Dec. 24, 1957 W. E. KNIEL ET AL 2,817,774

APPARATUS FOR IMPROVING ELECTRICAL SWITCH CONTACT RELIABILITY

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Fig. 1.

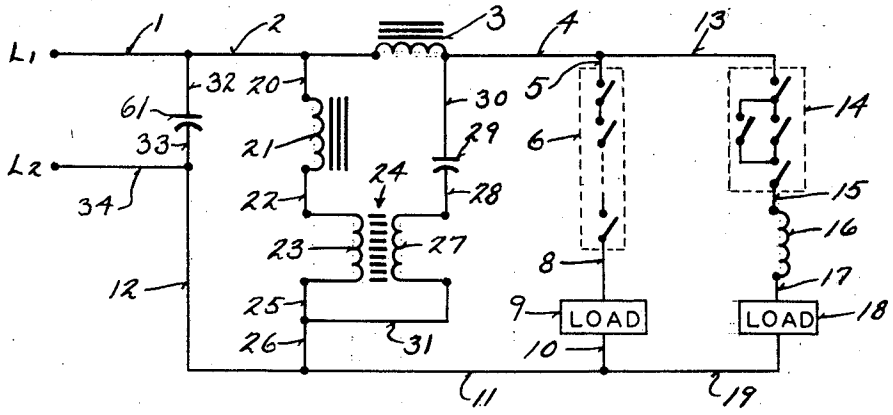


Fig. 2.

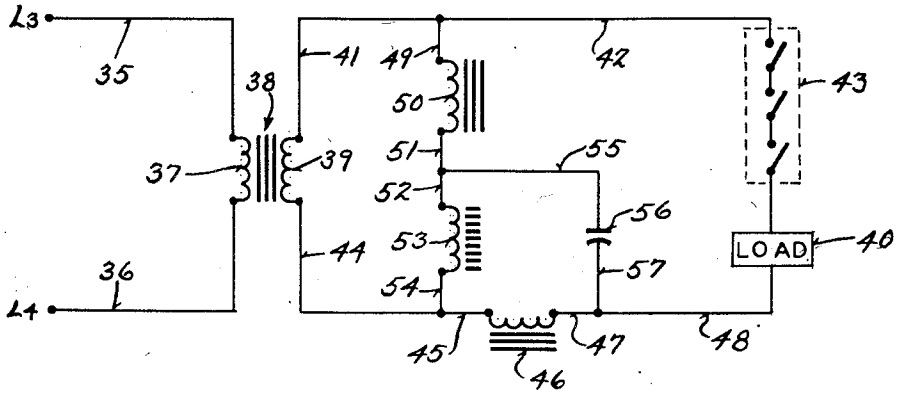
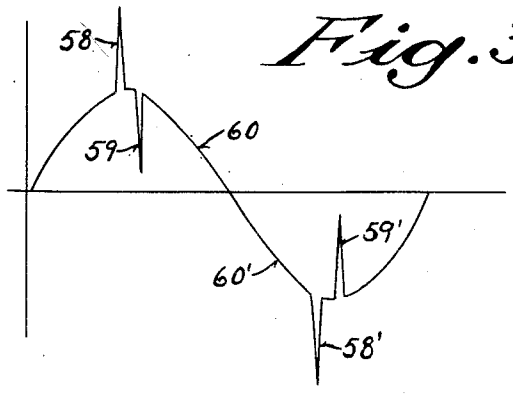


Fig. 3.



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APPARATUS FOR IMPROVING ELECTRICAL SWITCH CONTACT RELIABILITY

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4 Claims. (Cl. 307—137)

The invention relates to means for improving the reliability of electrical contacts to make or complete an electrical circuit when the electrical contacts are in the mechanically engaged position and where failure to make an electrical circuit is otherwise possible due to insulating corrosion products on the contact surfaces or adventitious presence of contact separating insulating substances. In certain electrical circuits controlled by switches the contacts sometimes fail to complete the circuit, even though they be urged toward engaged position. This appears to be due to films or particles of insulating or high resistance material interposed between the electrically conducting contact pieces.

Switches which are located in circuits where current carried is low and where voltages are moderate, such as so-called "control circuits" for power circuits, are among those which occasionally fail, due to this cause. This is particularly true where a plurality of switches are closed in series to complete a circuit, and the chance of a failure to make an electrical circuit is increased over a single contact because of the multiplicity of contacts in series where an insulating film or particle may prevent the establishment of an electrical circuit. In multiple function machines having control or pilot circuits for the actuating motors thereof, including a plurality of position or other conditioned sensing switches which close in series to provide a final executing control failure of one or several switches in the control circuit, has been experienced. This experience is not confined to apparatus exposed to dust or other unfavorable conditions, but is or appears to be aggravated thereby.

As the size, complexity and cost of multi-function machines have increased, the economic loss occasioned by unexpected stoppages has become a significant factor. Avoidance of the failure of one of a sequence of series connected control switches in such a machine is, therefore, much to be desired.

It is an object of this invention to provide an apparatus including an electrical circuit in which closure of a switch or a plurality of series and/or parallel connected switches is rendered more certain without modification of the switch per se and without increase of contact pressure thereof.

Another object is to provide an electrical apparatus which will impose a continuously repetitive impulsive electrical potential upon a switch controlled electrical circuit to increase the likelihood of effective completion thereof upon closure of a switch or switches contained, without impairing the switch capacity, without adversely affecting the primary function of the circuit and without entailing hazard to persons or equipment.

Another object of this invention is to provide circuit means which will increase the dependability of closure of a plurality of series connected switches and groups of such switches.

The foregoing and other objects and advantages of the apparatus of this invention will appear from the description following, in which reference is made to the accompanying drawing forming a part hereof, and in which

there is set forth by way of illustration and not of limitation forms in which the apparatus of the invention may be embodied.

In the drawing:

Fig. 1 is a circuit diagram of one form of the apparatus of this invention in which the circuits of both inductive and noninductive loads, controlled by switches, are rendered more certain of closure,

Fig. 2 is a circuit diagram of another form of the apparatus of this invention in a somewhat simpler form, and

Fig. 3 is a typified oscillographic representation of the impulsive character of the voltage produced in the load circuit prior to closure and across the contacts of the last to close of a switch in a group included in a circuit constructed in accordance with this invention.

In accordance with the invention there is placed across the switch or switches which are to be made more certain in their operation a rapidly repeating or recurring source of impulsive voltage. The impulsive voltage source is such that its voltage under open circuit conditions is high in relation to the normal operating voltage of the load controlled by the switches. The impulsive voltage source is arranged such that its voltage is additive to the normal switch operating voltage. Thus, upon attempted closure of a switch controlled circuit, if there be a minute insulating or poorly conducting gap between the contacts in one of the switches, which would normally cause a failure to make an electrical circuit, the high voltage of the impulsive source will exceed the breakdown voltage of the gap, after which the main circuit current will readily flow.

In the form of the apparatus of this invention illustrated in the circuit diagram set forth in Fig. 1, means for insuring closure of switches in several forms of control circuits are shown. In the apparatus shown, L1 and L2 are source terminals through which alternating current at commercial power frequency (say 60 cycles per second) is supplied. Terminal L1 is connected through leads 1 and 2 and impedance or choke 3 and leads 4 and 5 with a switch group 6 joined through lead 8 to a load 9 which is inductive in character such as the coil of an electromagnetically actuated switch or valve. Load 9 is connected, in turn, through leads 10 and 11 which join with lead 12 extending back to source terminal L2 through lead 34.

Lead 13 is shown conecting lead 4 to a switch group 14 containing three switches in series with one in parallel, but the number may be larger or smaller, and the arrangement different, as occasion may demand. The advantages of the invention will become more pronounced as the number of switches in the group is increased. In a typical instance, the switch group 6 may contain twenty to thirty or more contact pairs, as for example, in the circuits controlling the feed operations or the indexing of a milling machine with mechanized functions or a transfer line.

The other switch group 14 is connected through a lead 15 to inductive choke 16 and in turn through lead 17 to a noninductive load 18. The load 18 is joined, as shown, through lead 19 with the lead 11 and thence through lead 12 with the source terminal L2. Choke 16 is required when the load in noninductive for reasons to be explained.

Joined with lead 2 by lead 20 is a nonsaturable linear inductor 21 which is joined, in turn, by lead 22 with the primary winding 23 of a nonlinear saturable core transformer 24. Leads 25 and 26 connect the other terminal of the primary winding 23 of transformer 24 with leads 12 and 11. With substantially sinusoidal A. C. voltage supplied at commercial frequency at L1 and L2, the trans-

former 24 becomes a peaking or pulse transformer in which the peak pulse of voltage induced in the secondary winding 27 thereof may be made as high as desired by transformer action, but such induced voltage will be of an impulsive nature the pulses having been spaced to correspond with the impressed frequency at L1 and L2.

One terminal of the secondary 27 of transformer 24 is connected through lead 28 with capacitor 29 which is of a value low enough so that it will pass an insignficant flow of current at the applied commercial frequency through the transformer secondary. The capacitor 29 is connected, in turn, through lead 30 to lead 4. The other side of the transformer secondary 27 is connected through lead 31 to lead 26.

The switch group 6 in series with the load 9 has impressed upon it a voltage of the impressed frequency at L1 and L2 in series to an impulsive voltage delivered by the transformer 24 and feeding capacitor 29. The impulsive current is prevented from flowing back into the source of commercial frequency L1—L2 by the impedance or choke 3 which is designed to have a high value of impedance to the impulsive voltage developed in the transformer 24. It is assumed that the source of impressed frequency will have a low or negligible impedance to the impulsive voltage. If it does not, the high capacity capacitor 61 across the source of impressed voltage, L1 and L2, will furnish a low impedance path to such impulses. The capacitor 61 is connected to line 1 by lead 32 and to lead 34 by lead 33. It is further advantageous in most cases to include capacitor 61 to correct the lagging current drawn by the linear reactor 21 in series with the primary 23 of the transformer 24.

If a contact in the switch group 6 or 14 should fail to make an electrical circuit when all the contacts of the switch group are in the mechanically closed position, the impressed circuit voltage will appear across the defective contact, and in addition, the larger portion of the impulsive voltage developed by transformer 24, since, although the load 9 and the load 18 plus its reactance 16 have high impedance to this impulsive current, the impedance of the open contact will normally be much higher. Immediately the defective contact breaks down, due to the high voltages impressed across it, a current of the impressed frequency will then flow through the contacts and the load. Since the load 9 has a high impedance to the impulsive voltage, or such is introduced by the choke 16, the impulsive voltage will now appear across the load or the inserted inductive impedance 16.

Because of the high impedance of load 9 and 16 and 18, no substantial fall-off of the impulse voltage will take place, and the closing of either switch group 6 or 14 will not prevent the application of impulse voltage to the other switch group. This, of course, relies upon there being substantial impedance to the impulse voltage in each of the several load circuits.

The reactor 21 and the transformer 24 may be proportioned so that the pulse voltage occurs in the vicinity of the low frequency (60 cycle) current zero through the transformer, by causing the transformer core to saturate during the bulk of the low frequency current cycle. As the transformer becomes unsaturated near current zero, the drop at the linear reactor 21 will be transferred largely to the transformer. The voltage pulse thus coincides, or nearly so, with the maximum in the low frequency supply voltage.

Thus, the total voltage which is impressed across a contact, which has failed, is substantially the sum of the peak line voltage plus the voltage pulse which occurs at approximately the same instant. This results in a minimum pulse voltage being required, since if the insulating particle which prevents the proper contact operation is broken down by the pulse, the maximum low frequency voltage is available to develop the discharge into an arc and burn away the particle to form a metallic bridge or otherwise result in a good metallic contact.

In another related form the circuit of the invention may be constructed, as shown in Fig. 2. In this circuit the source terminals L3 and L4, providing alternating voltage at commercial frequency, say 60 cycles per second, are joined through leads 35 and 36 with the primary 37 of a control transformer 38 having a secondary 39 wound to deliver power at a suitable voltage, say 120 volts, to supply a load 40, such as the magnet coil of a line contactor switch.

One terminal of the secondary 39 is connected through leads 41 and 42 to switch group 43 which, in turn, joins with load 40 to control it. The other terminal of secondary 39 is joined through leads 44 and 45 with an inductive impedance or choke 46 joined, in turn, through leads 47 and 48 with load 40 to complete the load circuit.

Connected at the junction of leads 41 and 42 is a lead 49 which joins with one terminal of a nonsaturable linear inductive impedance or reactor 50, the opposite terminal of which is connected, as shown, by leads 51 and 52 with one terminal of a nonlinear saturable inductive impedance or reactor 53 which is wound to be saturated over all but a narrow phase angle close to current zero. The opposite terminal of the nonlinear reactor 53 is joined, in turn, by lead 54 with the junction between leads 44 and 45. A lead 55 joined with the junction between leads 51 and 52 connects with small capacity capacitor 56 which is connected, in turn, through lead 57 to the junction between leads 47 and 48.

In operation the circuit of Fig. 2 may be described by noting that the sinusoidal voltage of transformer 38, impressed across reactors 50 and 53, is approximately 90 degrees out of phase with the current drawn by this or by any other inductive load. The voltage drop across reactor 53, however, is substantial only for the brief interval, near current zero, at which this reactor is not saturated. This voltage drop rises suddenly and after a short, sustained interval falls suddenly and is applied across capacitor 56 so that there is a sudden pulse of charging current followed by an equal pulse of discharge current. These currents being carried in the circuit including well dampened choke 46 causes two pulses of voltage of opposite polarity to appear across the choke 46 and these pulses occur at approximately the peak of the voltage applied to the inductive load 40.

In Fig. 3 appears an illustrative graph of the pulse character of the voltage shown rising at 58—58′ and falling at 59—59′. It will be noted that the pulses 58—58′ become superimposed upon the lower frequency load source voltage 60—60′ at or near the peak thereof. Thus the total maximum voltage which is impressed across a putatively closed contact pair, which would otherwise be destined not to complete the circuit, is the sum of the peak line voltage plus the voltage pulse which occurs at approximately the same moment. Clearance of a substantial contact barrier is the result.

The effectiveness of the circuits of this invention may be made apparent by reference to an illustrative instance, where it was found that multiple switches would close and complete the circuit intended with greatly increased reliability where the improvement of this invention was employed. A so-called control circuit was arranged to supply alternating current at about 115 volts and 60 cycle frequency to the electromagnet of a line contactor switch through a group of switches joined in series. A pulse voltage was superimposed as above described. The contact conditioning action of the apparatus was such that a layer of cigarette paper placed between the contacts of one of the switches was not sufficient to prevent closure of the circuit. Actual perforation of the paper and establishment of contact through the perforation was effected repeatedly as often as the paper was reinserted or moved. With the pulse circuit elements disconnected, the control current

circuit was completely disabled by the interposition of the paper.

While the introduction of paper between contacts is an artificial means demonstrating the effectiveness of the apparatus of the invention, the likelihood of separation of the contacts by adventitious insulating material having a breakdown potential exceeding that of the paper is almost nil in any reasonably protected switch. Means for effectively overcoming the failure of a plurality of series switches, repeatedly closed, which has, heretofore, presented a serious problem, where a high level of dependability in a complex control circuit is required, is thus shown to be provided by the apparatus of this invention.

The effectiveness of the circuit of this invention depends upon the peak pulse potential superimposed rather than upon the duration or RMS value of the same. A voltage high enough to greatly increase the probability that closure failure will be avoided may be resorted to without hazard to human safety if the pulses are very brief and are intermittent rather than continuously repeated. While continuous direct current voltages or continuous low frequency voltages, as low as 20 volts or even lower, can, under certain circumstances, be fatal, very sharply peaked pulses of high equivalent frequency, but comparatively widely spaced, have been found to be entirely harmless at considerably higher voltages. The voltage produced by the circuit of this invention, although high, is within limits of safety because of its spaced pulse character, as may be observed in Fig. 3. The phase angles of the low frequency voltage over which the individual pulses occur may be seen to be less than 5% of a half cycle of the low frequency, while the entire disturbance 58—59 occupies less than 10% of a half cycle. Such very widely spaced, sharply peaked pulses are harmless at voltages ample to clear the contacts.

Because the pulses are sharply peaked their equivalent frequency is high and, on this account, the impedance thereto of the inductive reactance of an ordinary magnet coil of a line contactor switch, or of a relay or magnetically actuated valve, etc., is high. As a consequence, a plurality of circuits in parallel controlled by their several switch groups may be protected by a single source of peaked control current provided the source is not impaired by the loading which occurs upon closure of one of the switch groups. In the circuit of this invention, loading, due to closure of an inductively reactive load circuit, does not substantially impair the peaked character of the control current source.

Hazard to control equipment supplied from a source constructed in accordance with this invention is also nil since such equipment is usually constructed to standards such that its insulation will withstand 600 to 1000 volts or more. This is adequate to withstand the peak voltages which we employ.

We claim:

1. In a switch controlled load circuit a source of alternating load current of low frequency, a switch set and a load in series; a linear impedance and a nonlinear inductive impedance in series connected in shunt relation to said source, said nonlinear impedance having a pulse winding and a magnetic core saturated by said source save for a minor fraction of the alternating current cycle thereof during intervals near minimum current during which intervals there is created spaced peaked high equivalent frequency voltage impulses across said winding; a choke in series in said load circuit having an inductive impedance high with respect to said voltage pulse equivalent frequency and low with respect to said load current frequency; and a pulse circuit responsive to said voltage pulses across said pulse winding including a capacitive impedance high with respect to said load current frequency and low with respect to said pulse equivalent frequency, said pulse circuit being joined to said load circuit so as to include said choke in said pulse circuit, thereby superimposing said pulse voltage on said load current voltage.

2. A circuit in accordance with claim 1 wherein the linear impedance is an inductive impedance whereby the pulse voltage occurs substantially coincident with peak load current voltage.

3. A circuit in accordance with claim 1 wherein one end of the pulse circuit is connected between the linear and nonlinear impedances and its opposite end through its capacitor to junction with the load circuit, and the choke is disposed between the said junction with the load circuit and the nonlinear reactor.

4. A circuit in accordance with claim 1 wherein the pulse circuit includes a secondary transformer winding in transformer relation to the winding of the nonlinear impedance.

No references cited.