ELEC-E8421 - Components of Power Electronics

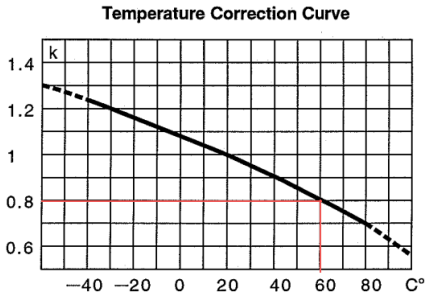
Exercise 1

1. First check the fuse current rating

Let's see if the fuse can withstand normal use without premature breakdown
Normal operations: constant current is 300 A.

Page 62 table shows that $I_n = 400A$, which holds at 20℃ temperature.
Page 28 thermal derating gives derating factor $k = 0.8$ @ 60℃.

Electrical Characteristics					Ordering Information				
Size	Rated Current RMS-Amps	I²t (A²S) Pre-arc	I²t (A²S) Clearing at 660V	Watts Loss	-FU/- Without Indicator	-FKE/- Type K Indicator for Micro	-FU/115 Without Indicator	-FKE/115 Type K Indicator for Micro	Car Q
	40	40	270	9	170M3608	170M3658	170M3708	170M3758	
	50	77	515	11	170M3609	170M3659	170M3709	170M3759	
	63	115	770	14	170M3610	170M3660	170M3710	170M3760	
	80	185	1250	18	170M3611	170M3661	170M3711	170M3761	
	100	360	2450	21	170M3612	170M3662	170M3712	170M3762	
	125	550	3700	26	170M3613	170M3663	170M3713	170M3763	
	160	1100	7500	30	170M3614	170M3664	170M3714	170M3764	
	200	2200	15000	35	170M3615	170M3665	170M3715	170M3765	
1"	250	4200	28500	40	170M3616	170M3666	170M3716	170M3766	
	315	7000	46500	50	170M3617	170M3667	170M3717	170M3767	
	350	10000	68500	55	170M3618	170M3668	170M3718	170M3768	
	400	15000	105000	60	170M3619	170M3669	170M3719	170M3769	
	450	21000	140000	65	170M3620	170M3670	170M3720	170M3770	
	500	27000	180000	70	170M3621	170M3671	170M3721	170M3771	
	550	34000	230000	75	170M3622	170M3672	170M3722	170M3772	
	630	48500	325000	80	170M3623	170M3673	170M3723	170M3773	



$$I_b \leq I_n \times k \times (1 + 0.05V) \times K_b$$

In additional without fans the air speed is close to 0.
Therefore $I_b(60℃) = 400 \times 0.8\ (1 + 0) \times 1 = 320\ A\ >\ 300\ A$.
Fuse does not burn under constant load

2. Check the thyristor current and voltage rating

2.1 First Check the I²t rating,

Highest occuring voltage is $400\ V + 10\%\ = 440\ V$ (worst case, typically 2 fuses work together)

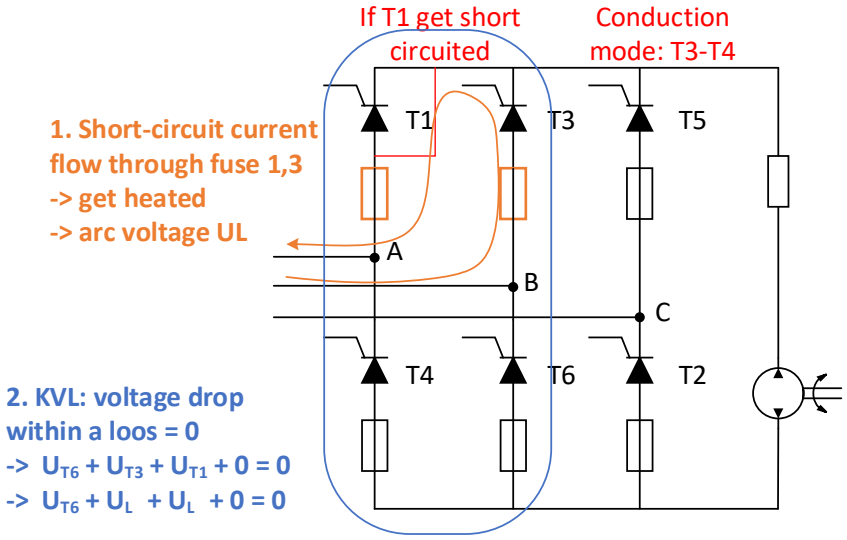
Page 62 table shows the clearing I^2t @ 660V, Page 63 figure gives derating factor $K = 0.65$:

$$I^2t\ (440\ V) = 0.65 \times 105\ 000\ A^2s = 68250\ A^2s,$$

Thyristor required that I^2t is less than 90 000 A_2s, so on that note this fuse is suitable.

2.2 Next, we will check the fuse arc voltage.

During short circuit two fuses are always in series, so their voltage stress is half of the grid voltage. With 400 V grid the $+10\%$ peak voltage is $V_p = 220\ V$. On page 63 arc voltage is given to be $580\ V\ @\ E_g = V_p = 220V$.
Worst case occurs in this situation:



- We notice that over T6 has 2 fuse voltages:
$$U_{T6} = 2 \times 580\ V = 1160\ V < 1500V$$
thyristor rating 1500 V, OK
- If only 1 breaks, → $V_p\ (440\ V) = 930\ V$, also OK.

3. Let's go through each periodic overload case:

3.1 500 A 60 s, once an hour:

Using timing table on Page 71, or final page of exercises: $I_t(60) = 950\ A$.
For frequently occurring loads: $I_{max} < 0.6\ I_t = 0.6 \times 950 = 570A > 500A$
fuse will not burn, OK

3.2 700 A, max 10s duration 2 times in a week

Using timing table on Page 71, or final page of exercises: $I_t(10) = 1360\ A$.
For 1-2 times occurring loads: $I_{max} < 0.7\ I_t = 0.7 \times 1360 = 952A > 700A$
fuse will not burn, OK

3.3 700 A, max 20s duration once a month

Using timing table on Page 71, or final page of exercises: $I_t(20) = 1150\ A$.

For seldom occurring loads: $I_{max} < 0.8\, I_t = 0.8 \times 1150 = 920A > 700A$

fuse will not burn, OK

3.4 1200 A, max 0.5s less than once a month.

Using timing table on Page 71, or final page of exercises: $I_t(0.5) = 1800\, A$.

For seldom occurring loads: $I_{max} < 0.7\, I_t = 0.7 \times 1800 = 1260A > 1200A$

fuse will not burn, OK

For frequently occurring loads: $I_{max} < 0.6\, I_t = 0.6 \times 1800 = 1080A < 1200A$

fuse will burn, risky!

Exercise 2

In the unbalanced case - Worst case: 1 Thyristor $Q_{rr} = 160\ \mu C$, two other $400\ \mu C$.

$$\Delta u = \frac{\Delta Q}{C} = \frac{Q_{rr(max)} - Q_{rr(min)}}{C} = \frac{(400 - 160)\ \mu C}{0.47\ \mu F} = 510V$$

In the balanced case - Thyristor #1 voltage:

$$U_1 = U_2 = U_3 = U_T'$$

$$U_T' = \frac{1}{n} \times [n \times U_1(t) + (n-1) \times \Delta u] = U_1(t) + \frac{n-1}{n} \times \Delta u$$

Difference from the median value:

$$\Delta u_1 = U_T' - U_1 = \frac{n-1}{n} \times \Delta u = \frac{3-1}{3} \times 510\, V = 340\, V$$

Depending on application value can be too large, so we might increase the capacitor next to thyristor, or choose thyristors based on their Q_{rr} charge properties