MSCDN – MP2A

Capacitor unbalance protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:
Pre release

2010/02	Document reformat due to rebrand
13/02/2003	R2 Thermal calculation example units added
10/02/2003	R1 First version

Software Revision History

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1 Introduction

The MSCDN-MP2A relay provides wide bandwidth, true RMS phase-by-phase Resistor Thermal Overload Protection and Resistor Open Circuit Protection and is suitable for capacitor bank applications. Together with its sister units MSCDN-MP1 and MP2B, this protection unit offers a complete solution for Main 1 and Main 2 protection of EHV capacitor banks.

These notes give guidance on the application of the relay and the protection elements integrated in it, reference may be made to the Commissioning Chapter, which provides detailed set-up instructions.

2 Resistor Thermal Overload Protection

2.1 Fault Setting Principles

The operate time of the thermal elements is given by

$$t = \tau \times \ln\left\{\frac{I^2 - I_P^2}{I^2 - (k \times I_B)^2}\right\} \sec \quad \text{...(Eq. 1)}$$

Where

I_P = Previous steady state current level

I_B = Basic current rating of resistor

k = Multiplier resulting in the overload pickup setting $k.I_B = I_\theta$

I = The measured resistor current

τ = Thermal time constant

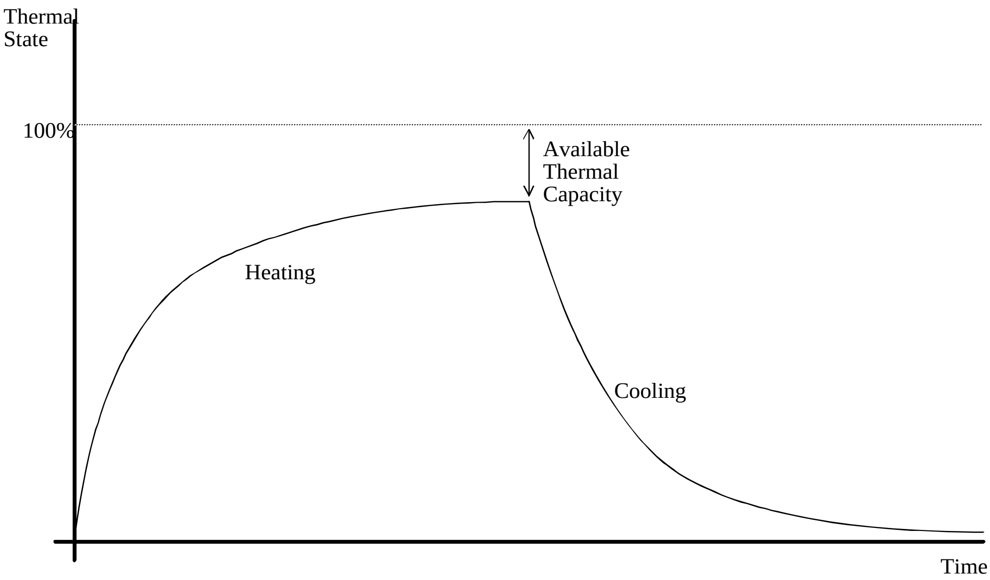

Figure 1 – Exponential heating and cooling curves

For the heating curve:

$$\theta = \frac{I^2}{I_\theta^2} \cdot (1 - e^{-t/\tau}) \times 100\% \quad \text{....(Eq.2)}$$

For the cooling curve:

$$\theta = \theta_F \cdot e^{-t/\tau} \quad \text{......(Eq.3)}$$

where: θ = thermal state at time t

θ_F = final thermal state before disconnection of device

I = measured thermal current

I_θ = thermal overload current setting (or $k.I_B$)

τ = thermal time constant

The final steady state thermal condition can be predicted for any steady state value of input current since when t>>τ,

$$\theta_F = \frac{I^2}{I_\theta^2} \times 100\% \quad \text{...(Eq. 4)}$$

The thermal overload setting I_θ is expressed as a fraction of the relay nominal current and is equivalent to the factor $k.I_B$ as defined in the IEC60255-8 thermal operating characteristics. It is the value of current above which 100% of thermal capacity will be reached after a period of time and it is therefore normally set slightly above the full load current of the protected device.

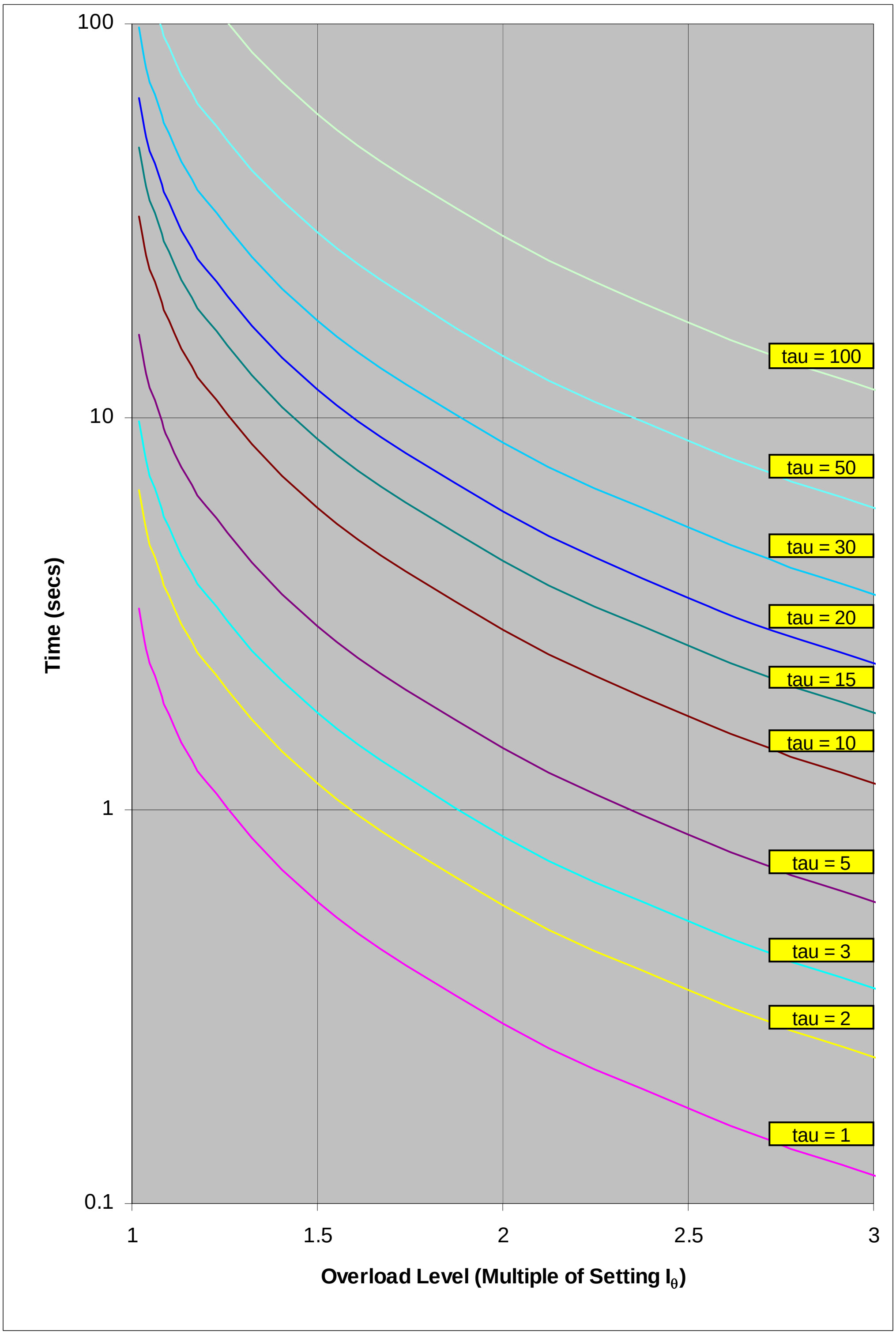

Figure 2 – IEC60255-8 cold curve (tau in seconds)

2.2 Setting Example

Resistor Thermal Characteristics

CURRENT IN AMPS	TIME IN SECS
12	Continuous
16	20
19	9
20	8
21	7
22	6
23	5
25	4
28	3
34	2
46	1
125	Maximum

CT Characteristics

Ratio	20/1

Alarm & Trip Requirements

Alarm level	105 %
Trip level (k)	110 %

Now I_B = 12/20 = 0.6 amps

And $I_\theta = k \times I_B = 1.1 \times I_B = 1.1 \times 0.6 =$ <u>0.66 Amps</u>

At an applied current of I = 16/20 = 0.8 amps, the resistor maximum withstand time is t = 20 seconds. Using a safety margin of 50%, then

$$0.5 \times 20s = \tau \times \ln\left\{\frac{0.8^2}{0.8^2 - 0.66^2}\right\}$$

Thus

$$\tau = \frac{10}{\ln\left(\frac{0.64}{0.2044}\right)}\sec = 8.76\sec$$

$\therefore$ τ = 9 seconds will be used to satisfy the 50% safety margin.

Resistor Thermal Characteristics

CURRENT IN AMPS	TIME IN SECS	RELAY CHARACTERISTICS
12.00	Continuous	Continuous
16.00	20.00	10.27
19.00	9.00	5.93
20.00	8.00	5.15
21.00	7.00	4.52
22.00	6.00	4.02
23.00	5.00	3.60
25.00	4.00	2.94
28.00	3.00	2.26
34.00	2.00	1.47

Steady state thermal energy =

$$\theta_F = \frac{I^2}{I_\theta^2} \times 100\%$$

$$\theta_F = \frac{1^2}{1.1^2} \times 100\% = 82.64\%$$

Alarm level thermal state =

$$\theta_F = \frac{1.05^2}{1.1^2} \times 100\% = 91\%$$

Re-arranging equation 1 we get

$$t = -\tau \times \ln\left\{1 - \left[\frac{\theta \times {I_\theta}^2}{I^2 \times 100}\right]\right\} \quad \text{.... (Eq.5)}$$

The maximum operating time of the Thermal Alarm (i.e. from cold) will given by :-

θ =	91	%
τ =	9	s
I =	1.05	
I_θ =	1.1	
t =	**60.02**	**s**

To achieve steady state thermal capacity of 82.6% (i.e. from cold) will given by :-

θ =	82.6	%
τ =	9	s
I =	1.05	
I_θ =	1.1	
t =	**21.33**	**s**

Therefore the operating time from steady state at rated current of the Thermal Alarm would be

t = 60s – 21.3s = 38.7s

Thermal Protection Settings

R1 & R2 49 Overload Setting (using 1A i/p)	0.66 xIn
R1 & R2 49 Time Constant	9 seconds
R1 & R2 49 Capacity Alarm	91 %

3 Resistor Open Circuit Protection

3.1 Fault Setting Principles

Open circuit conditions are difficult to detect in shunt connected resistors therefore two identical resistors are used in parallel on each phase and the resistor current is compared on a phase-by-phase basis. Under operating conditions if either resistor develops an open circuit then the Overcurrent element operates to either trip or alarm the situation.

The Overcurrent elements must be set to avoid operation due to resistor and CT tolerances.

The Overcurrent pickup and delay must be chosen to avoid operation under transient overload conditions that do not threaten the resistors thermal overload characteristics.

3.2 Setting Example

Resistor Characteristics

Value of Resistance per limb	432Ω
Maximum Tolerance	± 2.5%
Continuous Rating	12 A

CT Characteristics

Ratio	20/1

Variation of resistor secondary current due to resistor tolerance

Min Value 0.975 x 12/20 = 0.585A
Max Value 1.025 x 12/20 = 0.615A

Worst case spill under normal loading conditions = 0.03A

Open Circuit Protection Settings

50 Setting	0.1 A
50 Delay	1 second