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ELECTRIC CIRCUIT

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Fig. 1.

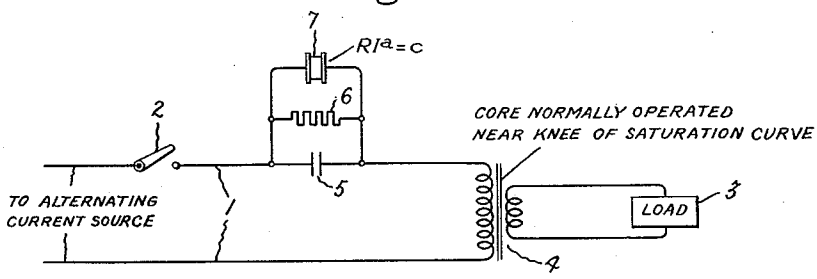
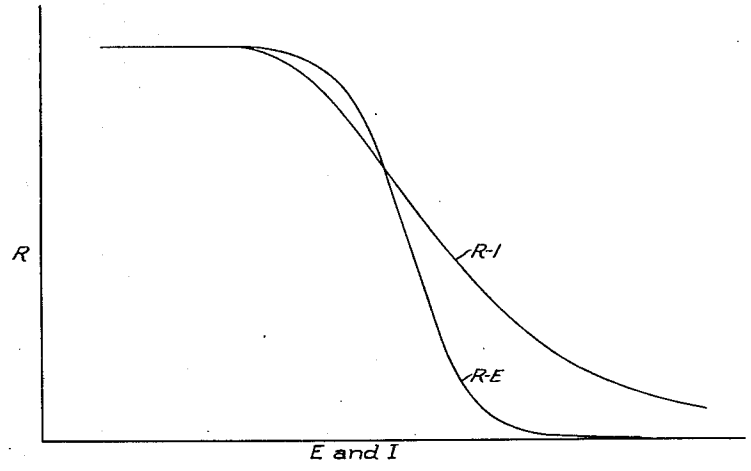


Fig. 2



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ELECTRIC CIRCUIT

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3 Claims. (Cl. 172—238)

This invention relates to electric circuits and more particularly to improvements in non-linear impedance networks.

In the present assignee's Buell Patent 2,120,855 there is described a system wherein a linear resistor which is connected across a series capacitor prevents the occurrence or continuance of abnormal magnetizing currents in a transformer which is excited through the series capacitor. Such abnormal currents arise by reason of a charge which the direct current component of the transformer inrush magnetizing current places on the capacitor, and the resistor serves to dissipate this charge. As shown in the patents, there is a maximum value of this resistance for any particular circuit above which suppression of the abnormal exciting currents will not occur. Obviously, it is desirable that this resistance not be substantially below this maximum value in order to prevent unnecessary losses in the circuit. However, when such a relatively high resistance is used overload or short circuit currents in the circuit produce objectionable voltage stresses in the capacitor so that additional protective equipment is necessary for effectively short circuiting the capacitor when short circuit conditions are such as to produce these overvoltages.

If the resistor reduces its resistance to a low enough value quickly enough in response to capacitor overvoltages the additional protective equipment could be eliminated. There is a negative resistance-current characteristic resistance material which is fast enough for this purpose. It is used in lightning arresters and is described and claimed in McEachron Patent 1,822,742 which is assigned to the assignee of the present application. The resistance characteristic of that material is defined by the equation $RI^a=C$ where R is its instantaneous resistance in ohms, I is its instantaneous current in amperes, a is an exponent the value of which depends upon the controls used in the manufacture of the material and which is typically slightly below unity, and C is a constant the value of which is determined by the physical dimensions of the material. The curve of this equation resembles a hyperbola, so that for very low values of current in the neighborhood of zero current the resistance is very large, it being theoretically infinite at zero current, and for currents of very high value the resistance falls to a very low value. Unfortunately, such a resistance characteristic is not suitable for the prevention of abnormal magnetizing currents because of the relatively large change in resistance which would occur throughout the normal variation in load current from no-load to full-load. Thus, if a choice were made which would adequately prevent abnormal exciting currents during no-load, then on full-load the resistor would have an excessive loss. If a reasonable value of resistance is chosen based on normal load operation the abnormal exciting current conditions could persist for an appreciable and objectionable length of time on no-load or light-load.

In accordance with this invention these difficulties are eliminated by combining a linear resistor and a non-linear resistor of the above type, the two being connected in parallel with each other. Under all conditions such a combination presents a maximum resistance low enough to avoid abnormal magnetizing current troubles while presenting a high enough resistance during normal load currents to prevent excessive losses and presenting a relatively low resistance when currents in the main circuit become excessive.

An object of the invention is to provide a new and improved electric circuit.

Another object of the invention is to provide a new and improved non-linear resistance control circuit.

A further object of the invention is to provide a new and improved impedance network.

The invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing Fig. 1 illustrates diagrammatically an embodiment of the invention and Fig. 2 shows the resistance-current and resistance-voltage characteristics of the non-linear network shown in Fig. 1.

Referring now to Fig. 1, there is shown therein an alternating-current circuit 1 the source end of which is connected to any suitable source of alternating current through a switch 2 and the load end of which is connected to a load 3 through a transformer 4 of conventional construction; that is to say, it has a magnetic core which is normally operated near the knee of its saturation curve. Connected in the circuit 1 is a series capacitor 5 the purpose of which is to neutralize some of the inductance of circuit 1.

In order to suppress abnormal frequency and magnitude exciting currents for the transformer 4 and also in order to protect the capacitor 5 against the effects of excessive currents in the circuit 1 there is effectively connected in shunt circuit relation therewith a resistance network

comprising a linear resistor 6 and a non-linear resistor 7, the two being connected in parallel with each other. By "linear resistor" is meant a conventional resistor whose resistance value is substantially constant throughout the normal range of currents which flow through it and the normal range of voltages which are impressed across it. The non-linear resistor 7 is preferably of the type described and claimed in the above-mentioned McEachron patent and it has a negative resistance-current characteristics in the sense that its resistance varies inversely with the current.

As the combined resistance of the two resistors 6 and 7 can never be greater than the lower valued resistor, it will be seen that at zero current in the circuit 1 corresponding to zero voltage across the capacitor 5 and the resistance network the effective resistance of the combination will be substantially the resistance of the resistor 6 even though the resistance of the resistor 7 has an infinitely high value. This value of resistance for resistor 6 is so chosen that at no-load on the circuit any abnormal magnetizing currents in the transformer 4 resulting from operation of the switch 2 or voltage surges on the circuit will be suppressed. The constants of the resistance characteristic of resistor 7 are so chosen that throughout the normal range of currents in circuit 1 the resistance of resistor 7 will still be substantially higher than the resistance of resistor 6 so that throughout the normal range of load currents the losses in the network are held to a relatively low value. However, upon the occurrence of excessive currents, such as overloads or short circuit currents of the order of ten times full-load current, the resistance of resistor 7 will substantially instantaneously drop to a value which is very much lower than that of resistor 6 so that, in effect, the capacitor 5 will be virtually short circuited, thus preventing injury to the capacitor by reason of excessive voltage stresses occurring therein.

In Fig. 2 there are shown resistance-voltage and resistance-current characteristics of a typical network of the type shown in Fig. 1. As will be seen from this figure, the resistance stays at a relatively very high and relatively constant value over the lower range of voltages and currents beyond which the resistance falls off relatively rapidly until finally at relatively very high values of voltage and current the resistance approaches zero as a limit. Thus, over the initial range of small currents the linear resistor determines the characteristic of the network, whereas over the higher range of currents and voltages the non-linear resistor determines the characteristics of the network, whereas between the low and the high ranges both resistors play a substantial part in shaping the characteristic curve of the network.

It should be understood that while the novel non-linear resistance network has been described in connection with a series capacitor, it is in no wise limited to such use and this novel network can be used in any electrical circuit or system where the type of characteristic shown in Fig. 2 will prove of value. Although the capacitor 5 has been shown as directly connected in the circuit, it should be understood that in practice this capacitor will usually be made up of a series-parallel connection of relatively small-size capacitor units and this series-parallel connection may either be connected directly in the circuit or it may be connected therein indirectly by means of a series transformer.

While there has been shown and described, a particular embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States, is:

1. In combination, a substantially instantaneously-acting non-linear resistor having a maximum resistance at zero current which is so high that said resistor is substantially an insulator, said resistor having a minimum resistance at high values of current which is so low as to constitute a virtual short circuit between its terminals, and means for substantially reducing the effective maximum resistance of said non-linear resistor without materially changing the effective value of its minimum resistance comprising a linear resistor connected in parallel therewith.

2. In combination, an alternating-current circuit for conducting power from a source to a load, a series capacitor connected in said circuit, a saturable core reactance connected across said circuit on the load side of said capacitor, a linear resistor connected across said capacitor for suppressing abnormal exciting currents in said reactance, and a negative resistance-current characteristic resistor connected across said capacitor for protecting it from overvoltages.

3. In combination, an alternating-current circuit for conducting power from a source to a load, a transformer connected between said circuit and said load, a series capacitor connected in said circuit between said source and said transformer, a linear resistor connected across said capacitor for suppressing abnormal exciting currents in said transformer, and a non-linear resistor connected across said capacitor for protecting it from over voltages, said non-linear resistor having a characteristic expressed by the equation $RI^{a}=C$ where R is the instantaneous value of its resistance in ohms, I is the instantaneous value of its current in amperes and a and C are constants.

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