Arc Flash HazardAnalysis
of
New Gulf Cogen Plant

Wharton County, Texas

Arc Flash Hazard of 480 VAC Circuit Breaker Failure

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Executive Summary:

The Short Circuit and Arc Flash study indicate certain areas of concern; (1) 2.4 KV Bus 1, (2) 2.4 kV Bus 2, (3) 480 V MCC 307, (4) Transformer TR-304 and (5) Transformer XT1A (13.8 kV). The Arc Flash coincident energy exceeds NFPA 70 E acceptable hazard levels in these areas for which PPE is required. The tabular data presented on Study Case: Arc Flash 1, summarizes the circuits and their respective parameters.

Wherever the Arc Flash Study shows the Hazard Level Risk of Level 3 or Level 4 that is where particular attention is is paid to minimize such risks

We propose new digital protective devices be retrofitted on CB-201 & 203 and their fault clearance times be modified to reduce the arc flash hazards on those circuits in particular. Our recommendations for selection of these devices are contained herein below. A table of Arc Flash labels required to be affixed to various equipments is provided in Appendix E.

The HL&P 138 Kv bus is listed because of the high energy levels associated and the hazards that are attendant to operators while in the switchyard performing operating procedures or maintenance. We are not recommending any specific modifications to protective devices in the switchyard at this time, rather it is important that operators be made aware of these hazards and be properly trained to perform operator tasks within the designated boundaries of the switchyard.

It is also noted that some loads were changed or modified such that CB- 211 was originally designed for motor operation and is now serving a transformer load. This change has to be field verified and corrective action in the form of proper Transformer protection relay and or additional transformer secondary relay should be installed.

The existing Transformer differential relays are single phase relays, and instead they should be replaced by 1-3 phase electronic relays, Schweitzer Engineering Laboratories, Relay Cat. No: SEL-387 A or equal, to protect two winding transformers.

For Main Circuit Breakers feeding the 480 V MCC's, CB 301 and CB 303 solid state trip devices should be installed to improve tripping times and therefore, to reduce the Arc Flash Hazard on the 480 V buses.

Methodology:

An electric arc or an arcing fault is a flashover of electric current through air in electrical equipment from one exposed live conductor to another or to ground. Arc flash hazard is the danger of excessive heat exposure and serious burn injury due to arcing faults in electrical power systems. Electric arcs produce intense heat, sound blast and pressure waves. They have extremely high temperatures, radiate intense heat, can ignite clothes and cause severe burns that can be fatal. Although electrical safety programs have existed since the beginning of electricity, arc flash hazard has not been prominently addressed until recently. The criterion used to develop arc-flash hazard analysis is developed by IEEE and is known as the IEEE-1584 Standard.

For the purpose of this study, an updated one line diagram was prepared and questions were asked of the operators in the field to determine which parts of the plant were not operating and therefore, though shown on the one line diagrams, electrical equipment such as pumps, motors, transformers and generators associated with the Steam Turbine Generator was not included in the Short Circuit Study. The 1- line model of the power plant was developed from existing documentary data together with field verified data to confirm nameplate ratings, cable sizes and equipment configurations.

Major segments of our final report:

- redrawn 1-line diagrams faithfully reflect the current physical layout of the electrical systems and form the basis of our analysis;
- current list of protective devices and their electrical parameters
- the physical sizes of interconnecting cables as described on the 1- lines
- the equipment ratings of motors and transformers
- the placement of protective devices comply with current codes and practices
- IEEE – 1584 & NFPA 70E codes provided the roadmap for Arc-flash hazards
- Rated HP, FLA, PF, Efficiency, no. of poles. RPM of motors
- Electrical conductor parameters; CU/AL cable, Seg Bus duct, Iso phase bus duct, size, ampere rating, length (ft), Insulation type, No. of conductors per phase and rating.
- Power distribution equipment: Mfr, model, rating data
- Electrical/Mechanical & Digital Over current Devices: Mfr, model, CT ratio, tap setting, time dial setting, and Inst trip setting.
- Fuses: Mfr, type, Cont amp rating, Short Circuit Interrupting Rating, volt rating.
- L.V. CBs: Mfr, type, Cont Amp Frame rating, LTPU, LTD, STP, STD, INST & GF settings, short cir interrupting rating.
- Molded case CBs: Mfr, type, Cont amp rating, Short cir interrupting rating, inst trip setting.
- Synchronous generators: KVA rating, Output voltage, Hz, No. of poles, saturated synch reactance (X'_{dv}), saturated sub transient reactance (X''_{dv}), transient time constant ($T_{d''}$), armature time constant (Ta).
- Transformers: MVA rating, Pri/Sec winding configuration, voltages, neutral grounding resistor rating, X/R ratio, % impedance at MVA.
- Positive and Zero sequence impedance in per unit on a 100 MVA basis.

Assumptions:

1. For the purpose of this study, Input Grid Data was taken to be 1821.16 MVA at 138 KV, which was obtained from the data on the drawings.
2. Equipment data was verified in the field, such as the nameplates of the transformers, high voltage circuit breakers, and motor loads.
3. The short circuit study and the relay coordination study were based on the drawings provided and that the electrical power system was constructed based on those drawings. However,

over time, some plant modifications were made that may not be reflected on those drawings. Through field observations we confirmed to the extent possible these "As- Built" drawings.

Discussion:

Short Circuit Analysis

Short Circuit Analysis on any electrical system is done so that the system and the associated equipment are properly selected and rated for safe operation of the equipment and the personnel operating them under all normal and abnormal situations. Short circuit analysis requires data on utility, generators, transformers, cables, transmission lines, motors, etc. The name plate of the equipment provides most of the necessary data. In the absence of a particular data, Power systems software such as ETAP has extensive library of manufacturer's data covering most electrical equipment in use today.

When performing short circuit studies, only 3-phase faults were considered when performing arc flash hazard analysis. This may seem odd, but it is consistent with the recommendations in IEEE-1584 and NFPA-70E. There are several reasons for this. One is that 3-phase faults generally give the highest possible short circuit energy and represent a worst case. Another important reason is that experience has shown that arcing faults in equipment or air that begin as line-to-ground faults, can escalate very rapidly into 3-phase faults as the air ionizes across phases. This progression from single-phase to 3-phase happens within a few cycles. Because of this, most testing done on arc flash energy has been based on 3-phase faults.

The highest fault current does not necessarily imply the highest possible arc flash hazard because the incident energy is a function of arcing time, which may be an inversely proportional function of the arcing current for Arc Flash Hazard determinations.

Protective Device Coordination Study

A protective device coordination study is carried out to improve system reliability. This study should be done a power system on a regular basis, perhaps every few years or whenever there are changes in the system. An added goal of such studies is the reduction of incident energy from arc flash. Therefore, while performing the study, one should simultaneously evaluate the arc flash hazard and seek to minimize the hazard by keeping the arcing time as low as possible.

The following procedures were used to determine arcing fault incident energies, bolted fault (short circuit) currents at each bus in the system.

We used the calculated currents to perform a device coordination study and developed system relay and trip settings. The settings were determined, using the ETAP software, by plotting the devices on time current curves. (TCC's)

Using IEEE-1584, arcing faults at each bus in the system were determined. It should be noted that different equations or multipliers are used in the software for voltages < 1.0 KV, 1.0kv<kV<15.0kV, open air, inside box, and various system parameters.

Arcing currents and breaker/relay trip times of each device were applied to determine arc hazard incident energies, arc flash boundaries, working distances and PPE requirements.

Arc Flash Hazard Study

The objective of the arc flash analysis is to investigate a worker's potential exposure to arc flash energy when working near electrical equipment for the purpose of injury prevention and the determination of safe work practices and also to determine the appropriate levels of personnel protective equipment (PPE) per IEEE-1584 and NFPA-70E.
E-TAP software was used to perform the short circuit and arc flash analysis. The arc flash calculations were performed at various buses. See the attached One Line Diagram E – 01 for schematic details.

Discussion and Results:

The report provides the calculated arc flash energy, arc flash protection boundary and the proper class of protective clothing required to optimize safety of arc flash exposure within the arc flash boundary.

The arc flash calculation is obtained from the IEEE Std. 1584-2004 method. The arc flash calculation requires an arcing fault from the bolted 3 phase fault current values derived from the ETAP ANSI short circuit calculations. The clearing time is obtained from the coordination study and is used to calculate the incident energy and arc flash boundary. The incident energy is then used to define the level of PPE required.

Protective Clothing (PPE) for each Hazard /Risk Category per (NFPA-70 E Table 130.7(C) (11)

Category 0: Non-melting, flammable materials with a fabric weight at least 4.5 oz/yd2

Category 1: FR shirt and FR pants or FR Overall

Category 2: Cotton underwear – conventional short sleeve and brief/short, plus FR shirt and FR pants.

Category 3: Cotton Underwear plus FR shirt & pants plus FR coverall

Category 4: Cotton underwear plus shirt & pants plus double layer switching coat pants.

REFERENCES:

Short-Circuit Analysis: The ETAP Short-Circuit Analysis program analyzes the effect of 3-phase, line-to-ground, line-to-line, and line-to-line-to-ground faults on electrical distribution systems. The program calculates the total short circuit currents as well as the contributions of individual motors, generators, and utility ties in the system. Fault duties are in compliance with the latest editions of the ANSI/IEEE Standards (C37 series) and IEC Standards (IEC 60909 and others).

Arc Flash Analysis: The ETAP Arc Flash Analysis module incorporates the latest software technology available to investigate a worker's potential exposure to arc flash energy, which may be required for the purpose of injury prevention and determination of appropriate levels of Personal Protective Equipment (PPE). The incident energy and flash protection boundaries are determined based on the following two available standards for arc flash analysis:
National Fire Protection Agency (NFPA) 70E-2000 and 2004
IEEE Standards 1584-2002 & IEEE 1584a 2004.

Conclusions:

1. Arc Flash Hazard risk levels of 3 and 4 are evident at several locations indicating proper PPE with respect to Category 3 and 4 must be worn when operating this equipment. The hazard labels provide specific recommendations for the level of PPE at each equipment location. It is important that the labels be affixed to the equipment to provide operators guidance for safe work practices.
2. Breaker 211 appears to have been designed with motor protection in mind while it now appears to feed transformer TR-303. We assume that at some time in the past a change was made that was not documented. We propose to revisit this breaker installation and field verify our observation. Then we will propose a modification that includes both transformer primary and secondary protection be installed'.

Recommendations:

1. **Documentation:** It is necessary to document the results of an arc flash hazard assessment in reports and drawings, and also provide protective signs and labels on equipment and in hazardous areas.
2. **Personal Protective Equipment (PPE) Plan:** Based upon the hazard assessment PPE must be selected and provided to the workers. Workers must wear the PPE properly, provide care and maintenance of the PPE, and inspect it before every use and dispose of it after its useful life has expired.
3. **Development of Procedures to Minimize Hazard:** The potential hazard can be minimized by developing safer working methods, providing protective shields, proper work planning etc.
4. **Training for Workers:** Workers who are exposed to arc flash hazard should be well trained to understand what the hazard is, how it is initiated, how to read the documents and warning labels, how to properly wear PPE, and how the hazard can be reduced with safer working procedures.
5. **Safety Audit:** Safety audits should be performed regularly to evaluate various aspects of a safety program. The safety audit should include arc flash hazard. It is necessary to keep the program ongoing rather than implement it as a one-time project.

6. **Replace 51 Relays:** Since available fault current is low, to improve the arc flash hazard situation, a solid state trip devices should be installed at these breakers to replace existing (51) relays.
7. **New Relays:** Three single phase transformer differential relays should be replaced with one (1) electronic solid state relay to perform the same function. An SEL-387A Relay or equal is recommended for this application.

Bibliography:

IEEE- 1584-2002, IEEE Guide for Performing Arc-Flash Hazard Calculations.
ETAP Brochure
NFPA 70E

Appendixes':
Appendix A: Table of 1-line diagrams used in Short Circuit & Arc Flash analysis.
Appendix B: TCC Coordination Curves Star 1 – 6
Appendix C: Table Arc-flash Label forms
Appendix D: ETAP Brochure