ELECTRICAL POWER SYSTEM FAULT ANALYSIS USING ETAP

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ABSTRACT

Short circuit analysis and arc flash analysis are crucial for ensuring the safety and reliability of any electrical network. The short circuit analysis will determine the available fault current in the system, while the arc flash analysis will determine the incident energy at each bus. The results of these analyses will be used to assess the adequacy of the system's protective devices and to develop arc flash hazard labels for the system's equipment. In this paper, a one-line diagram of the 3-bus system has been developed. This one-line diagram depicts the location and type of equipment including buses, transformers, circuit breakers, and loads. Subsequently the necessary data for each piece of equipment, such as its impedance and voltage rating are collected and the short circuit analysis is performed. This analysis will determine the available fault current at each bus in the system.

KEYWORDS

Short circuit analysis, Three bus system, Arc Flash

1. INTRODUCTION

Short circuit analysis stands as a pivotal discipline within electrical engineering, wielding the power to unveil critical insights into the magnitude and duration of currents during short circuit faults. A short circuit fault, arising from the unintended bridging of two points in an electrical circuit with distinct voltage levels, has the potential to unleash an overwhelming current flow. This occurrence not only jeopardizes equipment but also poses grave safety hazards to personnel working with or around the circuit.

The paramount objective of short circuit analysis is to design and operate electrical systems with uncompromising safety. It is a process that hinges on the profound comprehension of potential short circuit currents within a given system. Armed with this knowledge, engineers can meticulously select and design protective devices that possess the capability to safely interrupt the current flow when a fault materializes. Furthermore, short circuit analysis serves as a compass for assessing the repercussions of modifications to existing electrical systems, ensuring their continued robustness.

A short circuit study is performed to determine the magnitude of the potential current flowing in the power system at different time intervals after the fault has occurred[1]. The amplitude of the current flowing in the power system after a fault differs with time until it reaches equilibrium. The behavior is due to the characteristics and dynamics of the system[2].

System devices like cables, busbars, and disconnecting switches, must be able to withstand the maximum mechanical and thermal stress caused due to the maximum short-circuit current flowing through those devices[3].

The current during a short circuit at any point in the system is limited by the impedance of the circuit and the source equipment or sources at the fault point. It is not directly related to the size of the load on the system[4].

The calculated maximum short-circuit current is almost always required. In some cases, minimum holding values are also necessary to verify the sensitivity requirements of current sensitive protective devices[5].

The scale and complexity of many modern industrial systems can make long-term short-circuit current calculations impractical. Calculators are often used for large short circuit studies[6].

2. METHODOLOGY OF IEC SHORT CIRCUIT

IEC 60909 standard is used to examine the average plant's short circuit characteristics in ETAP. IEC uses current-based calculations, while ANSI uses impedance-based calculations. Standard IEC 60909 defines and presents a method implementing symmetrical components, that may be used by engineers not specialized in the field. The method is applicable to electrical networks with a nominal voltage of less than 550 kV and the standard explains the calculation of minimum and maximum short-circuit currents. The former is required in view of calibrating overcurrent protection devices and the latter is used to determine the rated characteristics for the electrical equipment. The procedure is as follows:

1. Calculate the equivalent voltage at the fault location, equal to c Un /3 where c is a voltage factor required in the calculation to account for voltage variations in space and in time, possible changes in transformer tapping's, sub transient behavior of generators and motors Depending on the required calculations.
2. Determine and add up the equivalent positive sequence, negative sequence, and zero sequence impedances upstream of the fault location.
3. Calculate the initial short-circuit current using the symmetrical components. Practically speaking and depending on the type of fault, the equations required for the calculation of the I_{sc} are indicated.
4. Once the rms value of the initial short-circuit current (I''_k) is known, it is possible to calculate the other values: I_p, peak value, I_b, rms value of the symmetrical short-circuit breaking current, I_{dc}, aperiodic component, I_k, rms value of the steady-state short-circuit current.

3. ANALYSIS OF ARC FLASH

3.1. Causes of Arc Flash:

Common causes of arc flash incidents include:

(1) Equipment Failure: When electrical equipment malfunctions or experiences a sudden breakdown, it can lead to the release of dangerous energy in the form of an arc flash.

(2) Dust and Debris: Accumulation of dust and debris on or near electrical components can create a path for electrical arcing, increasing the risk of an arc flash.

(3) Maintenance Issues: Inadequate maintenance, such as loose connections, corrosion, or worn-out components, can weaken the electrical system's integrity and increase the likelihood of an arc flash.

Understanding these common causes is essential for maintaining a safe working environment and preventing potentially life-threatening electrical accidents.

3.2 Impact and Effects of Arc Flash:

Arc flash incidents can result in devastating consequences:

Burns: Arc flashes can produce temperatures hotter than the surface of the sun, causing severe burns to anyone in the vicinity. These burns are not only painful but can lead to disfigurement and long-term physical and psychological trauma.

Injuries: Beyond burns, the force of an arc flash can propel individuals, leading to fractures, concussions, and other physical injuries. Shrapnel from damaged equipment can also cause harm.

Equipment Damage: Arc flashes can destroy electrical equipment, leading to costly downtime and repair or replacement expenses. This not only affects productivity but also strains resources.

3.3 Need for Effective Prevention:

Recognizing the dire consequences of arc flashes underscores the critical importance of effective prevention:

Safety Measures: Implementing comprehensive safety measures, such as wearing appropriate personal protective equipment (PPE) and following established safety procedures, is essential to minimize the risks associated with arc flash incidents.

Regular Maintenance: Thorough and routine maintenance of electrical systems can identify and address issues that might lead to arc flash events, reducing the likelihood of equipment failure.

Training and Awareness: Proper training and raising awareness among personnel are vital to ensure they understand the risks and know how to respond in case of an arc flash emergency.

Compliance with Standards: Adhering to industry standards and regulations related to electrical safety and arc flash prevention is crucial to mitigate these risks effectively.

3.4.Arc Flash Calculations (IEEE 1584 Standard):

Normal system analysis determines the bolted fault current available at various points throughout the electrical system. For incident energy, it is first necessary to input the circuit parameters in order to calculate free-air short-circuit arcing currents. Here it is noted that these arcing currents are significantly less than the available bolted-fault short circuit currents because the arc provides significant circuit impedance.[7] The IEEE 1584 equations for determining arcing currents (for system voltages less than 1000V) are:

$$\log I_a = K + 0.662\log I_{bf} + 0.0966V + 0.000526G + 0.5588V(\log I_{bf}) - 0.00304G(\log I_{bf})$$

Where:

log is the $\log_{10}$

I_a is arcing current (kA)

K is - 0.153 for open configuration and - 0.097 for box configuration

I_{bf} is bolted fault current for a three-phase fault (kA)

V is system voltage (kV)

G is the gap between conductors (mm)

and convert from $\log I_a = 10\log I_a$

The arcing current is then used for determining the incident energy. The IEEE 1584 equations for determining incident energy are to first determine the log 10 of the incident energy normalized:

$$\log E_n = K_1 + K_2 + 1.081\log I_a + 0.0011G$$

Where:

K_1 is -0.792 for open configurations, -0.555 for enclosed

K_2 is 0 for ungrounded & high resist.; -0.113 for grounded

I_a is arcing current (kA)

G is the distance between arcing buses (mm), 25 mm for MCC

Then,

$E_n = 10\log E_n$
Finally, convert from normalized:
$E = C_f \times E_n\ (t/0.2)\ (610_x/D_x)$
Where:
E is incident energy in cal/cm^2
C_f is calculation factor, 1.0 > 1kV; 1.5 <= 1kV
E_n is incident energy normalized for time & distance
t is arcing time (seconds)
D is the distance from arc to person (mm)

The apparent complexity of these equations makes solving them by hand cumbersome, but the "IEEE 1584 Guide" supplies an Excel spreadsheet that will automatically solve them, using input of basic information.[8]

4. MATHEMATICAL MODELLING USING ETAP

A single line diagram has been developed and the table 1 displays all the values given as input to the one-line diagram.

Elements	**Input**				
	Type	**Rating**		**Time Delay**	**Breaking Capacity**
Utility	3 Phase Swing	11 kV	190.526MVA		
11kV Bus	Swing Bus	11 kV			
HVCB	Siemens 12-3AG-25	12 kV	1250 A	0.046 sec	25 kA
Transformer	2-winding IEC Liquid Filled Delta – Star with secondary grounded	11 kV/415 V	2 MVA		
LVCB 1	L&T CN-CS 3200D	0.415 kV	3200 A	0.04 sec	100 kA
415V Bus 1	Load Bus	0.415 kV			
LVCB 2	L&T CN-CS3200 H1	0.415 kV	3200 A	0.04 sec	70 kA
Cable	BS5467 1/C CU XLPE insulated	1.0 kV	100 m	3 conductor/phase	
415V Bus 2	Load Bus	0.415 kV			
Load	Lumped	1.5 MVA	0.415 kV		

Table 1: Input Values of 3-Bus System

Where:
HVCB stands for High Voltage Circuit Breaker
LVCB stands for Low Voltage Circuit Breaker

5. RESULTS

On executing the following results are obtained and is shown in the figure 1.

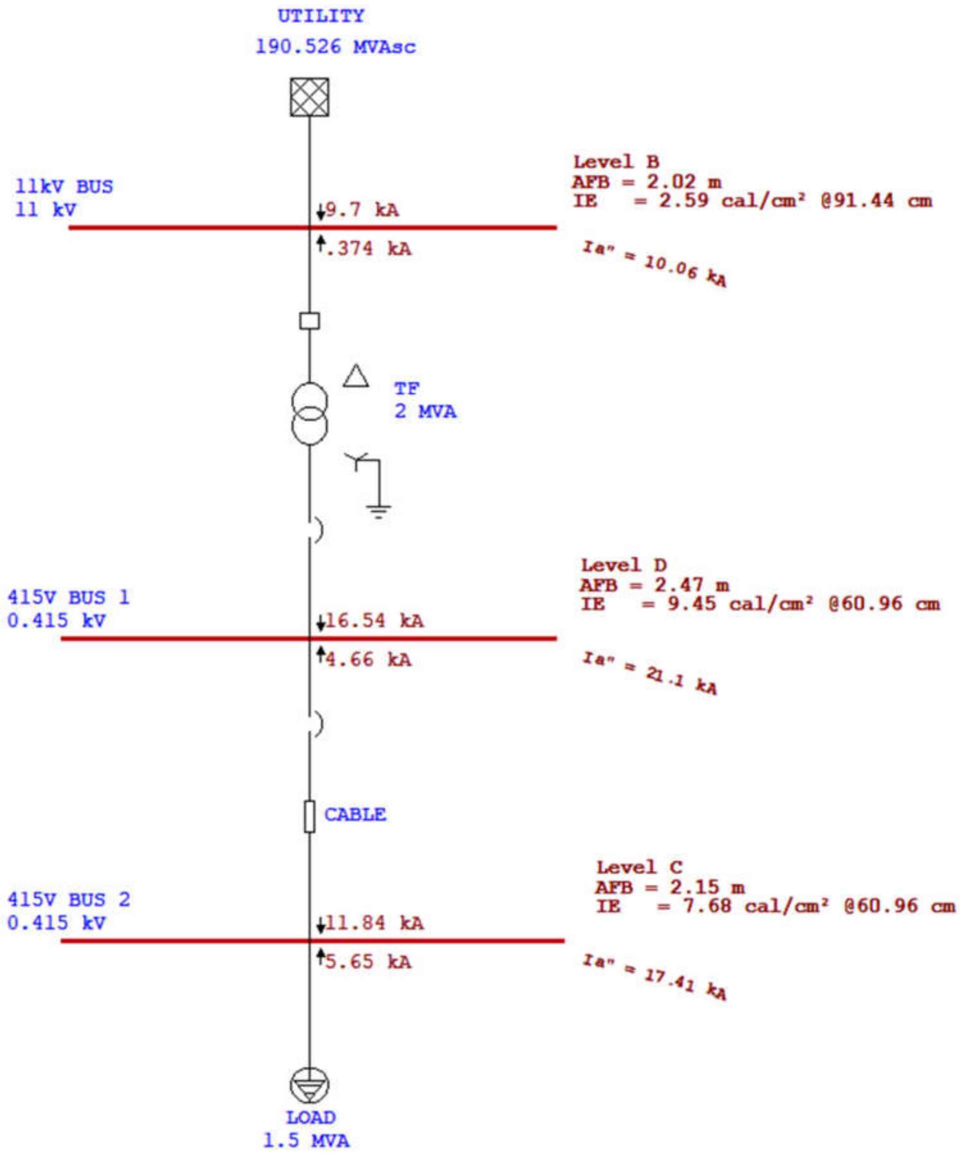

Figure 1: Results

6. CONCLUSION

Arc flash analysis, in synergy with short circuit analysis, takes safety to a higher plane. This analysis focuses on the potential for arc flash events within the electrical system, which can be triggered by short circuits or equipment failures. Arc flash incidents are characterized by intense heat and light, posing significant risks to personnel.

The combined analysis of short circuit and arc flash factors enables engineers to:

- Predict and quantify the incident energy of potential arc flash events.
- Establish safe working boundaries, such as arc flash boundaries and PPE requirements.
- Implement mitigation measures to minimize the impact of arc flash events, safeguarding both individuals and equipment.

7. REFERENCES

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