REF.: http://s.pangonilo.com/index.php/tutorials/mva-method/mva-method-short-circuit-calculation/1

MVA Method Short Circuit Calculation

A Short Circuit Study is an important tool in determining the ratings of electrical equipment to be installed in a project. It is also used as a basis in setting protection devices. Computer software simplifies this process however, in cases where it is not available, alternative methods should be used. The per-unit and ohmic method are very tedious manual calculation. These hand calculations are very prone to errors due to so many conversion required. In per unit, base conversion is a normal part of the calculation method while in ohmic method, complex entities conversion.The easy way to do hand calculation is the MVA method.

In this example, we shall be presenting a short circuit study of a power system. Motors are are already lumped with ratings 37kW and below assigned an impedance value of 25% while larger motors are 17%. A 4MVA generator is also included into the system to augment the utility.

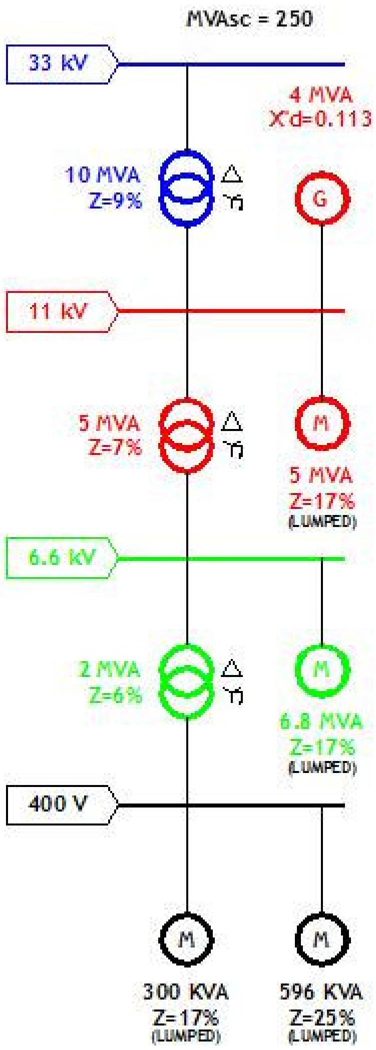


Figure 1

Utility: 33KV, 250 MVA_{sc}
Transformer 1: 10 MVA, 33/11KV, 9% Z

11KV Bus
Generator: 3MVA, $X''_d = 0.113$
Transformer 2: 5 MVA, 11/6.6KV, 7% Z
Motor 1: 5MVA (Lumped), 17% Z

6.6KV Bus
Transformer 3: 2 MVA, 6.6KV/400V, 6% Z
Motor 3: 6.8 MVA (Lumped), 17% Z

400V Bus
Motor 4: 300 KVA (Lumped), 17% Z
Motor 5: 596 KVA (Lumped), 25% Z

In the event of a short circuit, the sources of short circuit current are
1. Utility
2. Generators
3. Motors

Static loads such as heaters and lighting do not contribute to short circuit.

The "Equivalent MVA" are:

Transformers and Motors

$$MVA_{SC} = \frac{MVA}{Z}$$

Generators

$$MVA_{SC} = \frac{MVA}{X_d''}$$

Cables and Reactors

$$MVA_{SC} = \frac{KV^2}{Z}$$

In Figure 1, I have calculated the Equivalent MVAs of each equipment, writing it below the ratings.

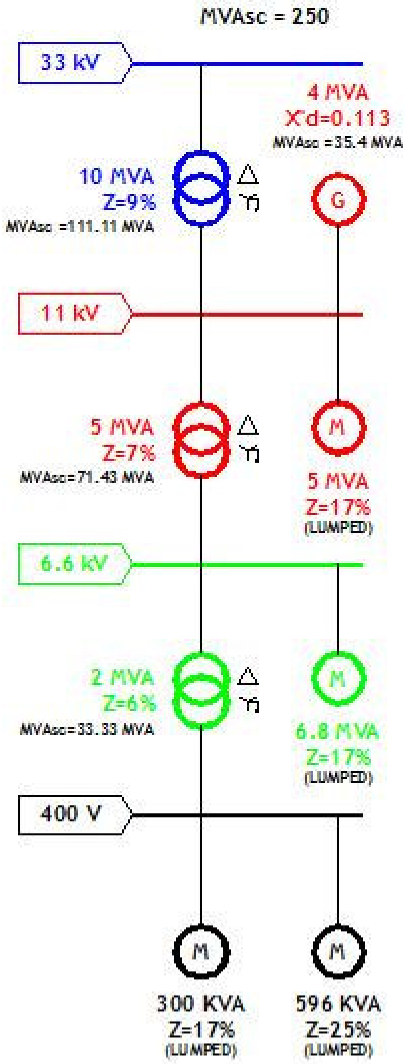


Figure 2

Utility: MVAsc = 250MVA
Transformer 1: MVAsc = 10 / 0.09 = 111.11 MVA

11KV Bus
Generator: MVAsc = 3 / 0.113 = 35.4 MVA
Transnformer 2: MVAsc = 5 / 0.07 = 71.43 MVA
Motor 1: MVAsc = 5 / 0.17 = 29.41 MVA

6.6KV Bus
Transformer 3: MVAsc = 2 / 0.06 = 33.33 MVA
Motor 3: MVAsc = 6.8 / 0.17 = 40 MVA

400V Bus
Motor 4: MVAsc = 0.3 / 0.17 = 1.76 MVA
Motor 5: MVAsc = 0.596 / 0.25 = 2.38 MVA

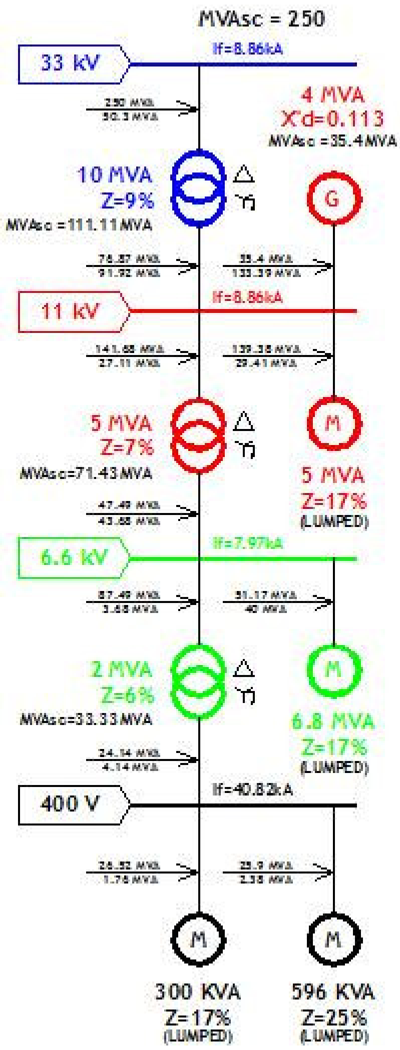


Figure 3

Upstream Contribution

Starting from the utility, combine MVAs writing each one above the arrows.

At Transformer 1:
MVAsc @ 33KV = 250 MVA
MVAsc @ 11KV = 1/ (1 / 250 + 1 /111.11) = 76.87 MVA

At Transformer 2:
MVAsc @ 11KV = 76.87 + 35.4 + 29.41 = 141.68 MVA
MVAsc @ 6.6KV = 1/ (1 / 141.68 + 1 / 71.43) = 47.49 MVA

At Transformer 3:
MVAsc @ 6.6KV = 47.49 + 40 = 87.49 MVA
MVAsc @ 400V = 1/ (1 / 87.49 + 1 / 33.33) = 24.14 MVA

At 400V Motors
Motor 3: MVAsc = 24.14 x 1.76 / (1.76 + 2.38) = 10.26 MVA
Motor 4: MVAsc = 24.14 x 2.38 / (1.76 + 2.38) = 13.88 MVA

Downstream Contribution

Starting from the bottom (400V Bus), I combined MVAs writing each one below the arrows. In this bus, the motor contribution to short circuit is the sum of the MVAs of the lumped motors Motor 3 and Motor 4.

At Transformer 3:
MVAsc @ 400V = 1.76 + 2.38 = 4.14 MVA
MVAsc @ 6.6KV = 1/ (1 / 4.14 + 1 / 33.33) = 3.68 MVA

At Transformer 2:
MVAsc @ 6.6KV = 3.68 + 40 = 43.68 MVA
MVAsc @ 11KV = 1/ (1 / 43.68 + 1 / 71.43) = 27.11 MVA

At Transformer 1:
MVAsc @ 11KV = 27.11 + 29.41 + 35.4 = 91.92 MVA
Note: Two downstream plus the generator contribution.
MVAsc @ 33KV = 1/ (1 / 91.92 + 1 /111.11) = 50.3 MVA

To determine the Faults Current at any bus on the power system, add the MVA values above and below the arrows. The sum should be the same on any branch.
Example:
11 KV Bus:
From Transformer 1: MVAsc = 76.87 + 91.92 = 168.79 MVA
From Generator : MVAsc = 35.4 + 133.39 = 168.79 MVA
From Transformer 2: MVAsc = 141.68 + 27.11 = 168.79MVA
From Motor 1: MVAsc = 139.38 + 29.41 = 168.79 MVA

This is a check that we have done the correct calculation.
Ifault @ 11KV = 168.79 / (1.732 x 11) = 8.86 kA

All we have done above are three phase faults, you may ask, how about single phase faults?

For single phase faults, positive sequence, negative sequence and zero sequence impedances need to be calculated.

If = 3 (I1 + I2 + I0)

Examining the circuit in Figure 1, at the 400V Bus, on Transformer 3 contributes to the zero sequence current.

For transformers, the negative sequence and zero sequence impedance are equal to the positive sequence impedance.

Z1 = Z2 = Z0 or
MVA1 = MVA2 = MVA0

At the 400V Bus

1 / MVAsc =1/3 (1 / MVAsc1 + 1 / MVAsc2 + 1 / MVAsc0)
1 / MVAsc = 1/3 (1 / 28.28 + 1 / 28.28 + 1 / 33.33)
MVAsc =3 xÂ 9.93 = 29.79Â MVA

If = 29.79 / (1.732 x 0.4) = 43 kA

At 6.6KV Bus

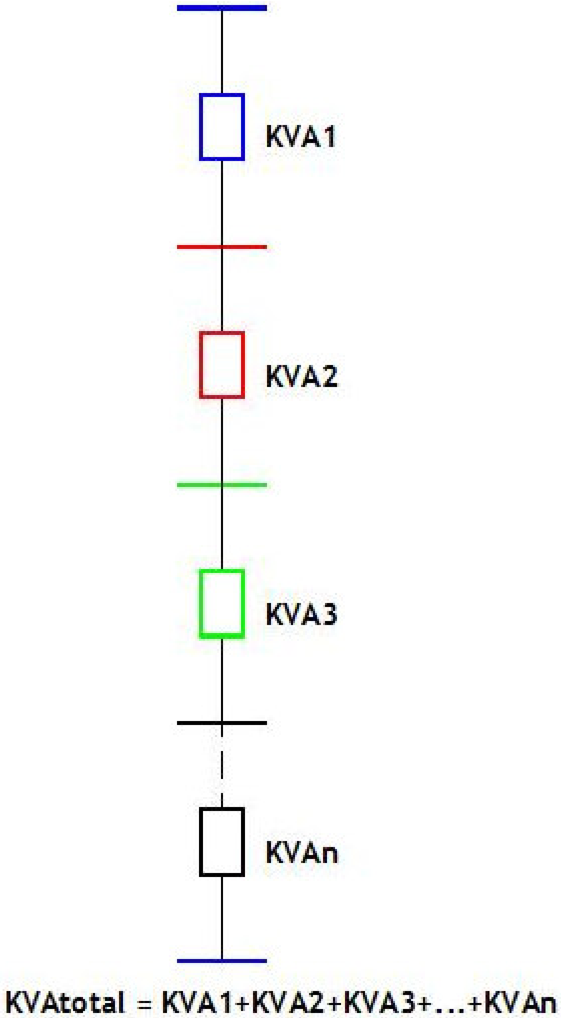
1 / MVAsc = 1/3 (1 / MVAsc1 + 1 / MVAsc2 + 1 / MVAsc0)
1 / MVAsc = 1/3 (1 / 91.17 + 1 / 91.17 + 1 / 71.43)
MVAsc = 3 x 27.83Â = 83.49 MVA

If = 83.49 / (1.732 x 6.6) = 7.26 kA

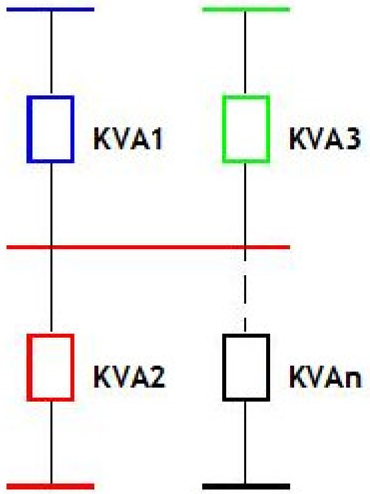
Conclusion:
This example illustrates that using the MVA Method of Short Circuit Calculation, it will be very easy to calculate the fault current at any node within a power system.

Combining KVAs

KVAs in series. The total KVAs in series (KVAtotal) is the reciprocal sum or inverse sum of all series KVAs.



KVAs in parallel. The total KVAs in parallel (KVAtotal) is the arithmetic sum of all parallel KVAs in parallel.



$$\frac{1}{KVAtotal} = \frac{1}{KVA1} + \frac{1}{KVA2} + \frac{1}{KVA3} + \ldots + \frac{1}{KVAn}$$

MINHA NOTA: The generator MVAsc and The motor 1 MVAsc

1. Both values are calculated:
   133.39 = 76.87 + 27.11 + 29.41

   139.38 = 76.87 + 27.11 + 35.4

2. *Short Circuit KVA of Circuit Elements*

Utility: KVA_{SC} = Utility FAULT DUTY (KVA)
Example:
Fault Duty = 0.04 pu @ 100MVA
KVA_{SC} = (100/0.04) x 1000 = 2,500,000 kVA

Generator: $KVA_{SC} = (100 \times KVA_G) / \%Z = KVA_G / X''_d$
Example:
Generator 50 MVA, 11 000 V, $X''_d = 0.113$
KVA_{SC} = (50 x 1000) / 0.113 = 442,478 kVA

Motor: $KVA_{SC} = (100 \times KVA_M) / \%Z = KVA_M / X''_d$
Example:

Motor 1500 HP, 4000V, FLA = 193, $X''_d = 0.167$.
$KVA_{SC} = 1500 / 0.167 = 9000$ kVA

Transformer: $KVA_{SC} = (100 \times KVA_T) / \%Z = KVA_T / Z_{pu}$
Example:
Transformer 132kV / 11kV, 3PH, 50/56MVA @ 55^{O}C, 66.5 / 74.5 MVA @ 65^{O}C, OA/FA, Z = 9% @ 50MVA
$KVA_{SC} = 50 \times 1000 / 0.09 = 555{,}555$ kVA

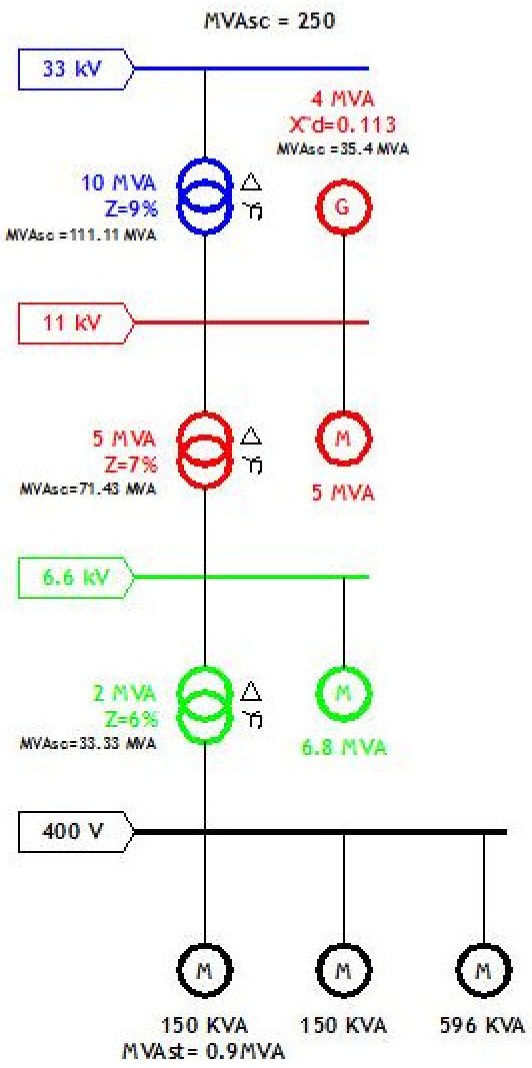
Reactor: $KVA_{SC} = (1000 \times KVA^2) / Z$ (ohms)
Example:
Reactor 11 kV, 0.125 ohms
$KVA_{SC} = 11^2 \times 1000 / 0.125 = 1{,}523{,}520$ kVA

Cable: $KVA_{SC} = (1000 \times KVA^2) / Z$ (ohms)
Example:
Cable : 3/C - 185 mm^2, 400V, 150 m, R = 0.0258 / km, X = 0.027 / km
$Z = (0.0258^2 + 0.027^2)^{0.5} \times 150 / 1000 = 0.0056$ ohms
$KVA_{SC} = 0.40^2 \times 1000 / 0.0056 = 28{,}571$ kVA

MVA Method Load Flow Calculation

In previous tutorials for the MVA method, we have discussed the importance of Short Circuit Study, combining KVAs and Short Circuit Calculations for three (3) phase and single phase faults. In this part of the tutorial, we will be discussing about Load Flow and Voltage Dips during motor starting.

We shall be using the same single line diagram as in the previous tutorial, except that the 2 x 150 MVa motors at the 400V Bus are now separate. We will calculate the Load Flow and Voltage dips for starting a 150MVA motor at the 400V Bus when all loads are running.



In Load Flow Calculations, the "Equivalent MVA" of equipment are:

Utility: MVA_{sc} = Utility Fault Duty (MVA_{sc})

Generator : $MVA_{sc} = 100 \times MVA_G / \%Z = MVA_G / X''_d$

$$MVA_{sc} = \frac{MVA}{X''_d}$$

Running Motor: MVA_M = Motor HP / 1000 = Motor KW / 0.75

Starting Motor : MVA_S = 6 x Motor HP / 1000 = 6 x Motor KW / 0.75

Transformer:

$$MVA_{SC} = \frac{MVA}{Z}$$

Reactor & Cable:

$$MVA_{SC} = \frac{KV^2}{Z}$$

Static Loads: MVA_{SC} = Actual MVA

The differences between a Short Circuit Calculation and Load Flow Calculation are:
1. Motor MVAs are equal to the rated Equivalent MVAs.
2. Starting Motor MVAs are equal to 6 times rated Equivalent MVAs.
3. Static Loads are included in the calculations.

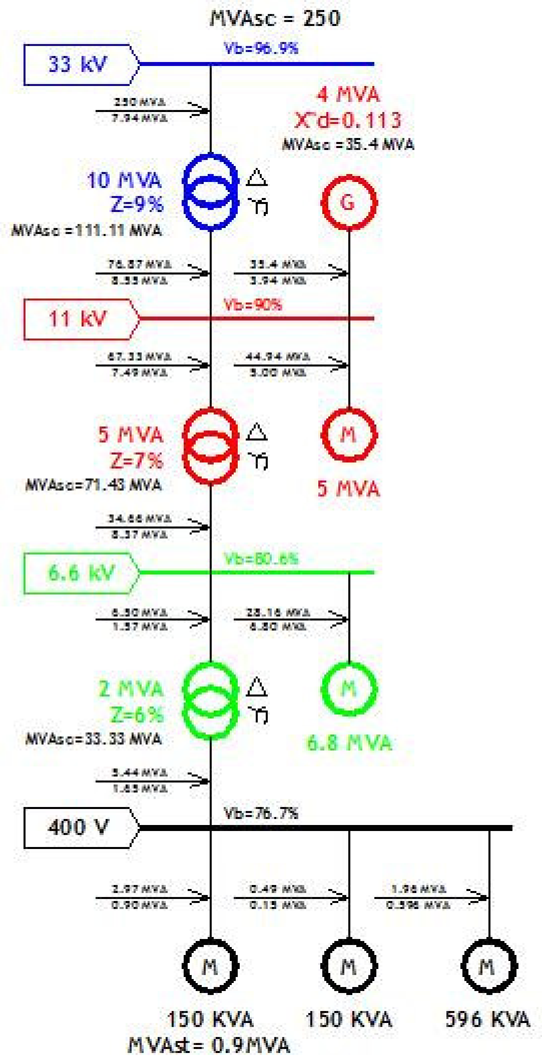
In this Load Flow Calculation, we assume that a 150 MVA motor is being started at the 400V Bus after all loads has been started.

In Load Flow, the upstream contribution is equal to the downstream. Available MVAs are equal to the ratio of the MVA_{sc} of each branch.

At 11KV Bus:
Upstream: MVA_t = 76.87 + 35.4 = 112.27 MVA
Downstream: MVA_t = 7.49 + 5.0 = 12.49 MVA

Voltage dip at the 400V Bus during motor starting

V_d = 2.97 / (2.97 + 0.9) = 76.7 % or 306.8 V



The above calculation indicates that when all loads are already running, starting a 150MVA motor at the 400V Bus is not possible as the voltage dip is lower that the 85% which is the minimum starting voltage for a motor. It means that operational procedures should be in placed to have efficient plant operations.

MVA Method Unbalance Fault Calculation

In the MVA Method Short Circuit Calculation tutorial, we have discussed how to calculate the three (3) phase and phase to ground fault currents.

The faults currents for three (3) phase unbalance faults are as follows:

1. Three (3) Phase Fault

$$KVA_{SC} = KVA_1$$

2. Phase to Ground Fault

$$KVA_{sc} = \frac{3}{\frac{1}{KVA_1} + \frac{1}{KVA_2} + \frac{1}{KVA_0}}$$

3. Phase to Phase Fault

$$KVA_{sc} = \frac{\sqrt{3} \times KVA_1}{2}$$

4. Phase to Phase to Ground Fault

$$KVA_{sc} = \frac{3 \times KVA_1 \times KVA_0}{KVA_1 + KVA_2 + KVA_0}$$

Using the same example as in the MVA Method Short Circuit Calculation tutorial, we will calculate the

1. Phase to phase Fault
2. Phase to phase to Ground Fault

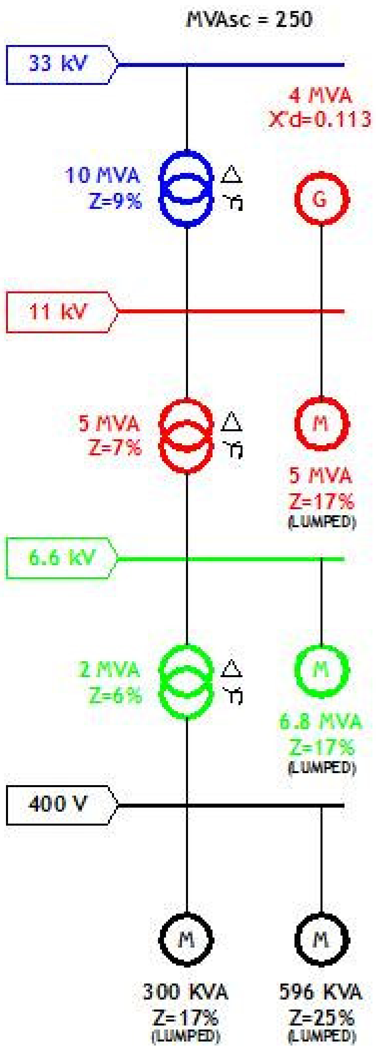


Figure 1

In the above example, we calculated the **Single Phase to Ground Faults**

At the 400V Bus

MVAsc =3 (1 / MVAsc1 + 1 / MVAsc2 + 1 / MVAsc0)

MVAsc = 3 (1 / 28.28 + 1 / 28.28 + 1 / 33.33)

MVAsc =3 x 9.93 = 29.79 MVA

I_f = 29.79 / (1.732 x 0.4) = 43 kA

At 6.6KV Bus

MVAsc = 3 (1 / MVAsc1 + 1 / MVAsc2 + 1 / MVAsc0)

MVAsc = 3 (1 / 91.17 + 1 / 91.17 + 1 / 71.43)

MVAsc = 3 x 27.83 = 83.49 MVA

If_f = 83.49 / (1.732 x 6.6) = 7.26 kA

Knowing the values of MVA_1, MVA_2 and MVA_0, we will be able to calculate the following unbalanced faults.

Phase to phase Faults

At the 400V Bus

$$KVA_{sc} = \frac{\sqrt{3} \times KVA_1}{2}$$

Using MVAs instead of KVAs

MVAsc = 1.732 (MVAsc1) / 2

MVAsc = 1.732Â (28.28) /2

MVAsc =24.5 MVA

I_f = 24.5 / (1.732 x 0.4) = 35.4 kA

At 6.6KV Bus

MVAsc = 1.732 (MVAsc1) / 2

MVAsc = 1.732Â (91.17) /2

MVAsc =78.96 MVA

I_f = 78.96 / (1.732 x 6.6) = 6.91 kA

Phase to phase to ground Faults

At the 400V Bus

$$KVA_{sc} = \frac{3 \times KVA_1 \times KVA_0}{KVA_1 + KVA_2 + KVA_0}$$

Using MVAs instead of KVAs

MVAsc = 3Â x 28.28 x 33.33 / (28.28 + 28.28 + 33.33)

MVAsc = 31.46 MVA

I_f = 31.6 / (1.732 x 0.4) = 45.4 kA

At 6.6KV Bus

MVAsc = 3 x 91.17 x 71.43 / (91.17 + 91.17 + 71.43)

MVAsc =77 MVA

I_f = 77 / (1.732 x 6.6) = 6.73 kA

NOTAS:

1. *davidcris castro says*

   In the calculation of the Line to Ground Fault at the 400V bus above, the MVAsc0 = 33.33 which is the equivalent MVA of the 2MVA Transformer only. Why is it that the contributions of the 300kVA and 596kVA motors are not considered? They are not blocked by the transformer. MVAsc0 must be 41.43. May be a case of oversight?…

   July 29, 2009, 7:31 AM

2. *Ver says*

   The contribution of the 400V motors are already considered on the MVAsc1 = 28.28 & MVAsc2 = 28.28. Motors do not contribute to the zero sequence fault current as these are commonly delta connected or if wye connected, motors are ungrounded thus not contributing to the zero sequence current. It is only the transformer therefore which contributes to the zero sequence current.