Sept. 1, 1964 E. L. LUEHRING 3,147,356

CIRCUITS FOR SWITCHES HAVING SERIES CONNECTED INTERRUPTER SECTIONS

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FIG-1

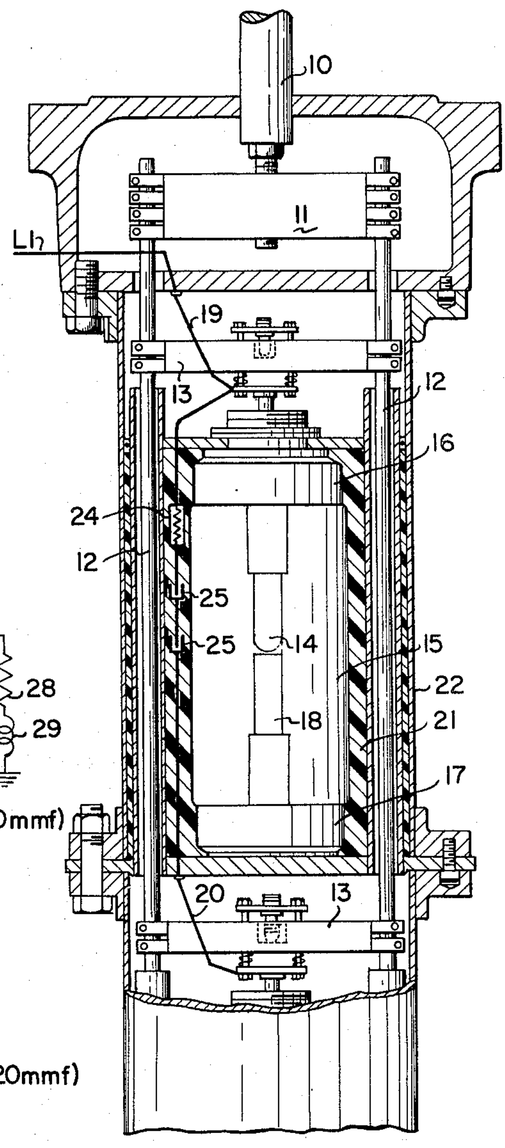
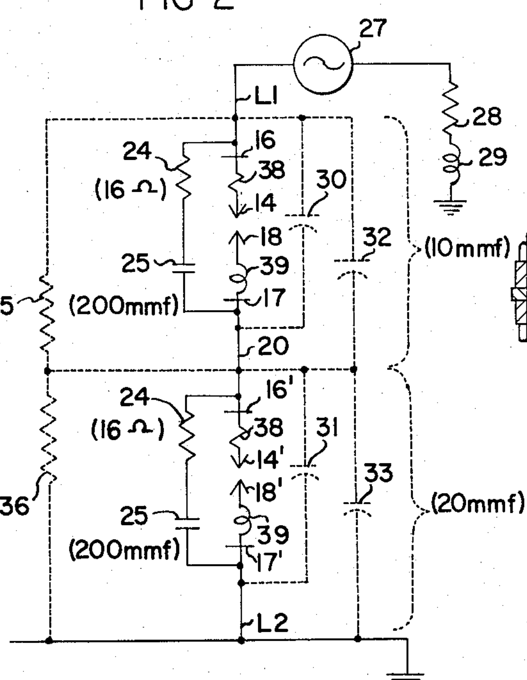


FIG-2



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CIRCUITS FOR SWITCHES HAVING SERIES CONNECTED INTERRUPTER SECTIONS

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The present invention relates to high voltage switches and has particular significance in connection with high voltage power line switching apparatus having series connected interrupters each of the type enclosed in vacuum or immersed in a fluid other than air.

As already explained in U.S. Patents 2,915,611 and 2,955,181, the voltages, and charging and interrupting currents, of present day transmission lines, transformers and capacitors, have been so large that as many as eight vacuum interrupters are arranged mechanically to operate together while electrically in series. In connection with such apparatus a difficulty in the past has been inability of the interrupters to divide the total voltage equally between them. Also the series arrangement of interrupters has caused transient overvoltages whereby the recovery voltage of one switch may be many times the voltage applied to all. For these reasons the individual interrupters had had to have such a high voltage rating that the total cost of a complete installation has been incompatible with the economics of modern practices, and even so any one of the interrupters is apt to be subject to ruinous arcing and damage.

It is an object of the present invention to provide simple and inexpensive means for overcoming the above mentioned difficulties.

Another object is to provide for series connected interrupters means which will afford linear voltage distribution thereover.

Other objects and advantages will become apparent and the invention may be better understood from consideration of the following description taken in connection with the accompanying drawing, in which:

FIG. 1 is a side view in part section showing a modular incapsulated vacuum interrupter provided with circuitry according to the invention and attached to the top of a like unit below and to tandem interrupter operation mechanism above;

FIG. 2 is a simplified schematic diagram provided for the purpose of explaining the operation of the present invention.

Although but one interrupter unit is shown in its entirety in FIG. 1, it should be understood that a number of like units are arranged to be mechanically operated in tandem. When an initial signal is sent by some means (not shown) to actuate a top mounted apparatus which may comprise a toggle (not shown herein but one example of which is illustrated and described in the above mentioned Patent 2,955,181) this operates a main pull rod **10**, draw bar **11**, insulating material operating rods **12**, and cross bars **13** which are provided, one for each unit, to eventually operate a mobile contact rod **14** of the respective interrupter. Each of the interrupter units may comprise a vacuumized glass envelope **15** having metal end caps **16**, **17**. The movable contact rod **14** is electrically attached as through a metallic bellows with end cap **16** and cooperates with a stationary contact rod **18** which is electrically in circuit with the end cap **17**. The movable contact **14** is in circuit with a flexible electrical connection shown diagrammatically at **19** which, in turn, is in circuit with an outside line indicated diagrammatically as L1, while the bottom cap **17** of the unit shown in section is connected through the flexible connection **20** to be in circuit with the movable rod **14'** of the next interrupter below, and so on. Each interrupter need not necessarily be of vacuum type since the enclosed contacts might be immersed in an inert gas or in a liquid such as oil, and each of the originally enclosed interrupters may be separately incapsulated in its own somewhat resilient material permanent shockproof container comprising a cellular foam **21** extending around the envelope and within an annular housing **22** as described and claimed in Patent 2,915,611.

In accordance with the illustrated embodiment of the present invention, see FIG. 2, each contact pair **14–18**, **14'–18'** is deliberately provided with a shunt circuit comprising a series arranged resistor **24** and capacitor **25** (FIG. 2) or capacitors (FIG. 1).

FIG. 2, for simplicity, shows only a single pair of interrupters (**14–18** and **14'–18'**) but the principles are equally applicable in cases where there are more than two such switch sections in series. As shown, a high voltage source **27** feeds line L1 and in turn the series connection of the interrupters cooperable with a return line L2 to supply a load as indicated diagrammatically at **28**, **29**.

Forgetting for the moment the effect of the provided resistors **24** and capacitors **25** there is inherently, as shown in dotted lines, a capacitance **30** between the end caps **16**, **17**, which capacitance has one value when the contacts are open and another when the contacts are closed, and there is an inherent capacitance **31** between the end caps **16'**, **17'** of the other interrupter. These are stray capacitances dependent in large measure on the dimension of the end caps and parts of associate potential, and there are other stray capacitances as illustrated at **32** and **33** and between the end caps and ground which, of course, presents a very large surface which is closest to the lowermost end caps. Inherent also are leakage resistances, as indicated at **35** representing the resistance between the terminals of the top switch, and at **36** for the resistance between the top terminal of the bottom switch and over the insulation to ground.

In the past it has been found almost impossible to calculate the effect of these leakage resistances and capacitances, because the capacitive reactance is one thing at 60 cycles and quite another when lightning strikes so that there are very high frequency components (up to 2 megacycles) and the capacitance predominates. But supposing that the sum total of the paralleled capacitance of **30** and **32** is 10×10^{-12} farads (10 mmf.) and, because so much closer to ground, the total of the leakage capacitance about switch **14'**, **18'** and to ground is 20×10^{-12} farads. Then there is 100% difference between the two values, and, there is going to be a much greater voltage across one unit than across the other and, because it is difficult to make all the interrupters operate at precisely the same moment, the situation is made even worse if one of the set of contacts **14–18** happens to be open, while the other is closed or arcing.

I have found that it is not enough to simply place one capacitor (**25**) across each set of interrupter contacts to introduce such a dominant influence that each such switch has a voltage across itself less dependent on the inherent characteristics of the switch, its distance from ground, and the operative state of the switch (whether open or closed, arcing or not). That is, it is not enough to just use capacitors (**25**) each, say of 200 mmf., placed across one interrupter pair on the theory that then the **16–17** total capacitance becomes 210 mmf. while the **16'–17'** total capacitance is only 220 mmf., a difference of less than 5% rather than the prior 100%.

The present invention has its basis in part on the realization that the straight contact stems have not only an inherent resistance (**38** in FIG. 2) but also an inherent inductance (symbolized at **39** in FIG. 2) so that regardless of whether or not capacitance (such as **25**) is added (to the inherent capacitance), for each interrupter a tank circuit is set up which achieves resonance at a certain frequency which not only causes radio noise but causes the voltage across the particular switch contacts to often rise to a value higher than the total voltage applied across all the switches in series. This will cause a deleterious spark over, around the outside of the enclosing bottle even if the switch is closed, or open and carrying current through an arc.

For some particular switches used, which switches were equipped with 12" diameter end caps, and cylindrical electrode type contacts 1" in diameter (0.785 sq. in. in contact area) with a ¼" spacing between electrodes when open, and which were 18" length overall (from outer end of one cap to outer end of the other), even with added shunt capacitors (**25** but without **24**) selected at 200 mmf. the resonant frequency for the tank circuit was about 30×10^6 cycles per sec., while 0.7 of the voltage at resonance was found at two frequencies differing by 1.5×10^6 cycles.

As is well known these frequencies become "f_0" and "f_1-f_2" in the equation for Q, or Figure of Merit, where

$$Q=\frac{f_0}{f_1-f_2}=\frac{30}{1.5}=20$$

From such a Q it is possible to obtain a desirable value for a series resistor (**24**) once the need thereof is recognized.

It should be noted that there were resonant circuits even before any swamping capacitor (**25**) was introduced. But the important thing is recognition of the fact that there are resonant circuits, that they permit of the calculation of a "Q" and, therefore, of the calculation of desired series resistance for a swamping capacitor in order to damp out resonance effects, or in other words to lower the Q. For some applications it has been found that desirable results are achieved when each interrupter has in shunt about its contacts the series circuit of a capacitor **25** of 200 mmf. and a resistor **24** of 16 ohms, for this lowers the Q, cuts radio noise, and prevents flashovers, by making the voltage distribution across each switch less dependent upon its inherent characteristics, distance from ground, and whether the switch is open or closed.

Instead of the single 16 ohm resistance **24** and single capacitance as illustrated in FIG. 2 for any one interrupter, it may be desirable to use, for example, for each interrupter three shunt circuits each having one resistance of 48 ohms and in series therewith an appropriate portion of the swamping capacitance.

It may be that the higher the frequency the less the relative effect of the leakage resistance, but nevertheless, even with lightning strokes, intentional introduction of both capacitance and resistance, together in series with each other and in shunt across the interrupter contacts of each pair, lowers the Q, and cuts down on overvoltage across any one interrupter while even for 60 cycles the voltage is fairly evenly divided, for example, 51% and 49%, instead of the prior 66% and 33%. This gives better voltage distribution between interrupters and allows the recovery voltage of each one to be substantially less than the voltage applied to all. As one interrupter stops arcing, its recovery voltage (that is the voltage trying to re-establish the arc) becomes a function of the circuit parameters of a desired circuit instead of a function of the parameters of an undesired tank circuit, open circuit voltages are more nearly evenly divided, and undesirable closed circuit overvoltages are avoided.

While I have illustrated and described a particular embodiment, various modifications may obviously be made without departing from the true spirit and scope of the invention which is intended to be defined only by the accompanying claims taken with all reasonable equivalents.

I claim:

1. In switch mechanism of the type having plural series connected interrupter contact pairs, a plurality of voltage dividing capacitors at least equal in number to the number of contact pairs and respectively arranged in shunt around the various contact pairs and provided additional to the inherent stray capacitance of the respective contact pairs, and plural resistors at least equal in number to the number of contact pairs and provided additional to inherent leakage resistance and respectively arranged at least one separately and permanently in series with each unit of voltage dividing capacitors with each such resistance capacitance circuit in sunt around a respective contact pair.

2. The combination of claim 1 further characterized by the resistors having ohmic values selected to lower the Q of each capacitor and contact pair circuit when the contacts of the respective pair are closed.

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