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(71) Applicant *(for all designated States except US)*: **ISRAEL ELECTRIC CORPORATION** [IL/IL]; P.O.B. 10, 31000 Haifa (IL).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **GUREVICH, Vladimir** [IL/IL]; 8/8 Ha'Eshchar Street, 35844 Haifa (IL). **SHKOLNIK, Anatoly** [IL/IL]; 123/4 Akko Road, 26411 Kiryat Motzkin (IL).

(74) Agents: **LUZZATTO, Kfir** et al.; P.O. Box 5352, 84152 Beer Sheva (IL).

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(54) **Title:** OPEN CIRCUIT IN SECONDARY WINDING PROTECTION FOR CURRENT TRANSFORMERS

(57) Abstract: Apparatus for continuously protecting current transformers from hazardous voltages due to open circuit in a secondary winding, which comprises solid state non-linear elements with voltage dependent conductivity, connected in parallel to the secondary winding output terminal of said current transformer. The conducting voltage of said solid state non-linear elements is configured to be more than the maximal operating voltage of the secondary winding and less than a hazardous voltage. A normally-open thermo-bimetal switch is placed with good thermal contact on the solid state non-linear elements. The operating temperature (switching ON) of the thermo-bimetal switch is configured to be more than the maximal ambient temperature at the relevant location, and the resetting temperature (switching OFF) of the thermo-bimetal switch is configured to be less than the minimal ambient temperature.

OPEN CIRCUIT IN SECONDARY WINDING PROTECTION FOR CURRENT TRANSFORMERS

Field of the Invention

The present invention relates to the protection of current transformers. Particularly, the invention relates to an apparatus which protects the current transformer from hazardous voltages due to an open circuit in a secondary winding.

Background of the Invention

In typical current transformers (CT), a 5 or 1 A current passes through the load of a meter or a protective relays apparatus which is connected to the CT's secondary winding at full primary current. The typical load input impedance of a meter or a protective relays apparatus which is connected to the CT's secondary winding is of the order of one to twenty Ohm. Therefore, the voltage on the CT's secondary winding is low under normal circumstances. Consequently, only low power and quite safe voltages are used in CT's secondary winding.

Nevertheless, if a secondary winding circuit of a CT becomes open due to secondary circuit failure or to any other reason, no load exists on the secondary winding circuit. As a result, the current transformer behaves like a current supply connected to a high impedance load (open circuit).

Consequently, a typical current transformer (i.e. with nominal power of 50 to 300 VA) in open secondary circuit condition produces extremely high and non-sinusoidal voltages. Those high voltages can be several hundreds or several thousands of volts in magnitude (i.e. peak value).

Therefore, if a human being closes the circuit with his body, a fatal charge of energy will be delivered to him. Another hazardous phenomena occurring due to high voltages across an open secondary circuit in CT is sparks and partial discharge that is generated in the CT. Consequently, a high hydrogen concentration is generated in the CT's oil. The high hydrogen concentration in the oil can result in the explosion of the current transformer.

The hazards presented by such situations of high voltages across an open secondary circuit in CT, are well known phenomena. It is important to prevent the accidental occurrence of lethal high voltages under all circumstances. Thus, metering and relays installations often incorporate elaborate protection arrangements designed to prevent an open circuit condition arising on the CT. Short-circuit of the CT winding can be done before disconnecting the meter or relay. This protects personnel as well as the winding of the transformer itself from destructive high voltages.

An elaborate protection device which is designed for an open circuit condition arising on the CT, usually employs a voltage-dependent resistor, which conducts current when the voltage across the secondary winding of the CT rises above the level of some tens of volts. However such circuits have suffered from the drawbacks of dissipative power of the order of tens of watts, and from being heated dramatically. Therefore, such protection devices have usually employed cumbersome and expensive cooling apparatus, such as large heat sinks.

GB 2183049 as well as the SLIMLINE SP-100 series current monitoring devices, produces by RHOMBERG (Australia), contain CT protection circuits. The abovementioned protection circuits consist of arrangements of semiconductors configured to conduct current at voltages below that which would be hazardous, but not to conduct at all at normal operating voltages. Such arrangements of semiconductors are positioned across the CT's output. Thus, a "short-circuit" is switched across the CT secondary winding when the CT secondary circuit "opens", protecting the CT and personnel from destructive and hazardous high voltages. However, if the current developed on the CT's secondary circuit is more than 2 to 3 A, which is the normal current level in a CT's secondary circuit, the semiconductors arrangements mentioned above will be dangerously heated. Therefore, there is a need for cumbersome and expensive cooling apparatuses, such as big heat sinks.

It is an object of the present invention to provide an improved apparatus that protects the secondary winding of a CT from hazardous voltages in case of an open secondary circuit of said CT.

This and other purposes and objects of the invention will become apparent from the description to follow.

Summary of the Invention

The present invention relates to an apparatus for continuously protecting current transformers from hazardous voltages due to open circuit in secondary winding, comprising: (a): two or more solid state non-linear elements with voltage dependent conductivity, connected in parallel to the secondary winding output terminal of the current transformer, wherein the conducting voltage of said solid state non-linear elements is configured to be more than the maximal operating voltage of the secondary winding and less than a hazardous voltage; and (b) first normally-open thermo-bimetal switch placed with good thermal contact on the solid state non-linear elements, the operating temperature (switching ON) of said first thermo-bimetal switch being configured to be more than the maximal ambient temperature at the relevant location, and the resetting temperature (switching OFF) of the first thermo-bimetal switch being configured to be less than the minimal ambient temperature. Alternatively, a thermo-bimetal switch without auto-resetting (auto switching OFF) is provided. The abovementioned thermo-bimetal switch may comprise manual resetting or latching (i.e. without resetting).

Preferably, the apparatus further comprises an additional alarm circuitry comprising an additional, second thermo-bimetal switch mounted with good thermal contact on the secondary side of the solid state non-linear elements. The operating temperature (switching ON) of said second thermo-bimetal switch being configured to be more than said maximal ambient temperature, and less than the operating temperature (switching ON) of said first thermo-bimetal switch.

Preferably, the solid state non-linear elements with voltage-dependent conductivity are two inversely connected diodes (i.e. dual diode) with a common cutoff electrode wherein the breakdown voltage of the p-n-junction of the dual diode is configured to be more than the maximal operating voltage of the current transformer secondary winding and less than the hazardous voltage.

Brief Description of the Drawings

In the drawings:

Fig. 1 is a block-diagram showing the current transformer protection device, according to a preferred embodiment of the present invention; and

Fig. 2 is a circuit diagram showing the current transformer protection device comprising an alarm, according to another preferred embodiment of the present invention.

Detailed Description of Preferred Embodiments

In order to prevent the occurrence of hazardous voltages due to abnormal open circuit in the current transformer's secondary winding, an economical and continuous protection device that facilitates solid state non-linear elements with voltage dependent conductivity, connected in parallel to the current transformer's secondary winding together with normally open thermo-switch, is described hereinafter with reference to Figs. 1 and 2.

The advantages and benefits of this invention will be described with reference to an illustrative example of a circuit consisting of arrangements of solid state non-linear elements with voltage depending conductivity connected in parallel to a secondary winding, together with normally open thermo-bimetal switches. The abovementioned arrangements of solid state non-linear elements are configured to conduct current at voltages below that which would be hazardous, but not to conduct at all at normal operating voltages. The operating temperature of the normally-open thermo-bimetal switch (switching ON) is configured to be more than the maximal ambient temperature, and the resetting temperature (switching OFF) is configured to be less than the minimal ambient temperature, for a given location.

The protection device may further comprise, if desired, an alarm circuitry configured to warn an operator about the occurrence of hazardous voltages due to abnormal open circuit in the current transformer's secondary winding. An additional thermo-bimetal switch is mounted with good thermal contact on the secondary side of the abovementioned solid state, non-linear elements. The operating temperature of the additional thermo-bimetal switch is configured to be more than the ambient temperature and less than the operating temperature of the first mentioned thermo-bimetal switch.

Turning now to the figures, Fig. 1 is a circuit diagram showing the current transformer protection device, according to a preferred embodiment of the present invention. The circuit diagram shows the complete circuit of the protection device 101 used in parallel with secondary winding output terminal of current transformer 106 and load meter 107. Alternatively, protection device 101 might be used in parallel with secondary winding output terminal of current transformer 106 and any protective relay, whenever the current transformer is to be used for fulfilling the aim of relay protection and not for metering purpose. The protection device 101 comprises a dual diode (two inversely connected diodes) 103 with cutoff common electrode, connected in parallel to secondary winding 105, together with normally-open thermo-bimetal switch 102. The breakdown voltage of the p-n-junction of the abovementioned dual diode 103 must be more than the maximal operating voltage normally generated at the secondary winding 105, and less than a voltage that would be hazardous. The operating temperature of the normally-open thermo-bimetal switch 102 (switching ON) is configured to be more than the maximal ambient temperature, and the resetting temperature (switching OFF) is configured to be less than the minimal ambient temperature for a given location. Furthermore, the thermo-bimetal switch 102 is placed with good thermal contact on dual diode 103.

In a first experiment of the abovementioned current transformer, a 170 kV insulation class with ratio of 1200:5 A was delivered with primary current of 1000 A through its primary winding (bar) 104. When the secondary circuit was opened, a 3800V voltage, at peak, was measured at the secondary winding 105.

A second experiment was executed with the same current transformer comprising protection device 101 connected to the secondary winding terminals. When the secondary circuit was opened, high voltage of 3800V was applied apply from secondary winding 105 to dual diode 103. Consequently, the diodes (i.e. maximum blocking voltage of 50V for the meter diode or maximum blocking voltage of 200V for the protective relay diode) instantly broke down and started heating intensively. The resistance of the diodes in such condition is very low (i.e. 1 to 3 Ohm). Therefore, the voltage across the secondary circuit dropped instantly from 1380V to 5V. Within 2 to 3 seconds the thermo-bimetal switch 102 was heated from diode 103 up to its peak up temperature and shorts diode 103 with the secondary winding 105. Thermo-bimetal switch 102 remained switched ON for a long period of time until it was chilled out with air at -10$°C$ (or until manual reset, when using a latching thermo-bimetal switch).

Fig. 2 is a circuit diagram showing the current transformer protection device comprising an alarm, according to another preferred embodiment of the invention. In this variant the protection device contains two thermo-bimetal switches 102 and 203, which are placed with good thermal contact on both sides of dual diode 103. The thermo-bimetal switch 203 turns ON alarm device 205, thus, activating the alarm before the thermo-bimetal switch 102 is activated.

Although embodiments of the present invention have been described by way of illustration, it will be understood that the invention may be carried out with many variations, modifications, and adaptations, without departing from its spirit or exceeding the scope of the claims.

Claims:

1. An apparatus for continuously protecting current transformers from hazardous voltages due to open circuit in a secondary winding, comprising:

   a. Two or more solid state non-linear elements with voltage dependent conductivity, connected in parallel to the secondary winding output terminal of said current transformer, wherein the conducting voltage of said solid state non-linear elements is configured to be more than the maximal operating voltage of the secondary winding and less than a hazardous voltage; and

   b. a first normally-open thermo-bimetal switch placed with good thermal contact on said solid state non-linear elements, the operating temperature (switching ON) of said first thermo-bimetal switch being configured to be more than the maximal ambient temperature at the relevant location, and the resetting temperature (switching OFF) of said first thermo-bimetal switch being configured to be less than said minimal ambient temperature.

2. The apparatus of claim 1 comprising additional alarm circuitry comprising an additional second thermo-bimetal switch mounted with good thermal contact on the secondary side of the solid state non-linear elements, the operating temperature (switching ON) of said second thermo-

bimetal switch being configured to be more than the maximal ambient temperature, and less than the operating temperature (switching ON) of the first thermo-bimetal switch.

3. The apparatus of claim 1 or 2, wherein the thermo-bimetal switches comprise manual resetting (manual switching OFF).

4. The apparatus of claim 1 or 2, wherein the thermo-bimetal switches can be accomplished without resetting (i.e. accomplished as latching).

5. The apparatus of claim 1 or 2, wherein the solid state non-linear elements with voltage dependent conductivity are two inversely connected diodes (dual diode) with a common cutoff electrode.

6. The apparatus of claim 5, wherein the breakdown voltage of the p-n-junction of the dual diode is configured to be more than the maximal operating voltage of the current transformer secondary winding and less than the hazardous voltage.

7. Apparatus for continuously protecting current transformers from hazardous voltages, essentially as described and illustrated.

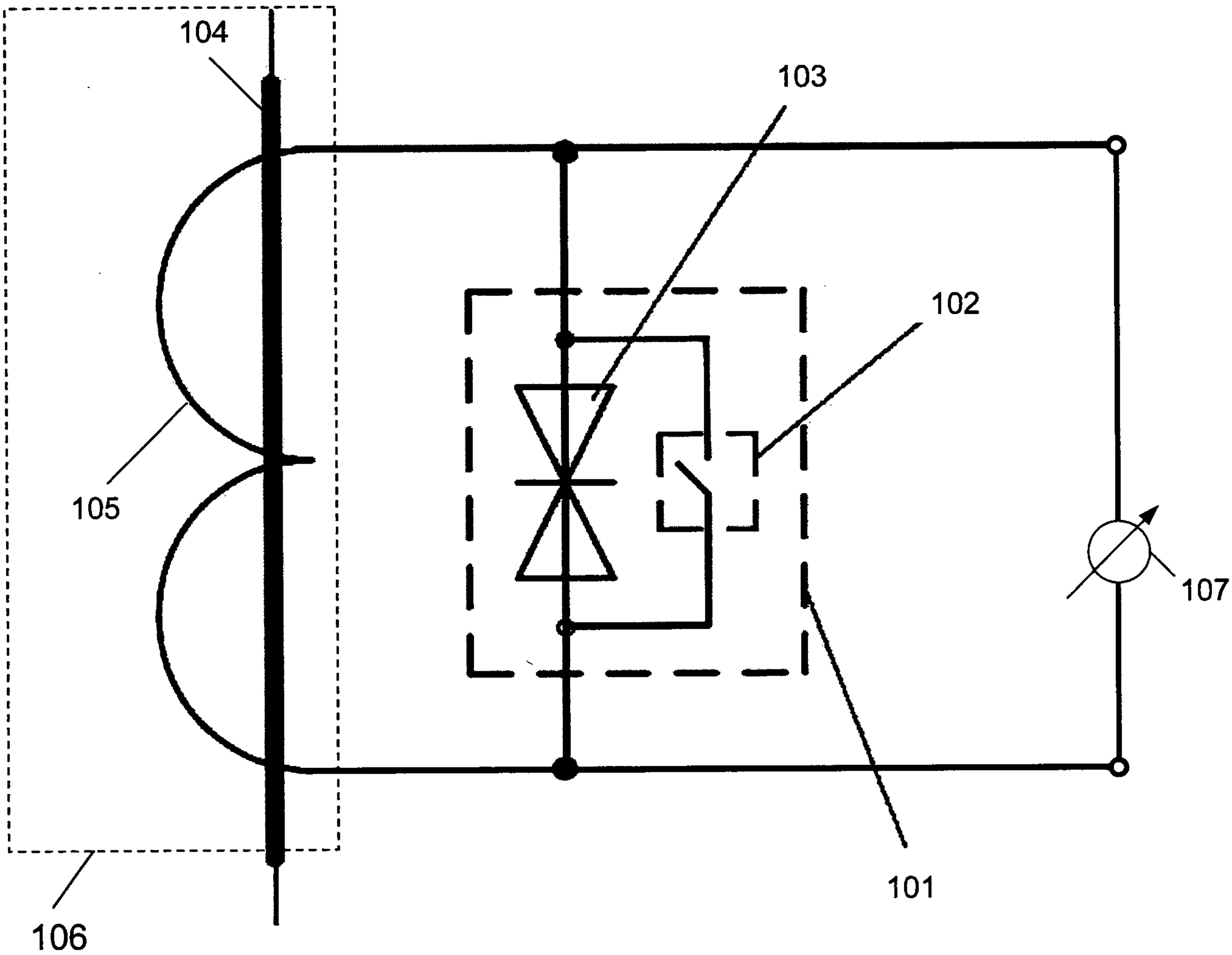

Fig. 1

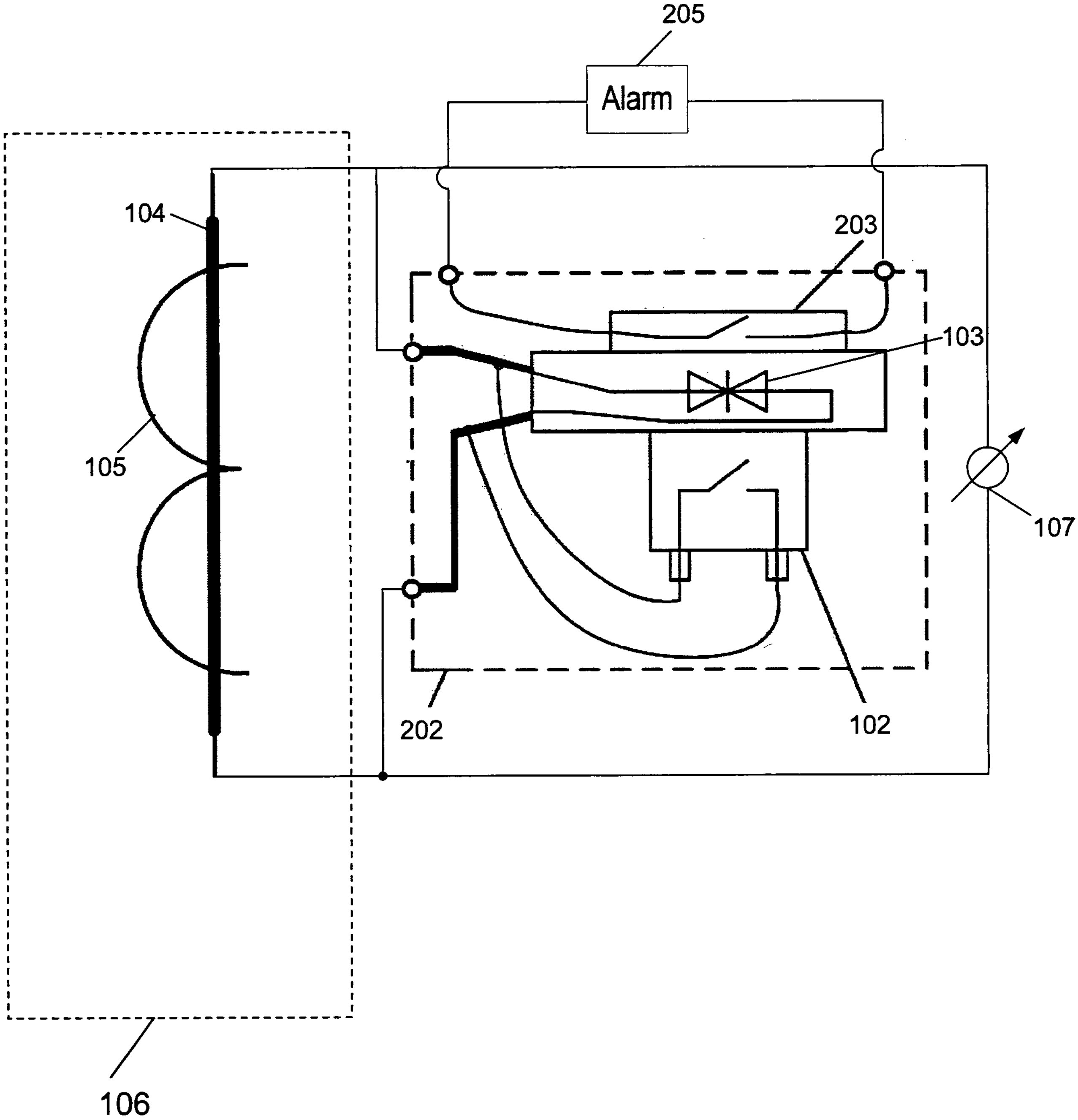

Fig. 2