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SERIES K: PROTECTION AGAINST INTERFERENCE

Self-restoring overcurrent protectors

ITU-T Recommendation K.30

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Self-restoring overcurrent protectors

Summary

Current-limiting protective devices are used worldwide to limit currents conducted by telecommunications wiring during high voltage faults on nearby power lines, due to electric traction systems, and from low voltage mains power contacts.

This Recommendation provides performance requirements for positive temperature coefficient (PTC) thermistors and contains information on coordination and application of self-restoring overcurrent protectors. These overcurrent protectors may be used inside the equipment to enable compliance with the requirements of the resistibility ITU-T Recs K.20, K.21 and K.45.

A PTC thermistor is mainly intended to limit overcurrents of relatively long duration and will normally have too slow a response time for switching transients or surges caused by lightning discharges, while semiconductor self-restoring overcurrent protectors (see Appendix II) have a faster response time than the PTC and will also operate for short duration surges.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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Self-restoring overcurrent protectors

1 Foreword

Current-limiting protective devices have been used worldwide to limit currents conducted by telecommunications wiring during faults from nearby power lines and electric traction systems. These devices are non-resetting, typically heat coils or fuses, placed at the Main Distribution Frame (MDF), at the subscriber network interface or inside communication equipment. Current-limiting devices, positive temperature coefficient (PTC) thermistors, which are self-restoring, have been introduced and are now in use in a variety of applications worldwide. These devices are based on resistors with positive temperature coefficient. This Recommendation presents performance parameters for PTC thermistors. A new generation of self-restoring overcurrent protectors using semiconductor technology are described in Appendix II.

2 Introduction

The purpose of this Recommendation is to provide performance requirements for PTC thermistors to ensure their satisfactory operation in telecommunication networks. This Recommendation also covers coordination of these devices fitted in the MDF and the equipment.

The PTC thermistor is intended for the same application as heat coils or fuses. However, as this device is self-restoring, there is no need for replacement after each operation when the device is used within the range of its self-restoring capability. This allows protection systems to be self-restoring for current limiting as well as voltage limiting.

A PTC thermistor is mainly intended to limit overcurrents of relatively long duration and will normally have too slow a response time for switching transients or surges caused by lightning discharges.

PTC thermistors have some characteristics that may limit the use of the device:

−   Due to frequency dependence of some PTC thermistors, the transmission in high frequency (tens of MHz) systems might be influenced.

−   As series resistance on the a and b conductors, the devices can effect the balance of the line.

−   An activated device might still let a small current flow in the circuit. This small current can be high enough to generate too high heat dissipation in other devices like secondary overvoltage protection components if careful coordination is not achieved.

−   An activated PTC thermistor may not self-restore on certain communications circuits, which have continuous current flow.

3 Scope

This Recommendation applies to current-limiting devices that address the principles of protection against overcurrents in accordance with ITU-T Rec. K.11. The performance parameters described herein are intended as a guide for general-purpose communications circuits. Specific systems, terminal equipment, or environments may have different needs.

4 Performance parameters

4.1 Environment characteristics

PTC thermistors should operate satisfactorily in temperature and humidity ranges selected for the intended application. The selected temperatures should be a designated range that is within the extreme values of $-40°$ C and $+70°$ C. The selected humidity range should be up to 95% r.h.

Tests contained in electrical characteristics, see 4.2, shall be performed at room temperature of $+25°$ C. Further testing may be performed at the selected extreme temperatures. However, the response time, the rated current, and the d.c. series-resistant characteristics of the device may differ from those specified at room temperature. Each test contained in 4.2 shall be performed on previously untested devices.

4.2 Electrical characteristics

4.2.1 Operation of PTC thermistors

The PTC thermistor operates to limit the current as an open circuit. The device operates to limit the current by increasing its resistance from a low to a high value.

The PTC thermistor is placed as a series element in the telecommunication loop. The current-limiting device may be provided in the same package with the primary protector unit on the MDF, at the subscriber network interface or on printed circuit boards of the communication equipment.

4.2.2 PTC thermistor operating characteristics

PTC thermistors are available with a variety of operating characteristics to suit the particular needs of each application. The following characteristics are of particular importance:

– Response time, T_R, is the maximum time required for the PTC thermistor to reduce a given fault current to an acceptable value that will not cause a damage or safety hazard to the protected load.

– Transition current, I_t, is the current level required to cause a PTC thermistor to change state at a given temperature and duration.

– Rated current, I_r, is the maximum current that a PTC thermistor is able to carry for a specified period of time. The selected current should be greater than the maximum normal operating current over the operating temperature range.

– Maximum voltage, V_{max}, is the highest voltage that may be applied to the PTC thermistor without altering its performance.

– Impulse and a.c. life are the number of lightning impulse and a.c. currents and voltages that a PTC thermistor withstands without experiencing a failure mode. End-of-life is defined when the d.c. resistance of the device is not within its specified limit values after the end of current applications or fails to meet the rated current and response time characteristics.

– The PTC thermistor should withstand overload surges and a.c. power without causing safety hazard or propagating fire.

Table I.1 shows examples of some PTC thermistor characteristics.

4.2.3 Response time, T_R

The PTC thermistor shall operate within the response time when the specified transition current (see Table I.1) is applied through its terminal. When the device operates, the current shall decrease to an acceptable current value.

The device shall have a resistance within the specified values measured after the source is disconnected. Restoral of the d.c. series resistance to its specified value shall be measured after a time period selected for the intended application.

Test method

Figure 1 depicts an example of a circuit that can be used to perform the test. The current source of Figure 1 shall have the transition current value as specified in the appropriate category when the current-limiting device is placed in the test circuit. Check that the current decreases to an acceptable current value within the appropriate response time. After the source is disconnected and the device has reached the ambient temperature and a specified time has passed, measure the resistance of the PTC thermistor to ensure it is within its specified values. Repeat the above procedure five times for each load current. The repetition rate shall be sufficient to avoid thermal accumulation.
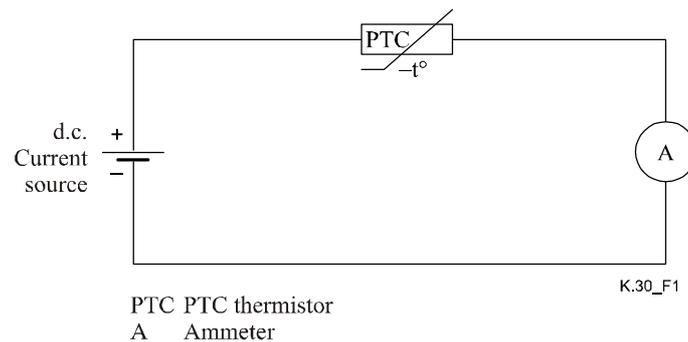

PTC   PTC thermistor
A   Ammeter

Figure 1/K.30 – Response time test circuit

4.2.4   Rated current, I_r

The PTC thermistors shall carry the specified rated current (see Table I.1) applied simultaneously to each current-limiting device as shown in Figure 2 for the appropriate test period.

During the rated current tests, the devices shall have a resistance within the specified values.

Test method

Figure 2 depicts an example of a circuit that can be used to perform the test. In applications where there is no thermal coupling between devices, only one device need be tested, rather than two devices simultaneously. The d.c. constant current source shall have the rated current value as specified in the appropriate category when the PTC thermistor is placed in the test circuit. During the rated current tests, measure the resistance of the device to ensure that it is within the specified values. The d.c. series resistance of the device is the quotient of the voltage measured across the PTC thermistor divided by the current measured by the ammeter.
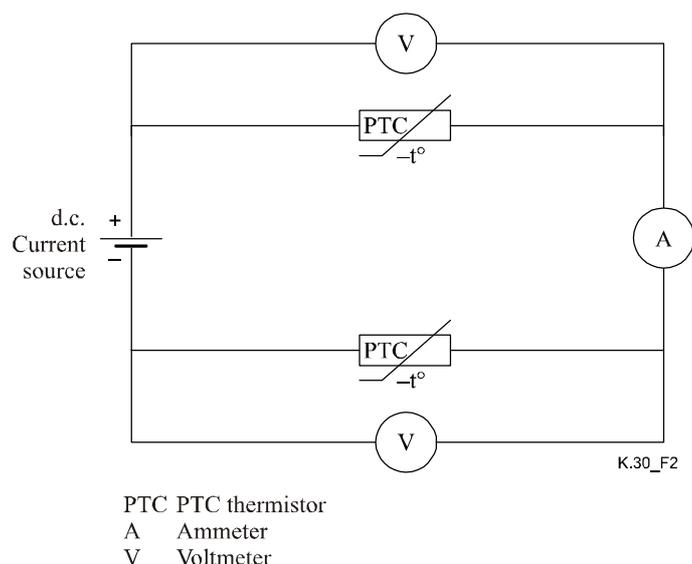
PTC PTC thermistor
A   Ammeter
V   Voltmeter

Figure 2/K.30 – Rated current test circuit

4.2.5   Impulse life

The PTC thermistor shall conduct the number of applications of impulse currents specified in the appropriate impulse life without experiencing a failure. Examples of test pulses are shown in Table I.2.

The end-of-life of the device is determined when:

−   its resistance is not within the specified limit values;

−   it fails to pass the rated current and response time test at 25° C.

Test method

Figure 3 depicts examples of circuits that can be used to perform the test. The generator may be defined as the waveforms for the open circuit voltage and the short circuit current, or as a generator with specified components. After each ten current applications, and when the device has reached the ambient temperature and a specified time has passed, measure the resistance of the devices to ensure that it is within the specified limit values. The impulse repetition rate shall be such as to avoid thermal accumulation.
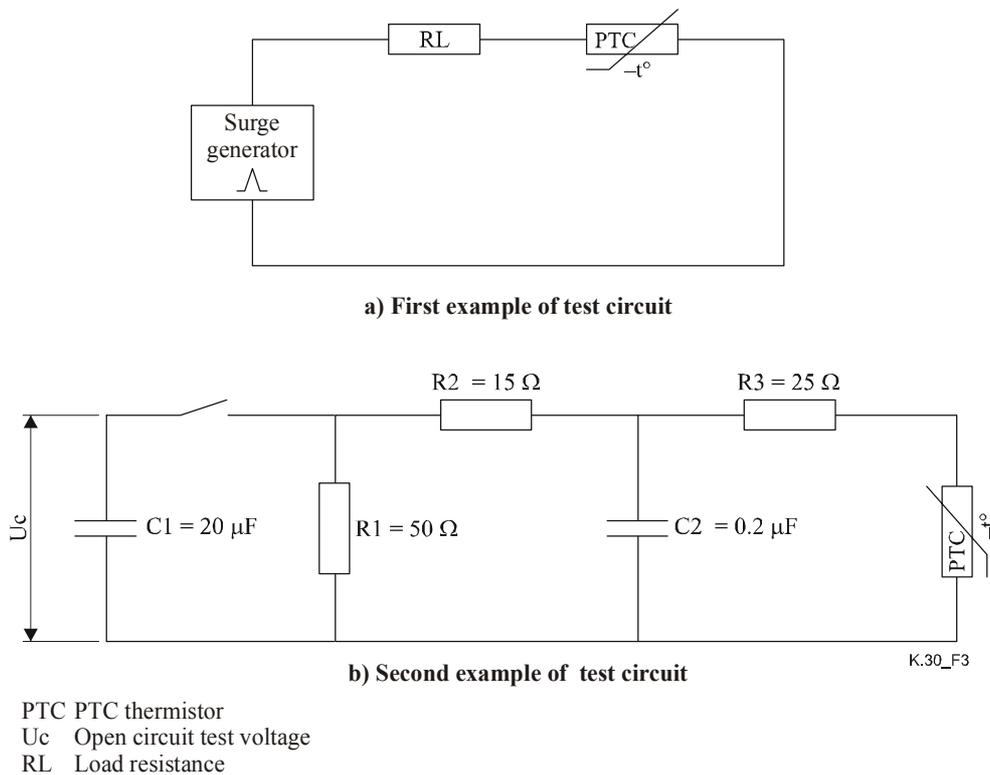
a) First example of test circuit

b) Second example of test circuit

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PTC PTC thermistor
Uc   Open circuit test voltage
RL   Load resistance

Figure 3/K.30 – Impulse life test circuit

4.2.6 a.c. life

The self-restoring current-limiting mechanism shall conduct the number of applications of the 48-62 Hz sinusoidal currents specified in the appropriate a.c. life without experiencing a failure. Examples of test values are shown in Table I.3.

The end-of-life of the PTC thermistor is determined when:

–   its resistance is not within its specified limit values;

–   it fails to pass the rated current and response time test at 25° C.

Test method

Figure 4 depicts an example of a circuit that can be used to perform the test. In applications where there is no thermal coupling between devices, only one device need be tested rather than two devices simultaneously. The open-circuit voltage and the short-circuit current of the generator shall be specified. After each ten current applications, and when the device has reached the ambient temperature and a specified time has passed, measure the resistance of the devices to ensure that it is within the specified limit values. Perform the rated current and response time test at 25° C. The a.c. repetition rate shall be such as to avoid thermal accumulation.

4.2.7 Failure mode test

The PTC thermistor shall survive or fail open circuit or high resistance mode when overloaded by a surge or an a.c. voltage.

The PTC thermistor shall withstand an application of a 48-62 Hz sinusoidal power contact current for a 15-minute duration with an open circuit voltage source and source resistance specified to be appropriate for the intended application.

The PTC thermistor shall withstand an application of an impulse current with an open circuit voltage source and source resistance specified to be appropriate for the intended application.

Test method

Figures 3 and 4 depict examples of circuits that can be used to perform the impulse and power contact tests respectively. During the current application, the PTC thermistor shall not cause a safety hazard or propagate a fire. Use cheesecloth wrapped on the housing containing the devices intended for the application as a fire hazard indicator.
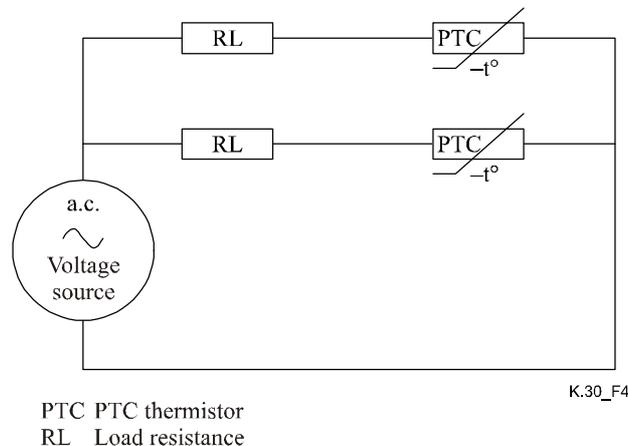

PTC   PTC thermistor
RL   Load resistance

Figure 4/K.30 – Failure mode test circuit

4.3   Selection of PTC thermistors

The PTC thermistor shall have no effect on circuit operations up to normal load current but should have high resistance at currents larger than the defined overload current and duration within the relevant temperature range.

A selection of the device may follow the steps below:

–   define the maximum operating current of the equipment at all relevant ambient temperatures;

–   define the minimum overload current and duration at all relevant ambient temperatures;

–   define the maximum fault current and voltage to which the device will be exposed;

–   choose a component with rated current greater than the maximum operating current at all relevant ambient temperatures using the thermal derating factor f_D defined in manufacturers' data sheet;

–   check that the device transition current is less than the minimum overload current at all relevant ambient temperatures using the factor f_D;

–   the response time depends on the specific energy i^2t (Ws/Ω) heating the device. The response time as a function of the current is normally given at 25° C. For different temperatures a derated fault current should be using the factor f_D.

         Response times should be below the time at which the currents can cause unacceptable damage to the protected load.

5   Coordination and application of PTC

When PTCs are installed in the MDF and the equipment, it should be noted that their operating current may vary with temperature, and that the ambient temperature at the location of the MDF and the equipment may be significantly different. In extreme situations, the overcurrent protection in the equipment may be prone to damage if no SPDs are installed in the MDF. In this case, it may be desirable to install overcurrent protection on the MDF where it can be easily replaced. In this situation, the PTC used in the MDF must operate first. This will require a very careful assessment

of the operating characteristics of both PTCs, taking into account the operating characteristics at different temperatures. This assessment should be done by both the network operator and the system manufacturer.

The overcurrent protectors specified in this Recommendation may be used in equipment to enable compliance with the requirements of equipment resistibility Recommendations (ITU-T Recs K.20, K.21 and K.45). They may also be used in an MDF to prevent damage to the equipment. Typical usage in this case would be for older equipment, or in areas where high levels of power induction occur, or where power contact is a problem.

Adding self-restoring overcurrent protectors to the MDF may provoke the following problems:

• Some operators may only use MDFs that accept three terminal protections. In this case, it may be difficult to add self-restoring overcurrent protectors to the MDF.

• Coordination problems may occur with PTC thermistors installed in an MDF due to the possible temperature difference between the MDF room and the location of the equipment.

• Coordination problems also may occur with PTC thermistors installed in an MDF due to the high-ohmic feeding bridges in older equipment.

• Balance problems may occur with self-restoring overcurrent protectors, particularly with polymer PTC thermistors. Operators will need to consider this issue.

• Reduction in reach: The addition of self-restoring overcurrent protectors to the MDF may reduce the allowable line length as a result of the devices' resistance.

Appendix I

Examples of characteristics of PTC thermistors

Table I.1/K.30 – Response time and rated current characteristics

Item	Transition current (A r.m.s.)	Maximum response time (s)	Rated current (A r.m.s.)	Test period	Nominal resistance Ω	Maximum resistance Ω	Minimum resistance Ω (Note)
1	1.875	210	1.2	3 hours	–	0.25	–
2	0.54	210	0.15 0.26	3 hours 30 s	1.5	4	0.8
3	0.5	210	0.135	1 hour	10	12	8
4	0.25 1.0	90 2.5	0.145	30 min	8.5	15	7
5	0.35 1.0 4.0	35 4 0.8	0.11	1 hour	15	18	12
6	0.2 1.0	90 1.0	0.11	30 min	17	30	13
NOTE – Minimum resistance is needed only in these applications where a minimum resistance level is important (e.g., coordination of primary and secondary overvoltage protectors).							

Table I.2/K.30 – Impulse life characteristics

Minimum open-circuit peak voltage (V)	Short-circuit impulse current (A)	Waveform (µs/µs)	Applications
1000	25	10/1000	30
1500	37.5	10/310	10

Table I.3/K.30 – a.c. life characteristics

Voltage (V r.m.s.)	Current (A r.m.s.)	Duration (s)	Applications
283	1	1	60
250	3	600	1
300	0.5	1	10
650 (Note)	1.1	2	10
NOTE – Lines without primary protection.			

Appendix II

Semiconductor self-restoring overcurrent protectors

Semiconductor limiting devices are intended to limit overcurrents of short or long duration and may be used to provide protection responses to all types of surge. This type of self-restoring overcurrent protector relies on an inherent semiconductor series element switching to a high impedance state at a specified line current.

Method of operation

These devices quickly change state at a predetermined current to stop further current flow into the equipment. The device is either placed as a series element in the telecommunication loop (placing a high resistance in the line during operation), or as a shunt device from both sides of the line to earth (when operated shunts the majority of the current to ground). The current-limiting device may be provided in the same package with the primary protector unit on the MDF, at the customer network interface, or on printed circuit boards of the communication equipment. The operating time for these devices can be in the order of fractions or of micro-seconds. Their reconnect time on completion of the transient can also be effectively instantaneous.

Table II.1/K.30 – Typical characteristics for semiconductor overcurrent protectors

Operate current (mA)	Reset current (mA)	Reset voltage (V)	Rated current	Rated voltage (V)	Operate time (µs)	Resistance (Ohms)
180	1	10	–	650	<1	12
180	1	10	–	1650	<1	18

– Operate current is the threshold current level required to cause a device to operate (change state).

– Reset current is the current level required to cause a shunt overcurrent device to return to its unoperated state.

– Reset voltage is the voltage level required to cause a series overcurrent protector to relax to its unoperated state.

– Rated current is the maximum current that the device is able to carry for a specified period of time.

– Rated voltage is the highest voltage that may be applied to the device without causing device damage.

– Operate time is the time taken to, in the case of the shunt device, change its state to its maximum conductive state, and in the case of the series device, to change its state to it maximum resistive state, in response to a threshold current.

– Resistance R is the non-reactive impedance of the device during normal operation.

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