PDC Power Flow Analysis. Project Solution Feasibility Analysis and System Component Size Checking
Chemical Plant Case Study

POWER ANALYTICS™

Business Situation

A load flow study determines how the electrical system will perform during normal and emergency operating conditions, providing the information needed to:

- Optimize circuit usage
- Develop practical voltage profiles
- Minimize kW and kVar losses
- Develop equipment specification guidelines
- Identify transformer tap settings

The Scope of Work involves the creation of a 3-phase steady state AC power system model of the 2.4 kV and 0.48 kV substations that are connected electrically to the initial plant model. In the current DesignBase model, the bus bars with the motors with a rated power less than 50 HP are considered in the motor schedule as per IEEE Brown Book. Large motors at 0.48 kV and medium voltage motors greater than 1.0 kV are modeled individually on their respective buses including all protective phase and ground over current relays and fuses. All substation low voltage power circuit breaker (LVPCB) are modeled. The entire plant system modeling is based on IEEE-399 "Brown Book." All system equipment must have a corresponding one-line diagram symbol in the model. This means that there can be no hidden database models. The purpose is for the facility to easily see all equipment, its associated data, to be able to link documents to the equipment as a data repository, and to see problems right on the one-line.

By extending the Chemical Plant with the new substation the following were concluded:

- In the 2.4 kV Power Substation there were no overloads and no bus voltage violations (no voltage drops above 5%)
- In the 0.48 kV Substation there were no overloads, but there are voltage drops above 5%. These were provided in the Power Flow Appendix. Also, it was concluded that as far as voltage drops are concerned the worst scenario is Scenario 1

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Technical Situation

The Chemical Plant electrical distribution system is a complex network structure of electrical components, operating at voltages: 69 kV, 2.4 kV, 0.48 kV, and 208. The network is constructed with ring circuits but operates normally with radial feeds and normally open (NO) bus sections except the incoming 69 kV circuits.

Solution

Paladin DesignBase software was used to perform the Power Flow Analysis. Today in power system design a current procedure is "Simulation Based Design." In the design process this approach allows the user to check the correctness of the proposed solutions based on several simulated scenarios.

A Case Study is provided where DesignBase tools were used for assisting the design of a 2.4/0.480 kV substation interconnected to the existing plant power system. However, the substation is part of a large Chemical Plant, and the system study was completed to determine the Bus Voltage Profile, Branch Loading, and Short Circuit Level in the plant system network and evaluate the switching and protective devices. Paladin DesignBase 4.0 software was used to complete the project. This presentation focuses on Power Flow Analysis.

Paladin DesignBase 4.0 is state-of-the-art computer aided design and simulation software providing real solutions to any electrical application. Based on the provided drawings and system data from the client, the Paladin DesignBase model has been generated. The electrical system extension of the Chemical Plant has been modeled as two separate models electrically interconnected to the existing plant system model.

Bus IDs, branch names, and equipment characteristics are shown on the DesignBase model drawing and project database. Equipment Naming has been input as per "One line diagrams provided by the client." However, in completing this model the plant drawings and data from plant engineers were employed.

To insure compliance with IEEE Standards, no exceptions or substitutions to the performance specification are allowed. The plant system model generated is made up of multiple model drawings that are electrically interconnected. All one-line symbols are spaced properly to facilitate viewing results on the one-line diagram while using back annotation.

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The following steps were implemented:

- Close communication with design engineers and contractors
- Getting the proposed design data:
  - System layout: one line connection diagram
  - Bus voltage magnitude and voltage phase at the substation PCC
  - Short circuit contribution at the substation PCC
  - Feeder data and length
  - XFMR type, manufacturer and XFMR data
  - Electrical motors data, location, motor switching equipment
  - Electrical loads, location, and estimated % running
- Based on the above input information, the substation model in DesignBase environment has been generated
- Having a close communication with the client, 4 scenarios were implemented:
  - Both 2.4 kV and 0.48 kV tie CBs open
  - The 2.4 kV tie CB closed and 0.48 kV tie CB open
  - Both 2.4 kV and 0.48 kV tie CBs closed
  - The 2.4 kV tie CB open and 0.48 kV tie CB closed

Once the substation model was completed, Power Flow was run. One needs to understand that the Power Flow convergence is the simplest way of checking if the given power system is feasible and the input data are consistent. During the power flow, we should not have large bus voltage drops (above 10%) and no more than 120% branch overloading. The main objectives of the Power Flow studies are:

- Verify that the input data for the system are consistent, and the system is feasible
- Verify that the bus voltages are within the limits +/- 5%
- Verify that the branches loading are within the limits, less than 80% loadings
- Verify that the power transformers loading are within the limits, less than 80% loadings
- Determine if the feeder sizes are correct

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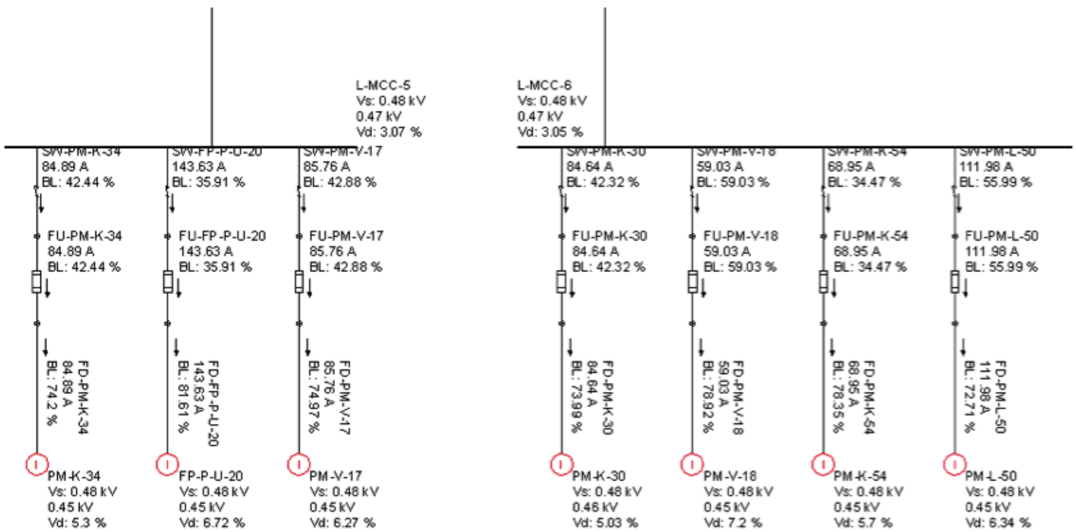
Power Flow System Configuration and Scenarios

Power Flow study is performed at 40°C ambient temperature to provide conservative bus voltage drop. The following configuration was considered in Power Flow (as per plant engineer recommendations):

- Generators are ON
- Utility lines are ON
- Available utility fault current is obtained from the model provided by the client
- All HV and MV CB are closed
- All LV CBs are closed, except the tie breakers that are normally open
- The exceptions to the above are the CBs that are clearly marked in the model as future, out of service, or for spare circuits, etc.
- All motors are running
- Tie breakers of all double-ended substations are open
- Power Flow is run at 40°C ambient temperature



0.48 kV Power Substation:
Bus Voltage Violation - Visualization

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Benefits

Load flow studies are performed using computer software that simulates actual steady-state power system operating conditions, enabling the evaluation of bus voltage profiles, real and reactive power flow, and losses. Conducting a load flow study using multiple scenarios helps ensure that the power system is adequately designed to satisfy your performance criteria. A properly designed system helps contain initial capital investment and future operating costs. For this application, the power flow analysis benefits include:

- Decrease unexpected downtime
- Reduce operating and maintenance costs
- Get more capacity out of existing assets

Services Your Company Used

In order to provide the power flow analysis, Power Analytics used Paladin DesignBase software. The software modules included:

Paladin DesignBase Power Flow Program

The Paladin® DesignBase™ Power Flow program is one of the most powerful, fast, and efficient power flow programs ever developed. Equipped with an easy-to-use, intelligent graphical interface, it supports advanced plotting, motor starting, and numerous options and modeling features.
The Power Flow program is based on advanced and robust solution algorithms that incorporate state-of-the-art solution techniques applicable to large and complex power systems.
Results can be written directly on the one-line using the back annotation features, or all the solution quantities (voltages and flows) are exportable to Microsoft Excel, and can be used to customize reports using Professional Report Writer. Back annotation features can be enhanced by using the coloring feature.

- Generator local/remote bus voltage control
- Four solution techniques: Newton-Raphson, fast de-coupled, hybrid solution, advanced Gauss Seidel
- Bus types can be defined as follows: "out of service," "load," "generator," or "swing bus"
- Multiple swing buses/co-generation units
- Multiple independent islands

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- Generator models can have different modes of operation: "fixed power output," "fixed active power and control voltage at the terminal or at a remote location"
- Two- and three-winding voltage control transformer models
- Transformers with fixed tap, voltage control, phase shifter (active power control), and reactive power control
- Transformers can be equipped with under load tap changers (ULTC) for local and remote bus voltage control
- SVC "static-var compensation" and shunt capacitor and reactors
- "Area interchange control" allows many areas to participate in the area power interchange; each area will have a dedicated generator for controlling the tie line power
- DC lines and converter models
- No bus-numbering limitations
- Line voltage regulator (LVR)
- Unlimited generators and/or motors schedules
- Transformer sizing through ADPF simulation

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 on Power Analytics' Paladin Software, visit www.PowerAnalytics.com.

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