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NON-LINEAR END-OF-LINE CLIPPER CIRCUIT FOR PULSERS

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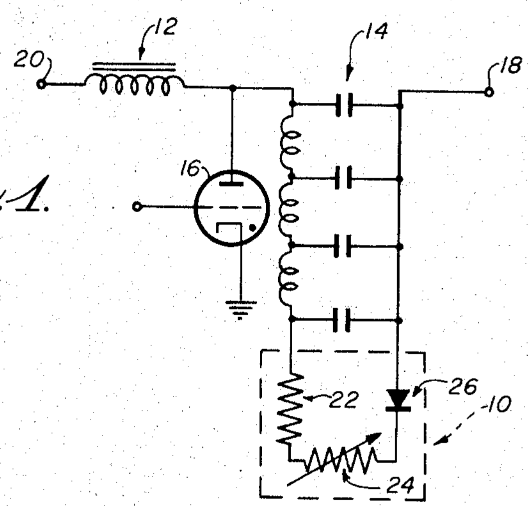
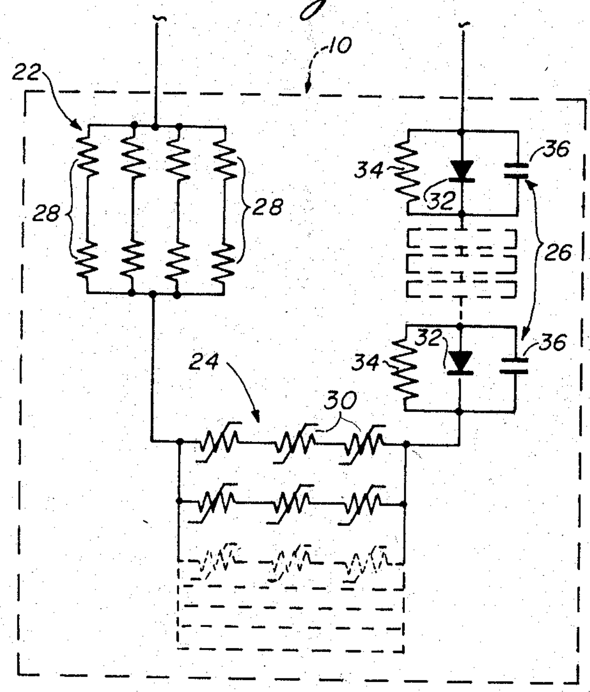


Fig. 1.

Fig. 2.



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NON-LINEAR END-OF-LINE CLIPPER CIRCUIT FOR PULSERS

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The present invention relates generally to a non-linear end-of-line clipper circuit for protecting a line-type pulser against load arcs which are commonly experienced when pulsing loads such as klystrons or magnetrons.

It is well known in the design of line-type pulser circuits commonly utilized in pulsing arc susceptible loads such as klystrons or magnetrons that faults can and readily do occur in the load. For example, some reverse voltage is required on a pulse-forming network, following the pulse, to shut off the gas or solid state type switch tube which is normally used to trigger the pulse into the load, in preparation for the next pulse-forming network cycle. However, if the load arcs or otherwise faults the pulse forming network is over-discharged, causing its voltage to nearly fully reverse. This full reverse voltage appearing at the anode of the switch tube of the pulser immediately after a conductive cycle is quite often destructive to the switch tube. In addition, if this full inverse voltage is removed, it should be done in as short a time as possible as compared with the half-cycle of oscillation of the charging reactor and the capacitance of the pulse-forming network, or the pulse-forming network will seriously overcharge. Overcharging of the pulse-forming network causes excessive load voltage and promotes repetitious arcing of the load with cumulative voltage buildup on the pulse-forming network in successive charging cycles until eventual circuit failure occurs.

There are prior art circuits available which utilize a combination of a "shunt-diode" and a series resistor connected thereto, to drain the pulse-forming network and thus remove the reverse voltage on the pulse-forming network due to load arcing. In circuits heretofore designed with relatively slow acting shunt diode circuitry, the charging reactor is still overstressed for a significant period of time following load arcing. Furthermore, full inverse voltage still appears at the anode of the switch tube promptly following each load arc with probable shortening of the life of such a switch tube.

An additional prior art circuit with improved protection for pulser circuitry consists of a very low impedance diode and series resistor matching the pulse-forming network and connected at the end thereof remote from the switch tube. With such an end-of-line clipper circuit a load arc at the switch tube end causes the pulse-forming network energy to be delivered to the clipper resistor without appearance of high inverse voltage at the switch tube end. The charging inductor is not overstressed. If the switch tube shuts off, the next charging cycle is entirely normal. In the past, gas diodes have been utilized in the circuit as the very low impedance diode, but inherent delay in achieving requisite ionization has tempered their effectiveness in short time pulse work. Pretriggered thyratrons have also been utilized in the circuit, but require complicated and expensive associated circuitry in order to operate successfully.

The recent availability of reliable low-impedance silicon diode assemblies have made this type of end-of-line clipper advantageous. However, performance is hampered because some inverse voltage is necessary on the pulse-forming network following a normal pulse as well as following a pulsed load arc in order to shut off the switch tube. A matched end-of-line clipper causes serious deionization or switch shut-off problems by too promptly removing or preventing the appearance of inverse voltage on the pulse-forming network. This is particularly true when utilizing inductive deionization control.

The present invention overcomes the above-mentioned shortcomings of various prior art protective circuits by providing an end-of-line clipper circuit capable of preventing the appearance of high inverse voltage at the anode of the switch tube therein following a load arc, while allowing stable deionization of the switch tube even under load arc and other drastic fault conditions.

Accordingly, it is an object of the present invention to provide an end-of-line clipper circuit for use with line-type pulsers wherein the clipper circuit utilizes a serially connected non-linear resistor.

It is another object of the present invention to provide a non-linear end-of-line clipper circuit capable of preventing the appearance of undesired high inverse voltage at the anode of the switch tube in a line-type pulser following a load arc.

Still another object of the present invention is to provide a non-linear end-of-line clipper circuit capable of rapidly draining the stored energy from the pulse-forming network of a line-type pulser except for that energy necessary to cause switch tube deionization.

Yet another object of the present invention is to provide a non-linear end-of-line clipper circuit capable of protecting a line-type pulser against load arcs while further preventing overstressing of the charging inductor following load arcing.

Other objects and advantages will be apparent in the following description and claims considered together with the accompanying drawing, in which;

FIGURE 1 is a schematic diagram exemplifying the mechanism of the present invention, as utilized in conjunction with a conventional line-type pulser circuit; and

FIGURE 2 is a schematic diagram depicting, in detail, the circuit of FIGURE 1.

Referring more particularly to FIG. 1, there is shown a non-linear end-of-line clipper circuit **10** in accordance with the invention, as utilized in a conventional line-type pulser herein exemplified as a charging inductor **12**, a pulse-forming network (PFN) **14** and gas switch tube **16**. The PFN **14** is coupled to a load such as for example, a klystron or magnetron (not shown) by means of an output terminal **18** with the other terminal of the load being connected to ground. The PFN **14** includes a tapped inductive element with capacitors having one side connected at top, input and output terminals of said inductive element and the other side connected to a common point. The PFN **14** is charged through the reactor **12** by a suitable D.C. power supply (not shown) which is connected to one end of the inductive element of the pulser by means of an input terminal **20**. At such time as the PFN **14** is charged, triggering of the gas switch tube **16** provides a closed current path through ground by which the PFN **14** is discharged into the load.

The end-of-line clipper circuit **10** in accordance with the invention comprises linear resistor means **22**, non-linear thyrite resistor means **24** and silicon diode assembly means **26**, serially connected together. The free end of linear resistor means **22** such as a common fixed resistor is connected to one side, i.e., the second end of the inductive element of the pulse-forming network **14**, and the free end of the silicon diode assembly means **26** is connected to the common point of connection of the capacitors of the pulse-forming network **14**, i.e., on the side thereof opposite the side connected to the inductive portion. The clipper circuit **10** assembly is therefore connected in parallel across the last capacitive element of PFN **14**. The positive or anode electrode of the silicon diode assembly means **26** is connected to the PFN **14**, and the negative or cathode electrode is connected to the non-linear thyrite resistor means **24**.

In operation, for very high pulse currents which are generated by load arcing, the thyrite resistor means **24** has a value less than the impedance of the pulse-forming network **14**. Thus the resistor means **22** is effectively inserted to supplement the resistor means **24**, to provide accurate matching. However, when the circuit elements are chosen to deliberately leave very low inverse voltages on the pulse-forming network **14** to cause shut-off of the gas switch tube **16**, the resistance of the thyrite resistor means **24** is much higher than the impedance of the pulse-forming network **14**. Hence the inverse voltage present remains on the pulse-forming network a sufficient period to enable the gas switch tube **16** to cease conducting.

If the total resistance of thyrite resistor means **24** and resistor means **2** exceeds the impedance of the PFN **14** by an order of magnitude, there is the possibility that switch **16** will arc back due to inverse voltage, and the behavior of the PFN **14** energy may cause failure of the silicon diode assembly means **26** due to reversal of its voltage immediately following conduction. Accordingly, an optimum safe design for the end-of-line clipper circuit elements is satisfactorily chosen where the sum of the resistances of the thyrite resistor **24** and the resistor **22** means under load arc conditions is close to the impedance of the pulse-forming network **14** at the lowest voltage operating level, and where the resistance of the thyrite resistor means **24** is much greater than the impedance of the pulse-forming network **14** for the level of inverse voltage necessary to deionize the gas tube **16**. Such action is satisfactorily achieved by choosing a value for resistor means **22** of the order of one-half the pulse-forming network impedance, and by adjusting the resistor means **24** to a value of the order of one-half the pulse-forming network impedance, at the lowest load arc current level.

Referring to FIG. 2 there is shown, in greater detail, the circuit of FIG. 1, including examples of the specific values and types of elements hereinbefore generally described. More particularly, linear resistor means **22** comprises for example a plurality of 10 ohm, 200 watt resistors **28** disposed two in series, with four of such serially connected resistors connected in parallel. The non-linear thyrite resistor means **24** is formed of, for example, 24 six inch diameter thyrite resistors **30** of the silicon carbide type such as General Electric's No. 69W60100, wherein the resistors **30** are disposed three in series, with eight of such serially connected resistors connected in parallel. The thyrite resistors are chosen from the wide range of such resistors available, i.e., having a thyrite current characteristic of the form $i=kv_n$, where i is the current through the resistor, v is the applied voltage, k is the conductivity of the unit in amperes at 1 volt applied, and n is a constant depending on the resistor material composition. Values of n thyrite resistors applicable with the invention may be chosen within the range of from 3 to 8. It is to be understood that although the invention is herein described utilizing thyrite resistors as the non-linear resistor means **24**, there are other devices available which may be substituted therefor, e.g. Western Electric Company's silicon carbide varistors, Globar Type BNR voltage sensitive resistors, etc. The silicon diode assembly means **26** is formed of 150 serially connected diodes **32**, for example of the type 1N1196A, wherein each of the diodes has connected thereacross, in parallel electrical relation therewith, a 510,000 ohm 1 watt resistor **34**, and a 0.01 microfarad 1 kilovolt capacitor **36**. Each diode **32** is shunted with a resistor **34** and a capacitor **36** to insure equal voltage division for each of the serially connected plurality of diodes **32**. The charging voltage applied to the pulse forming networks **14** is of the order of 40 to 42 kilovolts for the circuit parameters of above mention.

While the invention has been disclosed with respect to a preferred embodiment, it will be apparent to those skilled in the art that numerous variations and modifications may be made within the spirit and scope of the invention and it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. A non-linear end-of-line clipper circuit for protecting against load arcs a line-type pulser having a pulse-forming network comprising: resistor means coupled at one end thereof to the output end of one side of said pulse-forming network; said resistor means including a linear resistor serially connected to a variable non-linear thyrite resistor; low impedance diode assembly means including an anode and a cathode electrode, wherein said cathode is connected to the second end of said resistor means, and said anode is connected to the output end of the other side of said pulse-forming network, whereby said resistor means and said diode means are serially connected together in parallel relation across said pulse-forming network.

2. The non-linear end-of-line clipper circuit in accordance with claim **1** wherein said diode means comprises a silicon diode assembly of relatively low impedance.

3. The non-linear end-of-line clipper circuit in accordance with claim **2** wherein the resistances of said linear resistor and of said thyrite resistor are each made equal to approximately one-half the impedance of the pulse-forming network at the lowest load arc current level.

4. The non-linear end-of-line clipper circuit in accordance with claim **2** wherein said silicon diode assembly further comprises a silicon diode, a resistor connected in parallel relation across said silicon diode, and a capacitor connected in parallel relation across said silicon diode.

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