Bodo´s Power Systems®

PROTECTION

# Inrush-Current Limiting Wirewound Resistors to Charge the DC-Link Capacitor of an Electric Drive System

*When a drive system is powered up, a resistor is used to limit the inrush current during the charging of the DC-link capacitor. Without such a resistor, the current could destroy the drive input stage (the AC/DC converter) or trigger the upstream protection of the mains network. Furthermore, the resistor shall assure a smooth and complete charging of the DC-link capacitor.*

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**Charging the DC-Link Capacitor with Inrush-Current Limiting Resistors**

When limiting inrush currents with an ohmic resistor in series to the load, the resulting power loss decreases the power efficiency of the circuit. After the DC-link capacitor has been charged, however most power electronic circuits bypass the inrush current limiting component with a switching element, e.g. with a relay or triac.

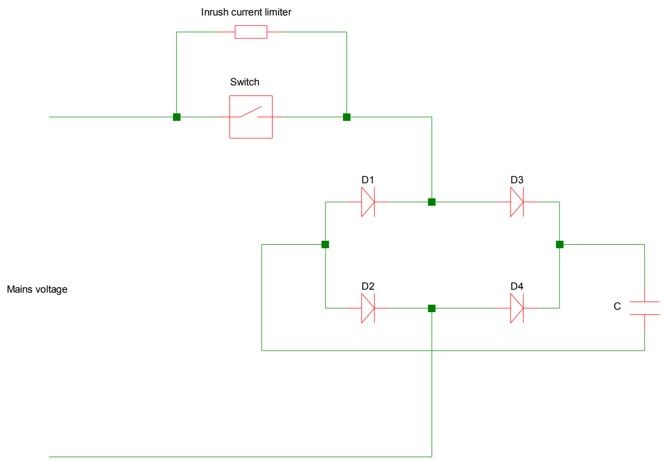


*Figure 1: Bypass-system to limit inrush currents*

In such a bypass-circuit, mostly PTC's or Wirewound Resistors are used to limit the inrush-current.

**Charging Resistors - Comparison between PTC's and Wirewound Resistors**

A PTC is a temperature dependent resistor. However, a Wirewound Resistor has a fixed resistance value and provides following advantages when used as a Charging Resistor:

- The energy amount which must be transferred to the DC-link capacitors during the charging-process could cause a PTC to heat up, thus increasing its resistance-value. In this case there is a risk that the DC-link capacitors will not be charged completely.
- By using a Wirewound Resistor, it is possible to calculate the exact inrush currents and charging-times under all operating temperatures. It can be assured that the DC-link capacitors will be always fully charged under all application conditions.
- With a correctly dimensioned Wirewound Resistor it is possible to repeat the switch-on processes of the device more quickly than with a PTC to achieve fully loaded capacitors. The suitable robustness can be verified in a test where the Wirewound Resistor is stressed to charge the capacitor within a defined time. Then the capacitor will be discharged within a defined waiting-time. These cycles are repeated according to the requested cycle-number.
- In contrast to a Wirewound Resistor, the voltage-dependence of a PTC must be respected when evaluating its resistance-temperature characteristics. At a constant temperature, the resistance of a PTC decreases as the voltage across the device is increased.
- The typical tolerance of the rated resistance of a PTC is -/+25%, from a Wirewound Resistor it is -/+5% only.
- In applications which can already be very warm during start-up (e.g. circulator-pump for hot water) using a PTC could result in lower charging currents and longer charging times.
- A Wirewound Resistor is more robust against transient impulses than a sintered ceramic PTC.
- In case of failure (e.g. the switching element has a malfunction or the capacitor short circuits) a PTC gets highly resistive, thereby protecting itself. After cooling down the PTC gets low ohmic and can be used again. However, the root cause of the failure in the circuit still exists.
- A Wirewound Resistor with the correct fusing characteristics triggers in case of failure and gets highly resistive. This behavior corresponds to the so-called self-protection of a PTC. However, a triggered Wirewound Resistor disconnects the electronics continuously from the mains, independent from its body temperature after triggering. Subsequently, there is a chance to analyze the root-cause of the failure before more serious damage occurs.
- In case of high capacitances of the DC-Link Capacitor, several resistor-elements have to be combined to assure the required Joule-rate. If the application needs the resetability function of a PTC, it is possible to combine one PTC with several Wirewound-

Resistors. In this way, more precise, quick and robust combinations can be realized than by using just PTCs.

**Ty-Ohm's Full Range of Wirewound Resistors:**
For the application as Charging Resistors, Ty-Ohm from Taiwan offers a complete range of Wirewound Resistors:

- Axial, Radial, SMD, Cement potted in ceramic cases.

The resistance-range is from 0.1Ω to 2 kΩ, the rated power covering a range from 1W to 12W.

Regarding the triggering characteristics, Ty-Ohm provides the following classifications:

- **Standard Fusing:** Fusing in less than 1 minute with 5 to 16 times rated wattage (depending on the range). Note: The fusing behavior itself is not precisely defined.
- **Fail-Safe Fusing I:** In a failure mode where the mains voltage (90Vac – 280Vac) is directly applied to the resistor for 5 seconds, the resistor will trigger and will disconnect the electronic circuit safely from the mains voltage. No flames, no explosion, no sound and no arc occurs.
- **Fail-Safe Fusing II:** As Fail-Safe-Fusing I. Additionally, by integrating a thermal protection into the Wirewound Resistor, it is assured that in failure mode the temperature of the resistor doesn't exceed the triggering temperature of the thermal fuse.

**Fail-Safe Fusing of Wirewound Resistors**
Generally, the safety of an electronic circuit is verified by applying individual failures to detect the behavior of the complete device. This means that each electronic component will be exposed to the failure modes: short-circuit, high ohmic, few ohms to ground.

**Fail-Safe Fusing I:**
Short-circuit represents 0Ω and cause the resistor to trigger in the specified way. In this case, no thermal protection is needed and the triggering of the resistor is according to the definition of Fail-Safe Fusing I.

**Fail-Safe Fusing II:**
Practical experience shows that electronic components could fail causing a connection to ground with a few ohms. The root-causes of such an undefined failure mode are e.g. surge-impulses, temperature, humidity, ageing. All electronic components which are in serial connection to the resistor may fail in this undefined way, e.g.:

- Capacitor, Bridge-Rectifier, Pi-Filter, Voltage Transformer, Switching Transistor, Control Circuit IC.

A high impedance failure of these components will not cause any safety problems to the circuit and will disconnect the circuit from the mains.

However, a low impedance failure of these components is critical in the following cases:

- The Wirewound Resistor is used as inrush-current limiter in series to the load.
- The bypass switching element faces a high-impedance failure but the device will not be switched off.

In both cases, a low impedance failure of one of the components in series to the resistor creates a voltage division of the mains voltage between the resistor and the failed component. Then the voltage across the resistor will be too low to trigger the resistor in a defined way according to Fail-Safe Fusing I. The resistance wire will get increasingly hot and stabilize at a steady state temperature lower than the melting temperature of the resistance wire. This temperature can cause a serious safety problem to the surrounding components, to the PCB or to the housing of the device.

The solution to avoid this scenario is to integrate a thermal protection into the Wirewound Resistor. Its purpose is to disconnect the resistor safely from the mains once the temperature of the resistance wire reaches the specified triggering temperature of the thermal protection.

The current rating and the triggering temperature of the thermal protection can be selected according to the application requirements, e.g. from 1A – 10A and from 130°C to 260°C or upon requirement.

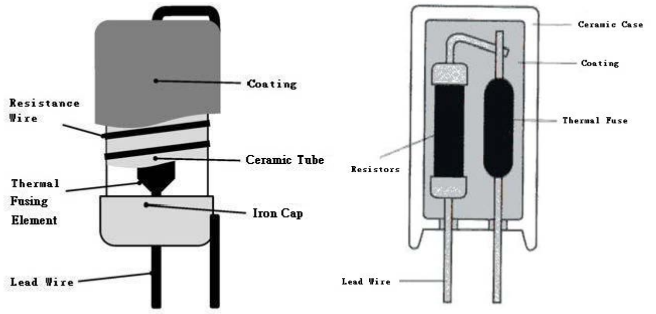


*Figure 2: leaded and cemented Wirewound Resistors with integrated thermal protection*

In case of applying a UL certification for a drive-system, a test might be necessary simulating a permanently open relay because of its failure mode. If the Wirewound Resistor has an integrated thermal protection, then it is no need to manage the protection of the drive by other means.

Ty-Ohm provides such Wirewound Resistors in accordance to Fail-Safe Fusing I and II – classification for leaded, SMD and cement resistors.

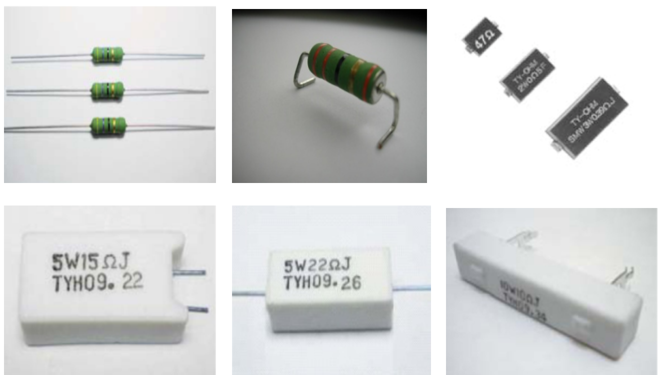


*Figure 3: Ty-Ohm's range of Wirewound Resistors: Axial, Radial, SMD, Cement - all available with or without integrated thermal protection*

The realization of highly dynamic and energy efficient electrical drives, converters and rectifier units with alternatingly quick accelerating and quick braking processes is supported by power resistors. Ty-Ohm's full range of Wirewound Resistors assure inrush-current limiting charging resistors in a highly precise, quick, robust and safe way.

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