Feb. 26, 1957 H. J. HALL 2,782,867

PULSER CIRCUIT

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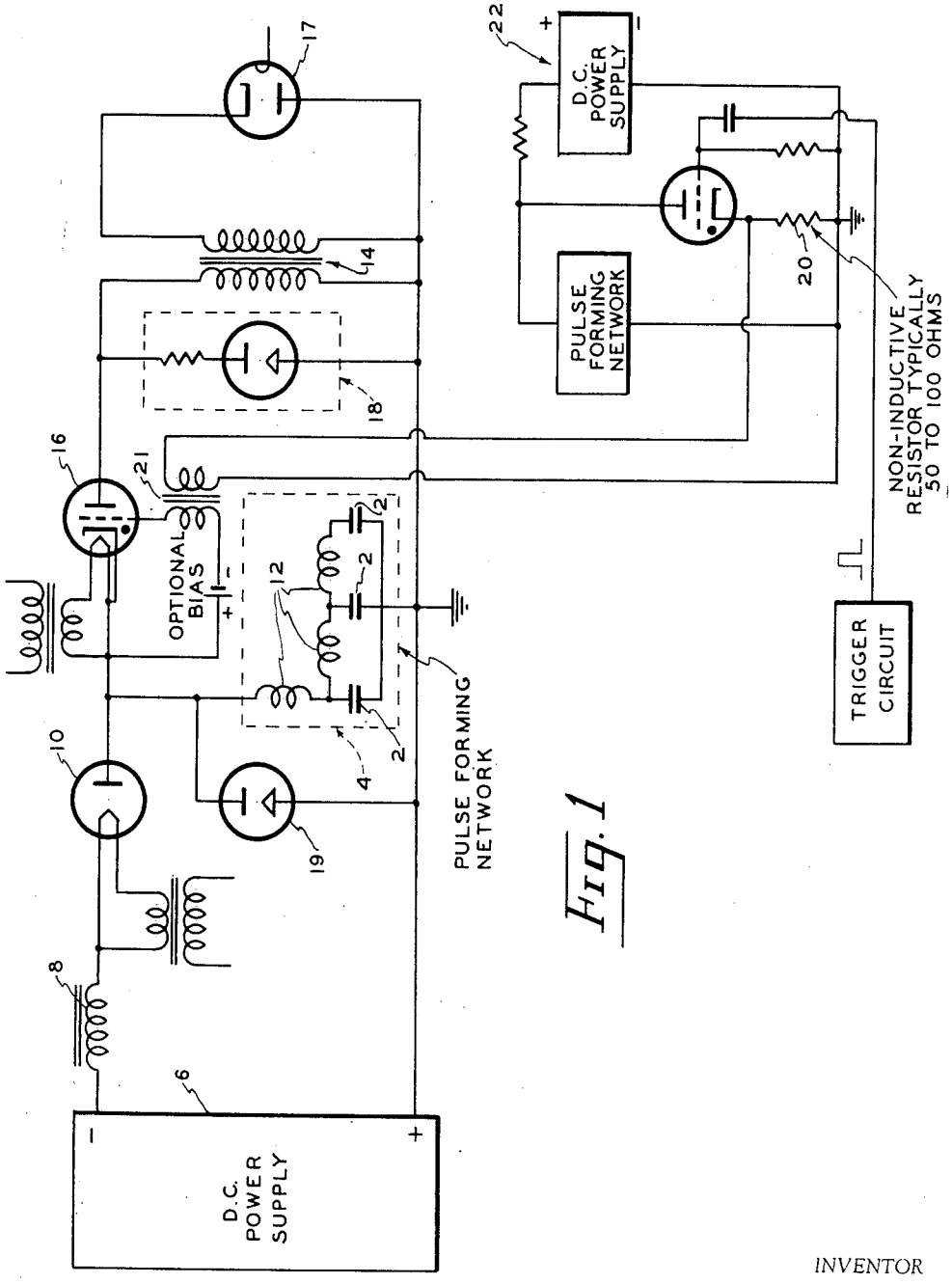


Fig. 1

INVENTOR
HERBERT J. HALL

BY Harold T. Stowell

ATTORNEY

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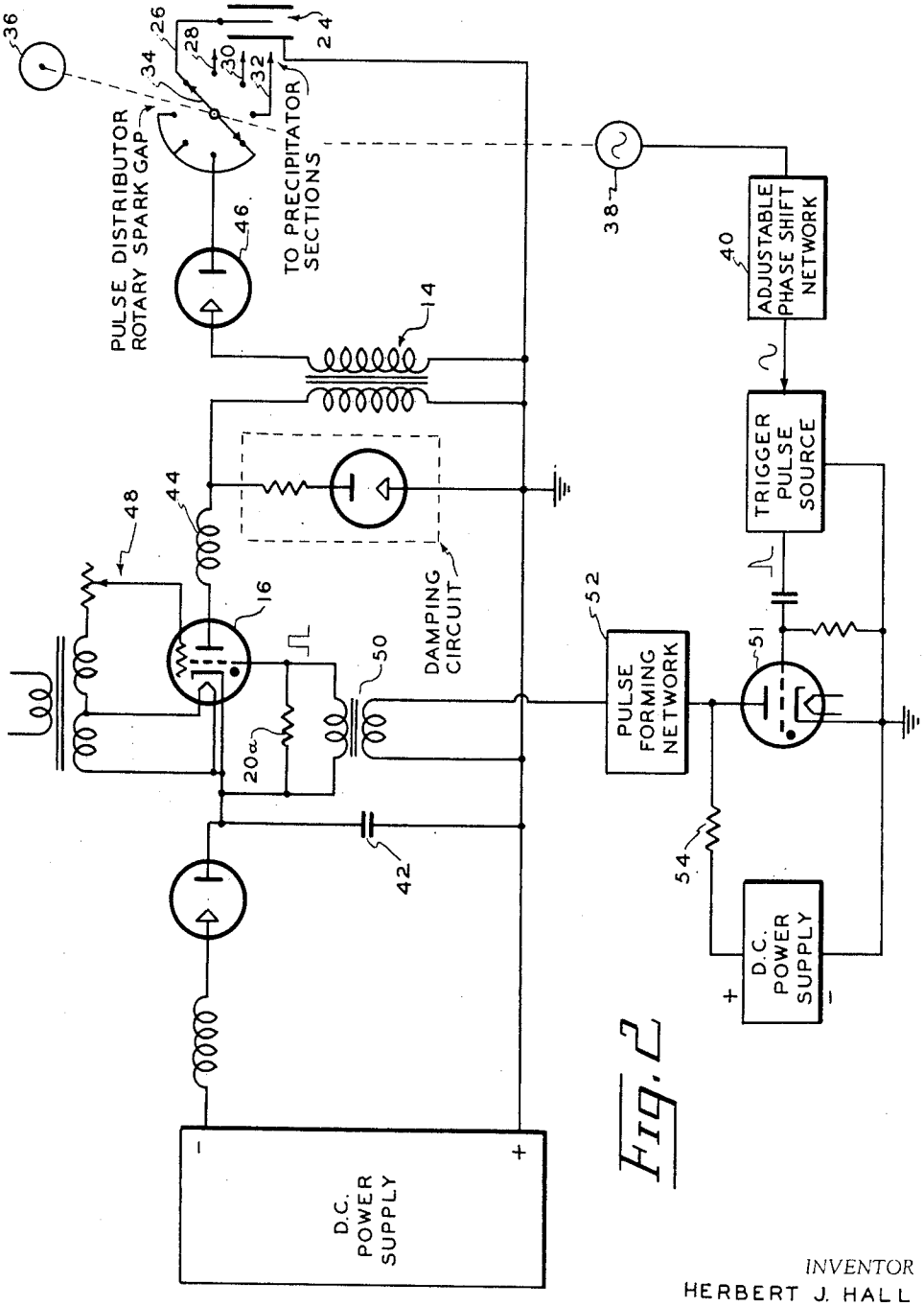


Fig. 2

INVENTOR
HERBERT J. HALL

BY Harold T. Stowell

ATTORNEY

United States Patent Office

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PULSER CIRCUIT

Herbert J. Hall, Hopewell Township, Mercer County, N. J., assignor to Research Corporation, New York, N. Y., a corporation of New York

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7 Claims. (Cl. 183—7)

This invention relates to electrical pulser circuits, wherein a load is energized by a succession of discrete increments of electrical energy separated by intervals of substantially greater duration than the duration of the increments of electrical energy. In particular, it relates to pulse circuits energizing a load wherein interelectrode sparking may occur during normal operation. Typical examples of such sparking loads are magnetrons and electrostatic precipitators. In order to obtain maximum power output from a magnetron, or maximum collection efficiency in an electrostatic precipitator, it is necessary to operate at the highest possible voltage which results in appreciable interelectrode sparking. It is a primary object of the invention to improve the operation of such circuits, particularly with reference to the above described sparking conditions.

To maintain stable operation and long tube life in pulse circuits of the type under consideration, disturbances caused by sparking in the load, by pulse transformer oscillations, or by stray capacitance circuit effects must either be eliminated or sufficiently attenuated. These circuit disturbances are relatively small and easy to control at low power levels but they rapidly increase in magnitude and design importance as the power level is raised. Certain of them are also aggravated with long pulse durations, for example, pulse durations greater than 50 microseconds in the type of circuit under consideration. An electrical precipitator for cleaning gases comprising spaced insulated electrodes between which the gases pass and across which a high voltage electrical discharge is maintained by periodically supplied increments of electrical energy to remove particles by electrostatic action, is subject to wide variations in load conditions. The mixtures of gas and suspended solid and/or liquid particles which are treated by the precipitator are very variable in physical, chemical, and electrical characteristics due to changes at the origin of the mixtures depending on the operating conditions in the furnace which produces the mixtures. The electrodes must also be periodically rapped to loose particles clinging to them which have been precipitated out of the gas, and the resulting falling material also greatly alters the nature of the gap or load between the electrodes. As a result, spark-overs frequently take place between the electrodes which temporarily short circuit the precipitator and initiate transients which, unless prevented from doing so, will travel back to the power supply circuit and cause difficulties of the type indicated above. A known system of the above type, together with certain means for minimizing some of the above described difficulties, is shown in U. S. Patent No. 2,509,548 to H. J. White. This patent shows the use of a rotary gap switch to provide the required periodic discharges. It has been found that greatly improved performance and stability may be obtained by using instead of such a gap switch, a high power hydrogen thyratron. The advantages of such use are applicable not only to precipitator circuits, but also to any circuit requiring high power load pulses, such, for example, as the commonly

employed magnetron circuits widely used in radar or similar pulse applications. However, as the power levels handled are increased, it is found that the sparking difficulties are also increased, to the point where the precautions which have sufficed for moderate power circuits are no longer adequate. As the power level increases, higher voltages employed require the use of large, oil-filled transformers and other components wherein it is more difficult to keep stray capacitances low.

According to the invention, an arrangement is provided wherein the pulse-forming network (or at least the capacitances associated with the pulse-forming network) may be isolated from the pulse transformer and the load circuit by placing the thyratron or other unidirectional switching device between it and the pulse transformer. In addition, all stray capacitances to ground associated with the charging circuit, thyratron filament transformer and grid-coupling transformer are so arranged as to add in parallel with the capacitance of the pulse-forming network and are thus discharged through the pulse transformer and not directly through the thyratron. Furthermore, the pulse transformer primary is isolated from the pulse-forming network charging circuit, at least in the direction of current flow in which damage could be done, and one side of the pulse-forming network is grounded. These features of the new circuit eliminate most of the disadvantages above recited, or minimize them to a point where they are no longer objectionable. It has been found that the maximum advantages of the circuit which will be described below are obtained when the thyratron grid circuit is provided with a very low impedance, in the order of between 50 and 100 ohms, as against 300 or more ohms usually employed. The use of this low grid circuit impedance has been found to simplify both tube and circuit design problems.

The specific nature of the invention, as well as other objects and advantages thereof, will clearly appear from a description of a preferred embodiment as shown in the accompanying drawings in which:

Fig. 1 is a schematic circuit diagram of the improved circuit applied to a generalized pulse load which is indicated by way of example as a magnetron; and

Fig. 2 shows a modification of the above circuit applied to the energization of several sections of a conventional electrical precipitator.

Referring to Fig. 1, condensers **2** of a pulse-forming network generally indicated at **4**, are charged to a suitable voltage from a D. C. power supply **6** through reactor **8** and a diode **10**. The energy thus stored is periodically discharged through inductances **12** and the primary of the pulse transformer **14** by means of the hydrogen thyratron **16**. The negative voltage pulse obtained is amplified by the pulse transformer and may be fed to a utilization device shown as a magnetron **17** connected across the secondary terminals. The shape of the pulse is controlled by the particular design of the pulse-forming network. The circuit is normally operated with a small post-pulse reverse voltage across the thyratron to assist in the deionization thereof, as is well understood. In the case of heretofore used circuits, if magnetron sparking should occur, a large reverse voltage appears across the condensers of the pulse-forming network and causes the charging voltage on the following pulse to rise considerably above its normal value. The use of a unidirectional shunting diode may serve to minimize this effect, if the operation is restricted to moderate power levels. However, at high power levels such as are contemplated in the present invention, this situation obviously results in unstable performance, producing a fluctuating output voltage which may perpetuate sparking, cause insulation overstresses in the circuit, and may cause the thyratron to go into continuous conduction

with complete cessation of normal operation. Moreover, in the prior art circuits, a number of stray capacitances, such as those of the various inductance elements to ground, must be discharged directly through the thyratron. This causes high peak currents and rapid rates of rise which may damage the thyratron. As the power level increases, higher voltages employed require the use of large, oil-filled transformers and other components wherein it is even more difficult to keep stray capacitances low. The improved circuit of Fig. 1 minimizes all of the above difficulties to the point where satisfactory operation is readily obtainable. It will be noted that the thyratron is now placed between the pulse-forming network and the pulse transformer, and the D. C. power supply is grounded on the positive side. One side of the pulse-forming network is accordingly now at ground potential and the other side is isolated against the previously described disturbances by the thyratron **16**. A conventional damping circuit is also shown at **18** to reduce the effect of reverse polarity pulses. A damping diode **19** may also be provided across network **4** if desired. All stray capacitances to ground associated with the charging circuit, thyratron filament transformer and grid-coupling transformer now add in parallel with the capacitance **2** of the pulse-forming network and are thus discharged through the pulse transformer and not directly through the thyratron. This circuit eliminates the major difficulties of the prior art circuits and permits stable operation at high power with sparking loads. Transient voltages due either to load sparking or normal pulse transformer oscillations are attenuated in the damping circuit **18** placed directly across the pulse transformer primary. Additional protection against such transients affecting the voltage across the network is obtained by the isolating properties of the thyratron. In order to obtain maximum effect of these isolating properties and to maintain stable operation, it has been found that the thyratron grid circuit must have a low impedance in the order of between 50 and 100 ohms. As in all pulse circuits, operation should be adjusted for some reverse voltage swing across the network, in this case, positive, to permit rapid deionization of the thyratron. A low grid circuit impedance is conveniently obtained from a conventional low power pulser **22** with a 50 ohm resistor load **20** in series with the thyratron cathode feeding a 1:1 isolating transformer **21**. It has also been found that the width of the grid triggering pulse should be kept to the minimum value required to fire the tube. The purpose of this requirement is to keep the deionization-time of the grid-cathode space to a minimum. Thus, the shorter the grid driving pulse with respect to the desired output pulse, the more time is available to permit deionization to occur. These factors are particularly important in high power operation.

The low impedance driver circuit for the thyratron is generally indicated at **22**, and contains no novel feature except for the low-resistance element **20**.

Fig. 2 shows the novel circuit of the invention applied to the energization of an electrical precipitator generally indicated at **24**. The central electrode of the precipitator is supplied by lead **26**. Similar leads **28**, **30**, and **32** supply similar sections of the same or adjacent precipitators, and are successively energized by rotary switch **34** which connects them in turn to the secondary of the pulse transformer **14**. The rotary switch is driven by any suitable motor **36**, which typically may be an alternating current motor running at 3600 R. P. M. A typical pulse repetition rate might be 480 per second distributed to the four sections shown. Motor **36** also drives a small alternator **38**, conveniently of the permanent magnet type, which, for the 480 cycle per second output above indicated, might be a 16-pole machine, or alternately a 240 cycle alternator having 8 poles could be used with a full-wave rectifier to supply the synchronizing voltage for a 480 per second pulse rate. The output alternator **38** is used to synchronize the driver circuit trigger pulse rate

so that thyratron **16** will be properly synchronized with the positions of the distributor switch **34**. The output of the alternator **38** is fed into a conventional adjustable phase shift network **40**, for proper adjustment of the overall system.

In Fig. 2 the pulse-forming network is simplified by reducing it to a pulse condenser **42** and an inductance **44** which now may be separated in the circuit as shown; this inductance, for example, may be the leakage inductance of the pulse transformer, thereby considerably simplifying the circuit while retaining the advantages of Fig. 1 by locating the pulse condenser **42** as shown. It may be noted again that, in the circuit of Figs. 1 and 2, the pulse condenser is charged directly from the D.-C. power supply and not through the primary of the pulse transformer as is common practice in conventional pulse circuits. In this way, post pulse oscillations of the transformer circuit cannot modulate the charging voltage waveform and thus cause unstable operation. A hold-off diode **46** is inserted, in accordance with known practice, between pulse transformer **14** and the distributor switch **34**. Since the high power hydrogen thyratron employed is of the type which usually has an internal hydrogen reservoir, and a heater, the circuit illustrates at **48** a suitable method of obtaining adjustable heater voltage therefor.

Grid-coupling pulse transformer **50** is shown with its primary connected in series with the trigger circuit pulse-forming network and the load resistor **20*a*** connected on the secondary side. The transformer is connected to supply a positive output pulse. Transformer **50** may conveniently have a 1:1 ratio, and **20*a*** is a non-inductive resistance of from 50 to 100 ohms. A driver circuit pulse-forming network **52**, supplied by low-power hydrogen thyratron **51**, may consist of a condenser and inductance in series, or any other well known circuit for this purpose may be used. The leakage inductance of the transformer **50**, with proper design, may be used as the series inductance in the driver circuit pulse-forming network, thus eliminating one component. The charging resistor **54** in the driver circuit may, if desired, be replaced by a linear charging choke to increase the electrical efficiency of the system. If this is done the charging choke inductance should preferably be designed for resonant charging with the capacitance in the pulse-forming network at the desired pulse repetition rate.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claims.

I claim:

1. A pulser circuit for loads subject to random sparking comprising a pulse transformer for supplying said load, a D. C. power supply, pulse forming circuit elements including capacitance means connected across and between the positive and the negative sides of said power supply so as to be charged thereby, a high-power thyratron having a control grid and being connected between the negative side to which said capacitance means is connected and one side of said pulse transformer the cathode of said thyratron being in said negative side, the positive side of said capacitance means and said pulse transformer being connected to a common ground, a trigger circuit for periodically biasing the grid of said thyratron to firing condition the grid circuit being of very low impedance.

2. The invention according to claim 1, wherein the common ground is the positive side of the D. C. power supply.

3. The invention according to claim 1 wherein the low-impedance circuit has an impedance value in the range between 50 and 100 ohms.

4. A pulse-charging system for energizing an electric precipitator comprising pulse-forming circuit elements including capacitor means, circuit elements including a series inductance means connecting a source of uni-

directional current across said capacitor means, pulsing circuit elements including a thyratron having a control grid and an inductance means connected in series across said capacitor means, said inductance means being supplied by the plate current of the thyratron the cathode of said thyratron and one side of said capacitor being associated with the negative side of said source of unidirectional current means for supplying periodic triggering pulses to the grid of said thyratron to periodically fire same, and circuit elements including a unidirectional current passing device connecting said pulsing circuit with complementary electrodes of a precipitator device.

5. The invention according to claim 4 including a low impedance input circuit between said means for supplying periodic triggering pulses and the thyratron grid, the impedance of the grid circuit being between 50 and 100 ohms.

6. The device according to claim 4 wherein the precipitator device comprises a number of similar precipitator sections, successive switching means for connecting said pulsing circuit in succession with each of said precipitator sections, an A. C. generator device driven in synchronism with the operation of said successive

switching means, phase shifting means supplied by the output of said generator, and an operative connection between said phase shifting means and said means for supplying periodic triggering pulses whereby the output of said last means is synchronized with the operation of said successive switching means.

7. The invention according to claim 6 wherein said successive switching means is a rotary switch, and a common driving motor for said rotary switch and said A. C. generator.

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