PDC and ARC FLASH INVESTIGATION

Chemical Plant Case Study

Business Situation

Electrical systems commonly use fuses and circuit breakers to protect their electrical equipment. In the event that a failure occurs, it would be desirable that a short circuit would affect only the portion of the electrical system where the failure occurs, instead of the entire system. A protective device coordination study is used to analyze the tripping times for the series of overcurrent devices being compared, generally from the source through the largest branch circuit device. The curves are a logarithmically graphical representation of the performance characteristics of the devices at a base voltage of 480 volts.

The methodology is to optimize the selectivity of the devices. Selectivity is the isolation of a faulted circuit to the point of fault without disturbing any of the other protective devices in the system. A properly coordinated system has each of its protective devices adjusted to minimize the negative impact of equipment failures.

As a result of the PDC and Arc Flash Investigation, the Chemical Plant was able to determine the best settings for the new substation protective devices and identify the arc flash hazards, including appropriate label requirements per IEEE 1584 and PPE level required for each electrical bus.

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Technical Situation

The main goal of the protective device coordination (PDC) study is to provide an optimal compromise between the desired system protection and system continuity goals. For maximum system continuity the protective devices have to be selected and adjusted so that only overcurrent protective devices nearest to the fault open and isolate the fault. While these goals are the ideal, most often the settings provided are a reasonable compromise between the often conflicting goals of service continuity and equipment protection/arc flash energy reduction. Where possible, by design, the protective device settings are provided such that the minimum amount of equipment is removed from service due to fault conditions.

For a given Chemical Plant, the protective device coordination (PDC) study was performed to determine the characteristics, ratings, and settings of protective devices to achieve optimum protection and selectivity in the new Power Substation of a Chemical Plant. The coordination curves were developed using the Paladin DesignBase PDC software. The coordination curves were plotted on log-log paper as operating time versus current magnitude to show protective device characteristics and coordination among protective devices.

The National Electric Code (NEC) guidelines are used for cable protection, transformer American National Standards Institute (ANSI) points, and transformer inrush current. Devices with different voltage levels are converted to a common base. If mis-coordination exists, the time-current curves are adjusted as far as possible without overlapping or crossing another curve. Often a compromise between protection and coordination must be made, and some overlap of characteristics may be necessary for the purposes of protection.

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Solution

Paladin DesignBase software was used to perform the PDC and Arc Flash Investigation. Once the electrical system components were identified and laid out as a network, various study aspects were completed and described in detail below.

Time Overcurrent Protection

Protective relay operating times are provided by the manufacturer, and only the ideal expected relay operating time is plotted. Adequate coordinating time interval between protective relays and the upstream protective device should allow for relay operation time, circuit breaker operating time, and a safety margin to allow for relay calibration tolerances. IEEE recommends 0.2 seconds coordinating interval for microprocessor based relays.

Differential Protection

Differential protection is limited to a zone of protection where current flowing into the zone must equal current leaving the zone under normal conditions. This requires Current Transmitters (CT) to be installed at all points where current may enter or leave the zone of protection. Selection of CTs is critical to the proper operation of a differential scheme. The CTs must reflect the primary waveform with fairly high levels of accuracy during periods of high current or DC offset, which may be seen during through faults or transformer inrush.

Motor Protection

For large induction motors, above 1000 HP, the dynamic motor starting program has been employed in order to generate the real motor starting curves that were automatically transferred to the PDC program. However, time-current characteristic curves have been developed for each bus within the scope and objectives of the study. Each coordination plot is accompanied by a one-line diagram to aid in the understanding and analysis of the coordination plots.

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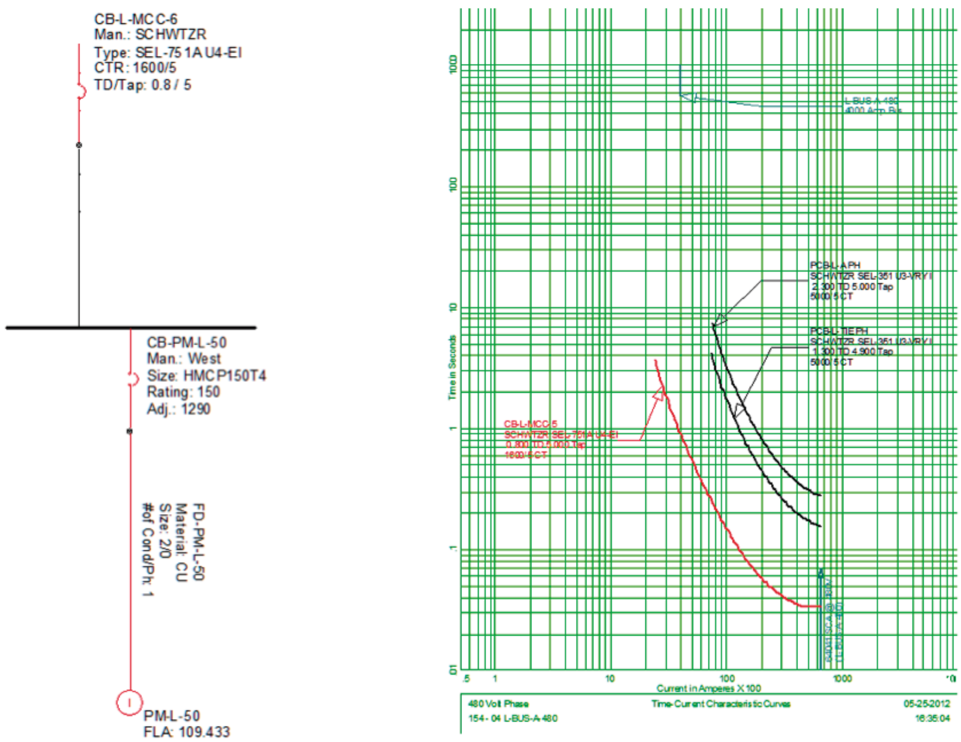
Coordination, PD Selectivity, and PD Curves Plots

The time-current coordination curves for each protective path were developed and are shown in several appendices. A description for each coordination path has been included to aid in understanding the degree of overcurrent protection provided, and the amount of coordination achieved between devices. Several protective paths were investigated in order to check the proper design, selectivity, and protective coordination. The figure below represents one path that was investigated, just as an example.



Arc Flash Investigation

Arc flash calculations are based on the IEEE 1584-2004 Standard and NFPA 70E-2012 regulations. Arc flash hazard analysis was performed in order to estimate:

- The level of Personal Protective Equipment (PPE) required at major pieces of equipment in the distribution system
- Arc-flash boundary distance
- Arc-flash incident energy at a typical working distance

The DesignBase 4.0 release Arc Flash Program uses empirical equations based on test results given in IEEE-1584 to provide an estimate of the energy falling on a surface removed from a fault.

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Procedure: Arc Flash – Worst Scenario Investigation

For the given Chemical Plant, the incident energy was estimated for the major buses in the system using the equations provided in the IEEE 1584 standard. Based on the energy values, the required PPE level is calculated using Table 130.7(C) (11) from NFPA 70E-2012.

Four scenarios were generated, as follows:

- Scenario 1: Minimum Short Circuit (both ties open, none of the SUB-L motors running)
- Scenario 2: 2.4 kV tie closed, 480 V tie open, all SUB-L motors running
- Scenario 3: Maximum Short Circuit (both ties closed, all SUB-L motors running)
- Scenario 4: 2.4 kV tie open, 480 V tie closed, all SUB-L motors running

Running DesignBase Arc Flash program for the four scenarios allows the program to automatically display the worst scenario for each system component as listed below:

Worst Case Arc Flash Results:

Bus Name	Protective Device Name	Bus V	Bus Bolted Fault (kA)	Branch Current (kA)	Critical Case	Arcing Current (kA)	Trip/ Delay Time (sec)	Config.	Arc Flash Boundary (inch)	Working Distance (inch)	Incident Energy (cal/cm^2)	PPE Class
1	2	3	4	5	6	7	8	9	10	11	12	13
L-BUS-A-	PCB-L-A PH	480	64.06	30.24	3	25.142	2.000	Swgr-	632.8	24.0	147.88	Danger
L-BUS-A-	CB-L-TC-244	480	64.05	6.06	3	29.575	2.000	Swgr-	712.8	24.0	176.26	Danger
L-BUS-B-	PCB-L-B PH	480	64.06	30.24	3	25.142	2.000	Swgr-	632.8	24.0	147.88	Danger
L-BUS-B-	CB-L-TC-245	480	64.05	6.06	3	29.575	2.000	Swgr-	712.8	24.0	176.26	Danger
L-MCC-5	CB-L-MCC-5	480	55.77	54.05	3	28.466	0.127	MCC-	90.5	17.9	17.04	3
L-MCC-6	CB-L-MCC-6	480	55.84	53.88	3	28.497	0.127	MCC-	90.6	17.9	17.07	3
L-BUS A	52-L-BUS-A	2400	50.79	21.51	3	47.951	1.056	Box-	2856.6	35.8	84.62	Danger
L-BUS A -	No Protection	2400	50.79	21.51	3	47.948	2.000	Box-	5507.6	35.8	160.28	Danger
L-BUS B	52-L-BUS-B	2400	50.79	21.51	3	47.951	1.056	Box-	2856.9	35.8	84.63	Danger
L-BUS B -	No Protection	2400	50.79	21.51	3	47.948	2.000	Box-	5507.6	35.8	160.28	Danger
L-MCC-1	CB-L-MCC-1	2400	49.99	47.77	3	47.209	0.258	Box-	658.5	35.8	20.30	3
L-MCC-2	CB-L-MCC-2	2400	49.97	48.47	3	47.186	0.258	Box-	658.2	35.8	20.28	3
L-MCC-3	CB-L-MCC-3	2400	49.99	47.65	3	47.213	0.258	Box-	658.6	35.8	20.30	3
L-MCC-4	CB-L-MCC-4	2400	49.95	48.91	3	47.171	0.258	Box-	657.9	35.8	20.28	3

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Benefits

For this application, two distinct benefits were realized; the protective device coordination and the arc flash area. The PDC benefits include:

- Increased facility reliability – downtime alone can cost $7,000 - $200,000 per hour!
- Increased equipment protection, enabling engineers to easily perform protective device studies
- Increased operating efficiency, providing accurate operating characteristics
- Prevent damage by identifying underrated equipment
- Prevent damage by identifying overloaded equipment

The arc flash study benefits include:

- Minimize the effects of arcing incidents at your facility – or prevent these accidents from happening at all!
- Protect the lives and health of the personnel who work on or around your electrical equipment. Increased operating efficiency, providing accurate operating characteristics
- Prevent damage to expensive electrical equipment by identifying abnormal conditions within the electrical system (e.g., underrated equipment or equipment that is overloaded)
- Improve the reliability of your electrical system, which, in turn, raises the operating efficiency of your facility
- Help your company comply with the safety mandates of the OSHA General Duty clause, NFPA Standards, and other applicable safety regulations
- Produce information that can reduce your company's workers' compensation costs and insurance rates.
- Provide important safety data for any subcontractors working at your facility
- Update all information related to your facility's electrical system – including its single-line diagram
- Guard your company against the high costs associated with arcing accidents: regulatory fines, legal fees, and increased insurance premiums

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Products and Services Your Company Used

In order to provide the PDC and arc flash studies, Power Analytics used Paladin DesignBase software. The software modules included:

Paladin DesignBase Protection Coordination Programs

Paladin® DesignBase™ Protection Coordination programs are designed for coordination of protective devices in three-phase, single-phase, and DC power systems, including transmission networks requiring Distance Relay Coordination. They provide engineers with very strong, efficient, and fast tools for selecting, comparing, and coordinating protective devices. Programs include:

Protective Device Coordination: AC
Protective Device Coordination: DC
Validated Protective Device Library
Impedance Relay Coordination*

Arc Flash Software Capabilities

- PDC works directly on the one-line diagram or on the user selected protective path
- Power Analytics Power Flow and Short Circuit programs are integrated in the PDC program
- PDC communicates with power flow, short circuit, and motor dynamic starting programs
- Intelligent PDC auto-select engine allowing upstream and downstream protective device coordination
- Powerful plotting engine
- Ability to simultaneously work on two PDC windows: protective path and time-current log-log space
- Graphically adjustable device settings with automatic settings display
- Multi-PD functions can be injected into the same device; the user can disable or enable the protection features in order to generate "what-if" scenarios
- Unlimited scenarios are available
- Professional reports are generated reporting settings of all devices within the project, or report the settings of all devices within the particular panel
- Direct fuse and relay data interpolation

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- PDC settings can be annotated on the one-line diagram or on the PDC network protective path
- Short circuit can be injected at any point in the network to generate device sequence of the operation report
- Easily export protective path and time-current curves to Word files for documentation purposes
- The arc flash analysis software generates IEEE 1584 and NFPA 70E look-up table results for different working distances and provides simple summary reports to communicate the arc flash analysis results

Paladin DesignBase Arc Flash and Fault Analysis Programs

Paladin® DesignBase™ Arc Flash and Fault Analysis programs are predicated on test results given in IEEE-1584 and recommendations of NFPA-70E, to help safety engineers estimate the energy falling on a surface removed from a fault.

These programs quickly identify the grade of clothing required by operators and easily provide protective signs for electrical equipment stating the type of protective clothing required when working around energized equipment. In addition, these packages quickly and accurately calculate the effects of flowing faults in three-phase, single-phase, and DC power distribution systems. Programs include:

Arc Flash: AC
Arc Flash: DC
Short Circuit: Classical
Short Circuit: ANSI / IEEE
Short Circuit: IEC 909
Short Circuit: Single-phase
AC Short Circuit: IEC 61363*
DC Short Circuit*

** Optional programs sold separately*

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About Power Analytics Corporation

Used by the power industry for more than 25 years, Power Analytics' software solutions have surged to the forefront of the electrical system planning, operation, and smart grid market space for use in energy intensive, mission-critical facilities and microgrids. Paladin products currently protect more than $100 billion in customer assets including financial data centers, air traffic control sites, military installations, deep sea oil platforms, and power generation and distribution facilities. The company is headquartered in San Diego, Calif., and has a smart grid center of excellence in Raleigh, N.C.

For more information about Power Analytics' Paladin Software, visit www.PowerAnalytics.com.

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