Switchboard Rating for Internal Arcing Fault Clearing Time and Peak Current Withstand

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I. Introduction

Many Electrical Engineers put "**20kA @ 0.2s**" ratings on the switchboards they are designing but they do not know how to calculate the rating or why they need to include the rating in their switchboard specification.

This is a sad and dangerous reality but even seasoned Electrical Engineers are not doing this calculation. It is either, they just copy whatever has been previously designed or worst, they are just doing guess works.

The purpose of this paper is to enable Electrical Engineers to calculate the Internal Arcing Fault Clearing Time and Peak Current Withstand of any switchboard they are assigned to design.

II. Disclaimer

This paper is presented for information only. Before using contents of this paper for practical applications, calculations should be verified by a competent person.

Use this material at your own risk and shall withhold the author from any liability.

III. Basis of Design

Calculations are based Australian Standards. Assumptions are based on industry practice.

IV. Fault Calculations

To provide an example on how to calculate the internal arcing fault clearing time and peak current withstand of a switchboard, let us consider a switchboard supplied from a 315KVA, 4% Z, 11KV/400V transformer using a 50 m - 240 mm² 3C+E cable.

Assume system fault at the point of supply to be 250MVA @ 11KV and no load contribution to the fault current.

What will be the rating of the board if the transformer is upgraded to 750KVA, 5% Z, 11KV/400V with a 250KW motor load?

Case I:

Point of Supply	:	11KV, 250MVA Fault Level
Transformer	:	315KVA, 11KV/400V, 4% Z
Supply Cable	:	50 m - 240 mm².

We shall use the MVA method to calculate the fault current at the switchboard.

Supply Cable:

From AS 3008.1 – 2009, Table 37, Column 4, the AC resistance @ 50Hz for a 240 mm² cable is 0.100 ohms/km @ 75^{O}C.
From AS 3008.1 – 2009, Table 31, Column 3 (PVC), the reactance @ 50Hz for a 240 mm² cable is 0.0835 ohms/km.

Zc = (50 m x 1 km / 1000 m) x (0.100 + j 0.0835) ohms / km
Zc = 6.51 x 10^{-3} ohms = 0.00651 ohms

The MVA equivalent for the cable:

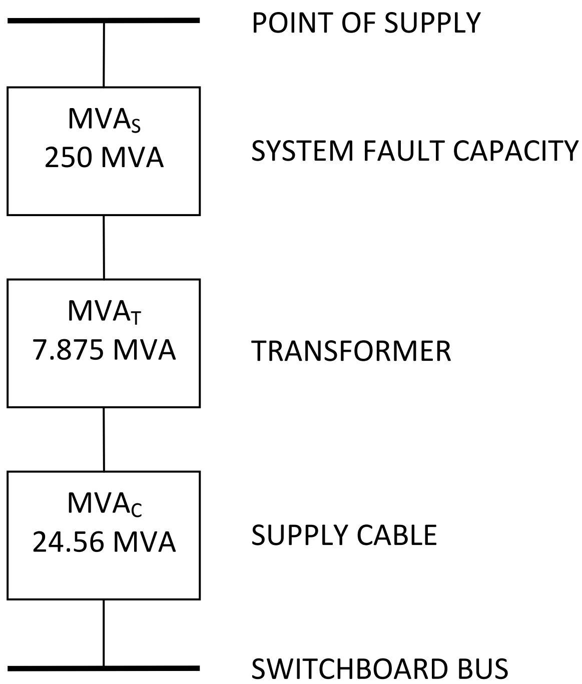
MVAc = (KV²)/Z = 0.4² / 0.00651
MVAc = 24.56 MVA.

Transformer:

MVA_T = KVA / [1000 x (%Z/100)] = 315 / [1000 x (4/100)]
MVA_T = 7.875 MVA

Point of Supply:

MVAs = 250 MVA



The total Fault MVA for the system will be:

$1/MVA_{TOTAL} = 1/MVA_S + 1/MVA_T + 1/MVA_C = (1/250) + (1/7.875) + (1/24.56)$

$MVA_{TOTAL} = 5.824$ MVA

$I_{FAULT} = (5.824 \times 1000) / (\sqrt{3} \times 400)$

I_{FAULT} = <u>8.4 kA</u>

<u>Case II:</u>

Point of Supply	:	11 KV, 250 MVA Fault Level
Transformer	:	750 KVA, 11 KV/400 V, 5% Z
Supply Cable	:	50 m – Size not specified.

AS the size of the cable is not specified, let us assume that it will be sized to the transformer rating. The transformer full load current is:

$I_T = (750 \times 1000) / (\sqrt{3} \times 400) = 1082.5$ A

Using parallel 240 mm² cables, from AS 3008.1 – 2009, Table 13, Column 25, the current-carrying capacity of a 240 mm² is 359 A. It is assumed that the cable is installed in an underground cable duct.
To calculate that number of cables, n:

n = 1082.5 / 359 = 3.01, assume 4 parallel cables.

Note: Derating factor should be applied to the cable current-carrying capacity and voltage drop should be check but these are beyond the scope of this paper.

From the first condition, the cable impedance for a single cable is

$Zc = 6.51 \times 10^{-3}$ ohms = 0.00651 ohms

For 4-parallel cables, Zc = 0.00651 / 4 = 0.00163 ohms

The MVA equivalent for the cable:

$MVAc = (KV^2)/Z = 0.4^2 / 0.00163$

MVAc = <u>98.16 MVA</u>.

<u>Motor Load Contribution:</u>

Motor Load = 250 kW, since there are no other given, let us assume it is a lump motor load, then the %Z will be 17%.

$MVA_M = 250 / (17\% \times 1000)$

MVA_M = <u>1.47 MVA</u>

<u>Transformer:</u>

$MVA_T = KVA / [1000 \times (\%Z/100)] = 750 / [1000 \times (5/100)]$
MVA_T = <u>15 MVA</u>

<u>Point of Supply:</u>

MVAs = <u>250 MVA</u>

The total Fault MVA for the system will be sum of upstream and downstream faults:

$1/MVA_{TOTAL-UPSTREAM} = 1/MVA_S + 1/MVA_T + 1/MVA_C$

$1/MVA_{TOTAL-UPSTREAM} = (1/250) + (1/15) + (1/98.56)$

$MVA_{TOTAL-UPSTREAM} = 12.37$ MVA

$MVA_{TOTAL-DOWNTREAM} = MVA_M = 1.47$ MVA

Then,

$MVA_{TOTAL} = MVA_{TOTAL-UPSTREAM} + MVA_{TOTAL-DOWNSTREAM}$

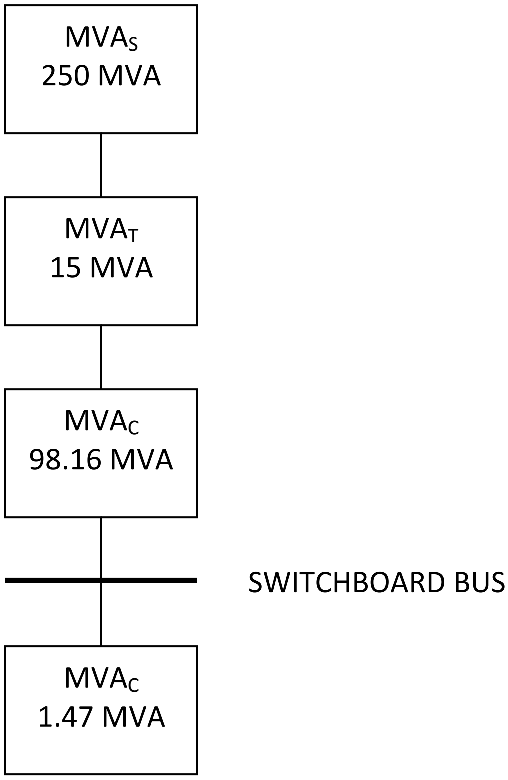
MVA_{TOTAL} = 12.37 + 1.47

MVA_{TOTAL} = <u>13.84 MVA</u>

The total fault current at the switchboard will be

I_{FAULT} = (13.84 x 1000) / (√3 x 400)

I_{FAULT} = <u>19.98 kA</u>



V. Equipment Ratings

Now that we know the fault current at the switchboard bus for both options, we can calculate the Internal Arcing Fault Clearing Time and Peak Current Withstand for the switchboard.

<u>Case I:</u>

As the main bus protection is not stated in the given, we can assume that it be able to protect the cable. Assume it to be 300A.

From AS 3000 – 2007, Clause 2.5.5.3, the maximum clearing time for an arcing fault to prevent damage to the switchboard is given by the formula

Clearing time, $t = (k_e \times I_r) / (I_f)^{1.5}$

Where:

t = clearing time, secs
k_e = 250 constant, based on acceptable volume damage
I_r = current rating of the switchboard
I_f = 30% of the prospective fault current

$t = (250 \times 300) / (8.4 \times 1000 \times 30\%)^{1.5}$

t = <u>0.59 secs</u>

To determine the electrodynamic stresses, AS/NZS 3439.1:2002 (IEC 60439-1:1999 MOD) Clause 7.5.3 Table 4 gives the relationship of the RMS value of short-circuit current and the peak withstand current. The *n* multiplier for 8.6 kA fault current is 1.7.

$I_{PEAK} = n \times I_F = 1.7 \times 8.6$

I_{PEAK} = <u>14.62 kA</u>

To ensure that the switchboard will be protected from arcing fault, the switchboard bus main protective device disconnection time shall be equal to or less that t = 0.59 seconds and mechanical bracings shall be able to withstand stresses at fault currents above the I_{PEAK} = 14.52 kA.

From above conditions, the switchboard in this case shall be rated **20 kA @ 0.2 secs**.

<u>Case II;</u>

Clearing time

$t = (k_e \times I_r) / (I_f)^{1.5}$

The main protection device shall be selected to the full load current of the transformer which is 1082.5 A. Let us use a 1000 A circuit breaker.

$t = (250 \times 1000) / (19.98 \times 1000 \times 30\%)^{1.5}$

t = 0.539 secs

From AS/NZS 3439.1:2002 (IEC 60439-1:1999 MOD) Clause 7.5.3 Table 4, the *n* multiplier for 19.98 kA fault current is 2.

$I_{PEAK} = n \times I_F = 2 \times 19.98$

$\mathbf{I_{PEAK} = 39.96\ kA}$

The switchboard in this case shall be rated **40 kA @ 0.2 secs**.

VI. Selection of Equipment

To future proof the switchboard in our case study, the higher rating needs to be selected. It should be made clear to the client however that the selected rating will have a higher initial investment.