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ELECTRONIC IGNITION AND GENERATOR
CONTROL APPARATUS

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The present invention relates to electronic ignition and generator control apparatus and more particularly to apparatus of this character especially suited for use in ignition systems for internal-combustion engines.

In the course of the development of the internal-combustion engine in mobile installations, it has been found desirable to include a source of electric power for generation of the igniting arc in the spark plug and means for initial starting of the unit. Various systems have been utilized to effect this purpose, the existing development being a combination of various contacting devices so constituted as to produce the desired result. The open air contact is subject, however, to very serious defects, the most prominent of which, of course, are actual mechanical wear, and oxidation due to the combined effects of heat and air. It has, therefore, seemed desirable to produce a system in which the excellent characteristics of the thermionic tube in respect to making and breaking contact may be made use of. Among these characteristics are freedom from variation in qualities due to change in barometric pressure, long trouble-free life with little or no deterioration until the end-point, extreme reliability of operation, and perfect flexibility of control.

The existing automotive systems make use of the storage battery or accumulator in conjunction with an electro-mechanical generator connected to the internal combustion engine by means suitable for maintaining the necessary power relationships for charging the battery. By virtue of the fact that the generator is mechanically connected to the internal combustion engine a variable voltage is generated which must be controlled by means calculated to limit the charging current. This means may, in the commonly used systems, consist of a simple compound wound direct current generator, the series winding of which provides the rising characteristic with load and the shunt of which is controlled by external means to produce the flat voltage characteristic, with respect to angular velocity of the mechanism. The external shunt field control means most often consists of a system of contactors so arranged as to reduce the controlled field excitation as the voltage generated across the armature rises.

In the system of the present invention, this control is effected by means of a grid-controlled, gas-discharge tube so connected as to reduce the field excitation as the generated E. M. F. across the generator armature rises with the angular velocity of the mechanism. This may readily be

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accomplished by providing a source of alternating voltage which is a function of the generated continuous or direct current voltage appearing across the generator brushes. Such an alternating voltage may easily be obtained from the conventional direct current generator by connecting diametrically a pair of slip rings to the generator armature and taking the resultant E. M. F. from these slip rings. This alternating voltage will be very nearly in the mathematical ratio of .707 of the generated continuous voltage. The addition of these slip rings to the generating unit is a simple mechanical expedient which adds little to the cost of the machine. This alternating voltage may then be increased by means of a suitable transformer.

It is apparent that in a system of the foregoing type the frequency of the generated alternating current will be a function of the angular rotative velocity of the machine. However, in the system of the present invention, variation in frequency may be eliminated as a problem in control of the field excitation, by means of suitable energy-storing capacitance.

The generated alternating current voltage is rectified to produce a proportional direct current control voltage which is utilized to control the generator field excitation to produce a generator output voltage having a "flat characteristic" with respect to the angular velocity of the machine.

Another feature of the system of the present invention is the provision of electronic ignition pulse generating means energized from the alternating current supplied by the generator. This is accomplished by means including a simple rectifying system providing a source of relatively high continuous voltage which may be used with a cold-cathode, grid-controlled, gas-discharge tube in association with a capacitance, charged through a relatively high resistance, and a conventional type of ignition coil. Initiation of the ignition pulse is effected by a voltage source so connected to the timing mechanism as to produce an instantaneous, highly-peaked pulse connected across the grid input circuit. Means for producing this pulse preferably includes a simple ratchet arrangement having a number of teeth corresponding to the number of cylinders in the associated internal-combustion engine and so constructed as to give a change in position of an element of a magnetic circuit, independent of the rotative speed of the internal-combustion engine, at the desired time. The output of the ignition coil is supplied to the rotor of the conventional distributor.

The present invention contemplates the production of ignition impulses before the engine is actually running by means including a disconnect clutch between the generator and its driving pulley enabling the generator to operate as a converter, energized from the battery, until the engine speeds up. When this occurs the generator is connected to the engine and maintains a charge in the storage battery in accordance with desired and predetermined characteristics.

The system of the present invention provides, in addition, a source of alternating current for general purposes at all times with the additional advantage of a high efficiency of conversion without the inherent disadvantages of vibrating contacts. A whole new field is therefore open in the matter of automotive accessories, such as the radio, induction defrosters, electrical instrumentation, and heating equipment. It is economical, more reliable, and more satisfactory than the existing types of systems. In addition, the characteristics of the thermionic tubes are such that the operation is not subject to the rapid deterioration after adjustment that is encountered with the existing mechanical systems.

An important application of the ignition system is in high-altitude aircraft operation where the independence of the characteristics of the thermionic tube from barometric pressure is of vital importance. In this connection it may be mentioned that the ignition contacts are replaced after each flight in high-altitude flying. The tremendous advantage of a system which is independent of altitude is thus apparent.

One of the primary objects of the present invention is the provision of new and improved voltage regulating and ignition apparatus for internal combustion engines.

Another of the primary objects of the present invention is to provide a new and improved ignition and generator control system for internal combustion engines, and more specifically, a control including electronic devices for controlling both the ignition and generator.

A further object of the present invention is to provide a new and improved internal combustion engine control system comprising an alternating current generator.

A still further object of the present invention is to provide a new and improved internal combustion engine control system including a battery and a converter, and more specifically, a converter having both direct and alternating current windings, the latter of which is utilized for producing a control voltage for imparting desired characteristics to the direct current windings and for supplying energy to the ignition means.

Another object of the present invention is to provide a new and improved internal combustion engine ignition system of the electronic type having means mechanically synchronized with the distributor for producing sharp peaked control pulses to control the electronic means.

A further object of the present invention is the provision of a new and improved generator for use with internal combustion engines.

Other objects and advantages of the present invention will become apparent from the ensuing description of an embodiment thereof, in the course of which reference is had to the accompanying drawing, in which

Fig. 1 is a diagrammatic representation of one embodiment of the invention; and

Fig. 2 is a schematic circuit diagram of the

novel generator included in the embodiment of the invention illustrated in Fig. 1.

The control system of the present invention is adapted particularly for internal combustion engines of various type, such as automobiles, tanks and especially high altitude aircraft where mechanical ignition and control devices have serious disadvantages. The control system includes, in the main; an ignition system 10; a voltage regulator 12; a generator 14, used also as a converter, and supplying power to the ignition system and voltage regulator; a disconnect clutch 16; a control switch 18, which may be the customary ignition switch; and a battery 20.

The battery may be of any conventional type. One terminal is connected to ground by conductor 22 and the other to one terminal of switch 18 by conductor 24. The other terminal of the switch is connected by conductor 26 to the terminal 28 of the generator 14.

The generator 14 is of novel construction in that it includes means for producing an alternating current control voltage proportional to its angular velocity, which voltage, in accordance with the primary features of the present invention is supplied to the ignition system 10 and the voltage regulator system 12, of which the latter controls the direct current winding of the generator to give it the desirable "flat characteristic."

The generator includes the customary high impedance shunt field 30, a low resistance series field 32, a commutator 34 connected to the armature winding 36 (of the distributed type). One terminal of the shunt field is connected to ground 38 and the other to terminal 38. One terminal of the series field is connected to the previously referred to terminal 28 and the other is connected by conductor to one of the generator brushes 40, the other of which is connected to ground.

The alternating current voltage is obtained from the armature winding 36, preferably by a pair of slip rings 42 connected to diametrically opposite points of the winding. This voltage is proportional to the angular velocity of the armature and is very nearly in the mathematical ratio of .707 of the continuous voltage generated by the generator. The slip rings can be added to a conventional generator and the necessary connections can be made both readily and economically.

The desired flat generator characteristic is provided by the voltage regulator 12 which is constructed and arranged to supply and control the excitation of the shunt field 30 in such manner that the excitation decreases as the angular velocity of the generator increases, the regulator being supplied with the generator alternating current voltage. The regulator includes means 44 for rectifying the alternating current voltage to provide a direct current control voltage.

It is preferred that the alternating current voltage be stepped up before it is supplied to the rectifier by suitable means, such as a transformer 46. The alternating current control voltage is supplied to the primary winding 48 of the transformer by the conductors 50 and 52 connected to the slip rings 42. The secondary winding 54 is connected to conductors 56 and 58, of which the latter is grounded.

The voltage regulator is connected across the secondary winding of the transformer by conductors 60 and 62 and it is constructed and arranged to provide a shunt field excitation which is inversely proportional to the generated voltage. It includes the previously referred to rectifier,

which is preferably of the copper oxide type, and an electron tube 64, preferably a grid-controlled, gas discharge tube (of the 2051 type or of the 0A4 type) connected to operate as a voltage regulator. The control grid 66 of the tube is supplied with a negative continuous voltage, very nearly proportional to the generator alternating current voltage, by the rectifier.

The rectifier 44 is connected to the junction of the voltage divider resistors 68 and 70, of which the former is adjustable, and which are connected across the secondary winding by the conductors 60 and 62. The other terminal of the rectifier is connected to the grid 66 of the tube and to the shunt field terminal 38 through the parallel connected capacitance 72 and grid leak resistor 74, the connection being effected by conductor 76. The anode 78 of tube 64 is connected to conductor 60 and the cathode 80 is connected to the conductor 76. A filter condenser 82 is connected in parallel with the shunt field winding to render the excitation of the shunt field free of any frequency variation effects.

The ignition system includes a cold cathode, grid controlled gas discharge tube 90 (as of the 631P1 type) adapted to be rendered conductive in timed relation with the operation of the engine and controlling ignition pulse producing means. The pulse producing means includes a capacitance 92 and an ignition coil or transformer 94, having a primary winding 96 in series with the tube and capacitance and through which the capacitance is discharged at timed intervals. The secondary winding 98 of the coil is connected across the distributor 100 and the ground connection 58. The distributor may be of any desired or conventional type and it has therefore not been illustrated in detail.

The capacitance 92 is connected to the anode 102 of tube 90 by conductor 104 and the cathode 106 of the tube is connected to one terminal of the primary winding 96 by conductor 108. The other terminal winding 96 is grounded.

The ignition pulse producing means is supplied with energy from the generator 14, preferably, by means including a rectifier tube 110 (which may be, for instance, of the 0F4 or 80 type) and a filter capacitance 112 connected in series across the secondary winding 54 of the transformer 46. The capacitance 92 is charged through a relatively high value resistor 114 connecting the anode end of the capacitance to the cathode of the rectifier tube.

The ignition pulses are produced at timed intervals synchronized with distributor operation by control voltage pulse producing means. The latter may take different forms. It may include a sharp peaked pulse voltage producing pickup 120 connected by conductor 122 to the control grid 124 of tube 90 operated as by a ratchet wheel 126 rotated in synchronism with the distributor. Each time an ignition pulse is to be produced, the ratchet wheel operates the pickup to apply a sharp peaked control voltage to the grid, thereby to render the tube conductive to effect the discharge of condenser 92 through the tube and the primary winding of the ignition coil.

In order that ignition pulses be produced before the engine is actually running, the generator is disconnected from its driving pulley by the disconnect clutch 16 so that it may operate as a converter and supply alternating current voltage to the ignition system. Under these conditions, the direct current windings of the generator operate as a motor (obtaining energy from the battery) to

rotate the armature, thereby to produce an alternating current voltage across the slip rings.

The disconnect clutch 16 is shown between the generator 14 and the generator driving pulleys 130 and 132, which are interconnected by a belt 134. Thus it normally disconnects the generator from the engine but connects the generator to the engine when the latter accelerates to some suitable speed.

The operation of the system as a whole will now be described. When the switch 18 is open the apparatus is inoperative. When the switch is closed the battery supplies energy to the generator 14, which runs as a converter to supply alternating current to the ignition system 10 and voltage regulator 12 through the step-up transformer 46. This alternating current is, of course, available for such other purposes as may be desired. The disconnect clutch 16 is open so that the generator may readily operate as a converter without driving any mechanical load.

When the internal combustion engine is started, as by closing a conventional starter switch, the ratchet 126 operates the pickup to produce control voltage pulses which are supplied to the control grid 124 of the tube 90, with the result that the capacitance 92, which is charged by the alternating current output from the rectifier 110—112 is discharged through the tube and the ignition transformer 94 to produce high voltage ignition pulses in timed relation with the distributor 100 through which the pulses are supplied to the proper ignition plug. The capacitance 92 is charged through resistor 114 connected to the rectifying means of which the capacitance 112 is made sufficiently large to maintain a continuous source of direct current power when the alternating frequency from the generator 14 is at its lowest point.

When the motor starts and accelerates to some desired predetermined speed, the generator is connected to the engine by the clutch 16. The direct current charging voltage will then build up as the motor speed is increased.

The alternating current voltage generated by the generator is a fixed proportion of the continuous voltage so that, as the latter rises, the alternating voltage will also rise. However, as the alternating voltage rises the negative bias applied to the grid 66 of the voltage regulator tube 64 increases. As the negative bias increases the average current passed by the tube decreases, thereby to decrease the excitation of the shunt field winding 30. The voltage regulator circuit may be made to level off at any desired charging rate and may be designed to produce different excitation voltages dependent upon the requirements of particular systems. Adjustment is effected by the adjustable resistor 68 whereby the regulator may be adjusted, in effect, to an infinite number of control points and the present apparatus is, in this respect also, superior to the usual regulators which have but two or three control positions.

While but a single embodiment of the invention has been described in detail, it should be understood that the details thereof are not to be construed as limitative of the invention, except in so far as set forth in the accompanying claims.

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

1. An ignition and generator control system for use with an internal combustion engine, including in combination, a generator having a di-

rect current exciting winding and means for producing an alternating current voltage proportional to the direct current output of the generator, clutch means normally disconnecting the generator from the engine, a step-up transformer coupled to the alternating current output of the generator, means coupled to the transformer for supplying ignition pulses to the engine, means coupled to the transformer for controlling the excitation of the direct current winding, means connecting the generator to a source of power during starting of the engine whereby the generator is operated as a converter to produce an alternating current output whereby ignition pulses are supplied to the engine, and means including said clutch means for connecting the generator to the engine after the engine has started.

2. An ignition and generator control system for use with an internal combustion engine, including in combination, a generator having a direct current exciting winding and means for producing an alternating current voltage proportional to the direct current output of the generator, clutch means normally disconnecting the generator from the engine, a step-up transformer coupled to the alternating current output of the generator, means coupled to the transformer for supplying ignition pulses to the engine, voltage regulator means coupled to the transformer for controlling the excitation of the direct current winding, a battery, means connecting the generator to the battery whereby the generator is operated as a converter to produce an alternating current output whereby ignition pulses are supplied to the engine, and means including said clutch means for connecting the generator to the engine after the engine has started, whereby the battery is charged under the control of the voltage regulator during operation of the engine.

3. A control system as claimed in claim 2, wherein said ignition and voltage regulator means are of the electronic type.

4. An ignition and generator control system for use with an internal combustion engine, including in combination, a generator having a direct current exciting winding and means for producing an alternating current voltage proportional to the direct current output of the generator, clutch means normally disconnecting the generator from the engine, a step-up transformer coupled to the alternating current output of the generator, means including rectifying means coupled to the transformer and a grid controlled gas discharge tube coupled to the rectifying means for supplying ignition pulses to the engine, voltage regulator means including a grid controlled gas discharge tube and rectifying means coupled to the transformer for controlling the excitation of the direct current winding, means connecting the generator to a source of power during starting of the engine whereby the generator is operated as a converter to produce an alternating current output whereby ignition pulses are supplied to the engine, and means including said clutch means for connecting the generator to the engine after the engine has started.

5. A control system for an internal combustion engine, including in combination, a generator adapted to be driven by the engine, means nor-

mally disconnecting the generator from the engine and adapted to connect it to the engine, means for operating the generator as a motor and for producing an output voltage during the starting of the engine, and means energized by said output voltage for supplying ignition pulses to the engine.

6. An internal combustion engine control system, including in combination, a generator having direct and alternating current voltage outputs for supplying a battery and the engine ignition, respectively, said alternating current output being proportional to the angular velocity of the generator, means energized by said alternating current output for supplying ignition pulses to the engine, and voltage regulator means energized by the alternating current output for controlling the direct current voltage output of the generator.

7. An internal combustion engine control system, including in combination, a generator having direct and alternating current voltage outputs for supplying a battery and the engine ignition, respectively, means energized by said alternating current output for supplying ignition pulses to the engine, and voltage regulator means energized by said alternating current output for controlling the direct current voltage output of the generator.

8. A control system for an internal combustion engine, including in combination, a dynamo electric machine including shunt and series field windings, a uniformly distributed armature winding, a commutator and slip rings connected to armature winding, means for energizing said series and armature windings with direct current to operate said device as a motor and to produce an alternating current voltage across said slip rings, means including electronic rectifying and pulse producing means for supplying ignition pulses to the engine, and means supplied with said alternating current voltage for controlling the excitation of said shunt field winding.

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