ATTACHMENT G SAMPLE CALCULATION OF FLASH PROTECTION BOUNDARY

ARC ENERGY AND TEMPERATURE RISE

The following provides an explanation of the development of the arc energy and temperature rise on a person's exposed skin due to the various strengths of electric arc blasts at various distances from the involved person. The formulae used in this explanation are from Ralph Lee's paper, "The Other Electrical Hazard, Electrical Arc Blast Burns," IEEE Transactions Industrial Applications, Vol. 1A-18, No. 3 Page 246, May/June 1982. The calculations are based on worst case arc impedance Attachment E.

BASIC EQUATIONS FOR CALCULATING FLASH PROTECTION BOUNDARY DISTANCES

The short-circuit symmetrical amperes from a bolted 3-phasefault at the transformer terminals is calculated with the following formula:

$$I_{sc} = \left\{ \left[\text{MVA base} \times 10^6 \right] \Big/ \left[\sqrt{3} \times V \right] \right\} \times \left\{ \frac{100}{\%Z} \right\} \qquad \text{(Eq. 1)}$$

Where: I is in Amperes; V is in Volts; and %Z is based on the transformer MVA.

A typical value for the maximum power in MW in a three-phase arc may be calculated using the following formula:

$$P = \left[\text{Maximum bolted fault in MVA}_{bf} \right] \times 0.7072 \qquad \text{(Eq. 2)}$$

The flash protection boundary distance is calculated in accordance with the following formulae:

$$P = 1.732 \times V \times I_{sc} \times 10^{-6} \times 0.707^2 \qquad \text{(Eq. 3)}$$

$$D_c = \left[2.65 \times MVA_{bf} \times t \right]^{1/2} ; \text{ or} \qquad \text{(Eq. 4)}$$

$$D_c = \left[53 \times MVA \times t \right]^{1/2} \qquad \text{(Eq. 5)}$$

Where:

D_c = Distance in feet of person from arc source for a just curable burn, i.e., skin temperature rise over a 30°C ambient remains less than 50°C.

MVA_{bf} = Bolted fault MVA at point involved

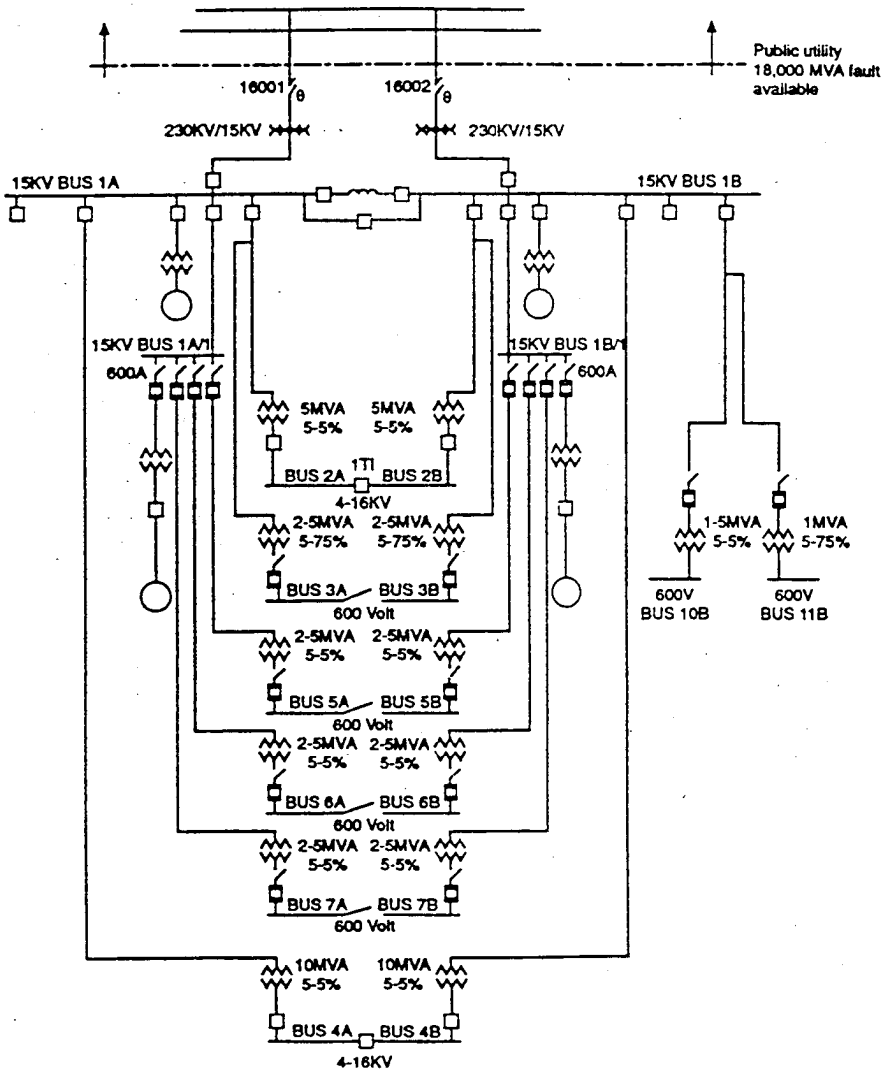
MVA = MVA rating of transformer. For transformers with MVA ratings below 0.75 MVA, multiply the transformer MVA rating by 1.25.

t = Time of arc exposure in seconds.

The clearing time for a current limiting fuse is approximately 1/4 cycle or 0.004 seconds. The clearing time of 5kV and 15kV circuit breakers can be 0.110 seconds (s) or 7.5 cycles in a 60 Hz system. This time consists of 0.016s for device 50 relay operation, 0.014s for device 86 relay operation, and 0.080s for the breaker contacts to clear the arc. The normative values used in these calculations are 0.1 seconds and 6 cycles

SINGLE LINE DIAGRAM OF A TYPICAL INDUSTRIAL COMPLEX

The single line diagram illustrates the complexity of a power distribution system in a typical large industrial plant. It is the basis used to evaluate the flash burn hazards at various locations in the distribution system and to perform the sample calculations that follow.



SAMPLE CALCULATIONS

Many of the electrical characteristics of the system and equipment are shown in Table 1. The sample calculation is made on the 4160 volt Bus 4A or 4B. Table 1 tabulates the results of calculating the flash protection boundary each part of the system.

1. Calculation is on a 4160 volt bus.
2. Transformer MVA (and base MVA) = 10 MVA
3. Transformer impedance on a 10 MVA base = 5.5%
4. Circuit breaker clearing time = 6 cycles
5. Based on (Eq. 1), calculate the short circuit current:

$$I_{sc} = \left\{ \left[10 \times 10^6 \right] \Big/ \left[\sqrt{3} \times 4160 \right] \right\} \times \left\{ \frac{100}{5.5} \right\}$$

$I_{sc} = 25,000$ Amperes

6. Based on (Eq. 3), calculate the power in the arc

$$P = 1.732 \times V \times I_{sc} \times 10^{-6} \times 0.707^2$$

$$P = 1.732 \times 4160 \times 25,000 \times 10^{-6} \times 0.707^2$$

$P = 91$ MW

7. Based on (Eq. 4), calculate the curable burn distance:

$$D_c = \left[2.65 \times \left(MVA_{bf} \right) \times t \right]^{1/2}$$

$$D_c = \left[2.65 \times \left(1.732 \times 4160 \times 25,000 \times 10^{-6} \right) \times t \right]^{1/2} = 6.9 \text{ feet} \Rightarrow 7.0 \text{ feet}$$

Or, using (Eq. 5), calculate the curable burn distance using an alternate method:

$$D_c = \left[53 \times MVA \times t \right]^{1/2}$$

$$D = \left[53 \times 10 \times 0.1 \right]^{1/2} = 7.28 \text{ feet}$$

Table 1

Flash Burn Hazards at Various Levels in a Large Industrial Plant

1	2	3	4	5	6	7
Bus Nominal Voltage Levels	System or Transformer MVA	System or Transformer %Z	Short Circuit Symmetrical Amperes	Arc MW	Fault Clearing Time-Cycles	Distance from Arc to Skin**
230,000 V	9000	1.11	23,000	4000	6.0	46.0
13, 800 V	750	9.4	31,300	374	6.0	14.1
Load Side of all 13.8 kV Fuses	750	9.4	31,300	374	1.0	5.8
4,160 V	10	5.5	25,000	91	6.0	7.3
4,160 V	5	5.5	12,600	45	6.0	6.7
Line Side of Incoming 600 V Fuse	2.5	5.5	44,000	23	6.0	3.7
600 V Bus	2.5	5.5	44,000	23	0.25	0.74
600 V Bus	1.5	5.5	26,000	27	6.0	2.8
600 V Bus	1.0	5.57	17,000	17	6.0	2.3

**Distance limits skin temperature to a curable burn, i.e., limits skin temperature rise to 80°C or less