Electrical Fault Level Calculations Using the MVA Method

By Lee Wai Meng J. M. PANG & SEAH (PTE) LTD

Introduction

With modern day personal computers, hand calculations for electrical fault level are becoming a thing of the past. The classical hand calculations, either the ohmic method or the per unit method, will need many formulas and conversions. The ohmic method is cumbersome when there are several different voltage levels. The per unit method is not much better because of the many conversions of data to the choosen base values. The complexity is significantly increased when symmetrical component theory is used to solve single phase to earth faults, double phase to earth faults, and phase to phase faults. Most electrical engineers will blindly memorize these abstract formula and cumbersome conversions. When these engineers are needed to provide on the spot estimates of fault level which are quick and reasonably accurate, they will often fail to deliver. When software programmes are used, it is not uncommon to have errors in modelling and data entry, which will produce fault level several order of magnitude in error from the correct value. This article describes the MVA method, a hand calculation method which is easy to use, easy to remember, quick and accurate.

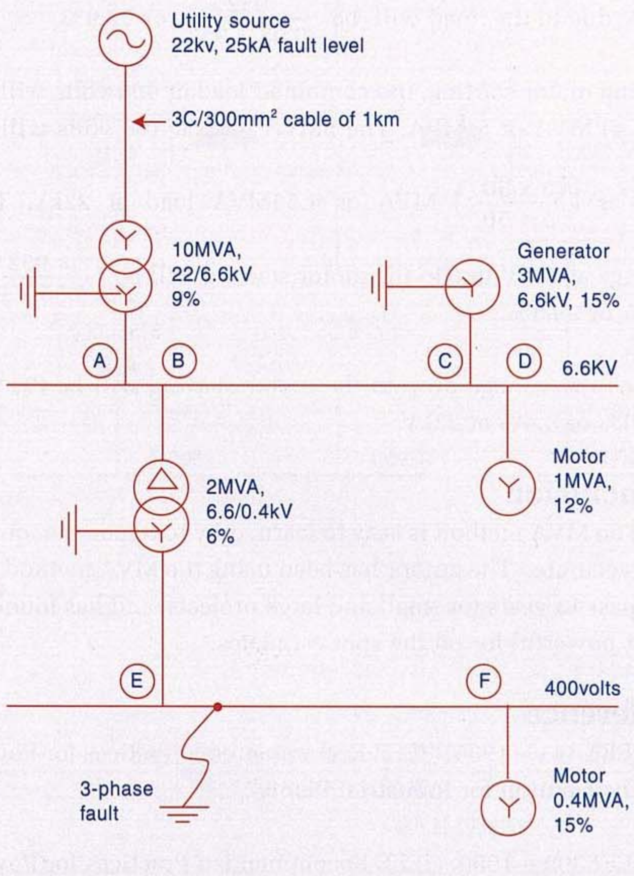

Figure 1: Typical single line

The MVA Method

The MVA method is a modification of the ohmic method. The first step is to convert the typical single line diagram to the equivalent MVA single line diagram, and then to reduce the MVA single line diagram into a single MVA value at the point of fault. The components of a typical single line are the utility source, transformers, motors, cables and internal generators. Figure 1 is a typical single line diagram.

22kV Utility Source

The MVA value will be $\sqrt{3} \times 22 \times 25 = 952$MVA.

The utility source has a 25kA fault level.

10MVA Transformer

The MVA value will be $\frac{10}{0.09} = 111$ MVA

The transformer has 9% impedance

2MVA Transformer

The MVA value will be $\frac{2}{0.06} = 33$ MVA

The transformer has 6% impedance

6.6kV Motor

The MVA value will be $\frac{1}{0.12} = 8.3$ MVA

The motor has a sub-transient reactance of 12% and will contribute fault current to the fault.

400 Volts Motor

The MVA value will be $\frac{0.4}{0.15} = 2.7$ MVA

The motor has sub-transient reactance of 15% and will contribute fault current to the fault.

Internal Generator

The MVA value will be $\frac{3}{0.15} = 20$ MVA

The generator is synchronized to the utility source and has a sub-transient reactance of 15%.

22kV Cable

The MVA value will be $\frac{V^2}{Z}$,

Where V is the phase to phase voltage in kV

Z is the per phase impedance in ohm.

The MVA value will be $\frac{22 \times 22}{0.2} = 2420$ MVA

MVA Single Line

Figure 2 is the equivalent MVA single line of the typical single line of Figure 1. The next step is to reduce the MVA single line to a single MVA value at the point of fault. The reduction uses basic mathematics, either add up the MVA values or "parallel up" the MVA values. Figure 3 illustrates the steps for the reduction of the MVA single line to a single MVA value at the point of fault. The fault level for a 3 phase fault at 400 volts is 28.7MVA or 41.4kA.

Advantages of the MVA Method

- There is no need to convert impedance from one voltage to another, a requirement in the ohmic method .
- There is no need to select a common MVA base and then to convert the data to the common MVA base, a requirement in the per unit method. The formulas for conversion are complex and not easy to remember.
- Both the ohmic method and per unit method usually end up with small decimals. It is more prone to make mistakes in the decimal with resulting errors several orders of magnitude from the correct value.
- The MVA method uses large whole numbers. This makes for easier manipulation and hence less prone to errors.

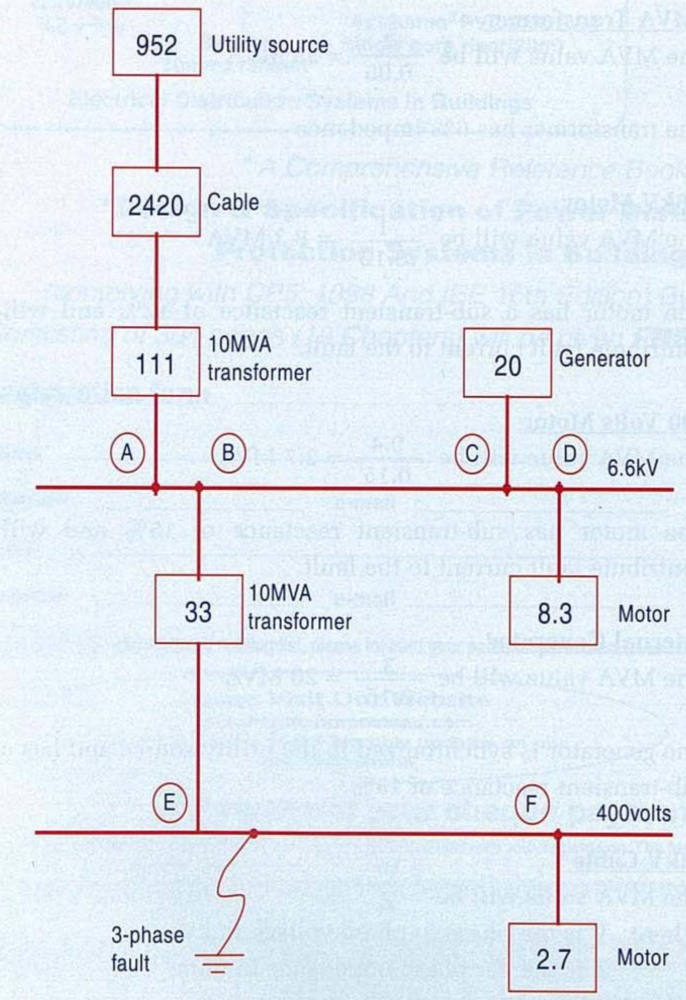

Figure 2: Equivalent MVA single line

Single Phase to Earth Fault

So far the calculations were for three phase fault. The MVA method can be used to calculate single phase to earth fault, and illustrated in Figure 4. The positive sequence MVA will be the value calculated in the previous example, and in most applications the positive sequence MVA will be the same as the negative sequence MVA. The zero sequence MVA will usually be different from the positive sequence MVA. For example in Figure 1, only the 2MVA transformer will contribute to the earth fault at 400 volts through the neutral connected solid to earth.

The zero sequence MVA of the 2MVA transformer is equal to the positive sequence

MVA value of the transformer of ($\frac{2}{0.06}$) MVA or 33.3 MVA.

Voltage Drop During Motor Starting

The MVA method can also be used to calculate the voltage drop during large motor starting. The voltage drop is equal to the motor starting MVA divided by the sum of the motor starting MVA and the short-circuit MVA. Figure 5 is an example. A constant 1 MVA load is assumed before the starting of the large motor. The MVA value of the transformer is 50MVA. The 1MVA load at 400 volts will be seen as a ($\frac{1 \times 50}{1 + 50}$) MVA or 0.98 MVA load at 22kV. The voltage at

22kV due to the load will be $\frac{952}{0.98 + 952}$ or 99.9%.

During motor starting, the combined load at 400 volts will be (1 + 4) MVA or 5 MVA. The 5MVA load at 400 volts will be

seen as ($\frac{5 \times 50}{5 + 50}$) MVA or 4.55MVA load at 22kV. The

voltage at 22kV due to the motor starting will be $\frac{952}{4.55 + 952}$ MVA or 99.5%.

Hence the voltage drop to the motor starting will be (99.9 – 99.5)% or 0.4% at 22kV.

Conclusion

The MVA method is easy to learn, easy to remember, quick and accurate. The author has been using the MVA method for the past 13 years for small and large projects, and has found it most powerful for on the spot estimates.

Reference

[1] IEEE 141 – 1986, "IEEE Recommended Practices for Power Distribution for Industrial Plants"

[2] IEEE399 – 1990, "IEEE Recommended Practices for Power System Analysis."