having a three phase stator winding 86 and a single phase rotor winding 87; the three phase stator winding 81 being connected to the three phase stator winding 86. The single phase winding 87 is connected across the source of potential 21 and is adapted to be rotated by the induction motor 37 through suitable gearing 88.

The single phase winding 82 is connected by leads 89 to the input of the amplifier 41 controlling the variable phase 43 of the induction motor 37. When the rotors 82 and 87 are in positional agreement, no voltage will be induced in the rotor winding 82. The variable phase 43 of the induction motor will be de-energized and no angular displacement of the rotor winding 87 will take place.

When the control handle 11 is moved, the magnetic balance heretofore had will be disturbed, causing a voltage to be induced in the

rotor winding 82. The voltage due to the positional disagreement will be amplified by the amplifier 41 and applied to the variable phase 43. The induction motor 37 is thus operated to displace the rotor 87 into positional agreement with that of the rotor 82. Rotation of the motor 37 will vary the bias of the speeder spring 52 of the propeller governor 13 through the gear train 47 and pinion 49 in the manner hereinbefore described.

The circuit for the control of the speeder spring 52 for the master engine 16 is the same as that described in connection with Fig. 1.

Means is now provided to induce in series with the positional signal voltage of the rotor 82 a signal voltage in proportion to the speed difference of the two engines.

To this end, a rotary transformer 90 is provided having a rotor coil 91 connected across the source of potential 21 and movable with respect to a stator winding 92. The stator winding 92 is connected in series by the leads 89 to the rotor winding 82 and the amplifier 41. The rotor 92 is adapted to be rotated by the rotor 72 of the differential motor 69 through a suitable coupling or gearing 93.

When the two engines 16 and 17 are in agreement as to their respective speeds, the rotating magnetic fields in the stator and rotor windings of the differential motor 69 impressed thereon by the generators 61 and 60, respectively, cancel one another and no rotation of the rotor 72 will take place. A difference in speeds of the two magnetic fields will, due to the magnetic reaction of the two fields, cause an angular displacement of the rotor 72. Through the gearing 93, the rotor 72 will angularly displace the rotor 91 of the rotary transformer 90 to induce a voltage in the stator winding 92. This change in the induced voltage will be in proportion to the difference in speed of the two engines and is added in series with the signal voltage of that of the rotor 82. The induction motor 37 is operated to displace the rotor 87 for rebalancing the circuit described. The rotation of the motor 37 will also vary the bias of the speeder spring 52 of the propeller governor 13 to vary the pitch of propeller 15 to bring into synchronism the speed of the engine 17 with that of the master engine 16.

It will be appreciated that the speed control and synchronizing systems hereinabove described are independent of fluctuations either in the amplitude or in the frequency of the voltage source 21 since the system depends upon its operation on magnetically balanced circuits. Since all of the induction devices are connected to the same source of supply any changes taking place therein, take place equally throughout the entire system. Variations in the calibration of the speeder springs 52 and/or in the characteristics of the fly ball members 56 are automatically compensated for in synchronizing the engine speeds in that the speed of the engines govern the magnetic balance of the circuits. The circuits will bias the speeder springs more or less as needed for any particular required engine speed.

It will thus be seen that there is provided a control and synchronizing system in which the several objects of this invention are achieved and which is well adapted to meet the conditions of practical use.

As various possible embodiments may be made of the invention above set forth, and as various

changes might be made in the two embodiments set forth above, it is to be understood that all matter herein described, or illustrated in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

Having thus described our invention, we claim as new and desire to secure by Letters Patent:

1. In speed control and synchronizing systems for engines, one of said engines acting as a master or reference engine, the combination with speed regulating means for each engine, of motive means for actuating said speed regulating means, a displaceable control lever, inductive means coupled to said control lever adapted to develop signal voltages responsive to the displacement of said lever, means responsive to said signal voltages to operate said motive means; and differential means for varying the initial signal voltages in response to the differences in the engine speeds to vary the actuation of the speed regulating means associated with each engine except that of the reference engine, to synchronize the engine speeds to that of the reference engine.

2. In speed control and synchronizing systems for engines, one of said engines acting as a master or reference engine, the combination with speed regulating means for each engine, of motive means for actuating said speed regulating means, a displaceable control lever, inductive means coupled to said lever and adapted to develop signal voltages responsive to the displacement thereof, means responsive to said signal voltages to operate said motive means, means for developing a signal responsive to the speed of each engine; and differential means for varying the initial signal voltages except that of the reference engine in response to differences in the speed signals to vary the operation of the motive means to synchronize the engine speeds to that of the reference engine.

3. In speed control and synchronizing systems for engines, one of said engines acting as master or reference engine, the combination with speed regulating means for each engine, of motive means for actuating said speed regulating means, a displaceable control lever, a circuit for controlling said motive means including an inductive device for each engine coupled to said lever and adapted to develop signal voltages responsive to the displacement thereof for operating said motive means, inductive devices coupled to said motive means for cancelling said signal voltages when the engine speed is in agreement with lever displacement; and means for varying the signal voltages of said inductive devices, except that for the reference engine, in response to the differences in engine speeds to synchronize the speeds with that of the reference engine.

4. A speed control and synchronizing system for engines, one of said engines acting as the master or reference engine, comprising a propeller governor for each of said engines including a speeder spring and fly ball members, a servomotor for each governor adapted to vary the bias of said speeder spring to affect the response of said fly ball members to engine speed, a control lever, an inductive device for each servomotor coupled to said lever and adapted to develop signal voltages in response to the movement thereof for operating said servomotor, inductive devices connected to each of said first devices and driven by said servomotors for nullifying the signal voltages of said first devices when the speeds

of said engines are in agreement with the position of said lever, means driven by each engine for developing a signal in response to the speed thereof, induction means connected to said driven means and responsive to the speed signals and modifying the initial signal voltages, except that of the reference engine, to synchronize the engine speeds with that of the reference engine.

5. A speed control and synchronizing system for two engines, one of said engines acting as the master engine, comprising a propeller governor for each of said engines including a speeder spring and fly ball members, a servomotor for each governor adapted to vary the bias of said speeder spring to affect the response of said fly ball members to engine speed, a control lever, an inductive device for each servomotor coupled to said lever and adapted to develop signal voltages in response to the movement thereof for operating said servomotor, inductive devices connected to each of said first devices and driven by said servomotors for nullifying the signal voltages of said first devices when the speed of said engines are in agreement with the position of said lever, means driven by each engine developing a signal in response to the speed thereof, a differential motor having a stator and a rotor each connected to one of said signal means, a rotary transformer having a stator and a rotor, said rotor being driven by said differential rotor, the transformer stator being connected in series with the induction device of the slave engine, the changes in voltage induced in the transformer stator modifying the initial signal voltage to bring the slave engine into synchronism with the master engine.

6. A speed control and synchronizing system for two engines, one of said engines acting as the master engine, comprising a propeller governor for each of said engines including a speeder spring and fly ball members, a servomotor for each governor adapted to vary the bias of said speeder spring to affect the response of said fly ball members to engine speed, a control lever, an inductive device for each servomotor coupled to said lever and adapted to develop signal voltages in response to the movement thereof for operating said servomotor, inductive devices connected to each of said first devices and driven by said servomotors for nullifying the signal voltages of said first devices when the speed of said engines are

in agreement with the position of said lever, means driven by each engine developing a signal in response to the speed thereof, a differential motor having a stator and a rotor each connected to one of said engine driven signal means, and means coupling said differential rotor to the slave engine induction device to alter the signal voltages developed thereby for synchronizing the speeds of the slave engine to that of the master engine.

7. A speed control and synchronizing system for a plurality of engines having speed regulating means, one of said engines serving as a master engine; comprising means for developing a signal voltage in accordance with a desired engine speed, motive means actuating each of the speed regulating means responsive to said signal voltages, means driven by the engines to develop signals responsive to engine speeds, and differential means responsive to the speed signals and operative upon differences in the speeds of said engines to vary the initial signal voltages controlling the slave motive means for synchronizing the speeds of the engines.

8. A control system for two engines comprising a differential motor having a stator and a rotor, an induction device for each engine and driven thereby, connected to said differential rotor and stator respectively and developing a rotating magnetic field therein, a difference in the speeds of the rotating fields displacing said differential rotor; induction means for developing a signal voltage in accordance with desired engine speed, speed regulating means for each engine responsive to said signal voltages, and means operable upon displacement of said differential rotor to vary the signal voltages to one of said speed regulating means to synchronize engine speeds.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,562,917	Richter	Nov. 24, 1925
2,205,265	Kalin	June 18, 1940
2,412,605	Drake	Dec. 17, 1946