Distribution Fault Location

1. Introduction

The objective of our project is to create an integrated fault locating system that accurate locates faults in real-time. The system will be available for users in a single interface outage management system (OMS). Our OMS system or Distribution Fault Location system will create a quick and accurate way to locate a fault for faster repair time and low outage percentages. Our goal is to give SDG&E a working fault location system that can be re-created on a larger scale. We are also looking to minimize the need or reliability on customer outage calls and introduce the utilization of new technologies in the power grind system.

Currently SDG&E, as well as most utility companies', outage management system depend on customer calls as their primary source for narrowing fault locations. This method is reliable but time consuming because there is a dependence on the percentage of calls from a specific area. There is a need for faster technologies to minimize that initial alert time. They are currently testing various approaches that create databases that aren't being integrated into a single system.

The intention of this proposal is to propose our project idea to building an outage management system that will combine various sources of fault data and will go into a single web-based interface. In order to develop a solution for a Distribution Fault Location System, our group will utilized the knowledge from several engineering courses that are included in Howard's engineering curriculum. A common knowledge in the Power Systems course will be essential in understanding faults types and how to create a usable power system. The Advanced Digital Systems course gives us a good understanding in VHDL coding and the use of an FPGA board. A good understanding of circuit analysis is given to us in the Network Analysis courses. In the remaining portion of this proposal, we will give a description of the problem, the current status of art, the engineering approach of the project, the task and deliverables, and the project management.

2. Problem Formulation

San Diego Gas and Electric as well as all other utility companies across the country are implementing the new federal "Smart Grid" initiatives to improve their power grid's efficiency. SDG&E has gone a step further by creating an initiative plan called OpEx 20/20. This is the utilities way of creating a greener/ smarter electric grid as well as satisfying the requirements set by the DOE. Under the umbrella of OpEx 20/20 one of the initiatives is to update their (OMS) system. As mentioned before in order to locate an outage or a fault the OMS system relies on customer calls. They must receive a certain number of calls before an outage location can be confirmed by operators. Because of this system outage times are a lot longer than the industry and the customers would prefer.

Our senior design project will integrate various fault locating approaches into the DFL system application with web accessible fault location capabilities. The various fault locating approaches that we create will mirror or will be taken directly from fault locating approaches that have already been developed, however, our web-based OMS system will bring this data together into one functioning application that gathers accurate, real-time data and is easily accessible. Once each component runs and the fault data from the power system is analyzed, the fault location will be available on the web- based application to be used by restoration crew.

The Distribution Fault Location System needs:

-A web-based OMS application that includes:

-XY coordinate map with fault location distance marked

-Table with time, fault data, and XY coordinate location

-Graphing of fault data

The following design components:

-A small scale three-phase power system

-A digital system determining the exact fault line

-A mapping system with fault distances from source

-Load flow table/ graphs for fault analysis

The following constraints will have to be taken into consideration when developing the DFL system:

-Utility distribution power systems are very large circuits, our system is on a much smaller scale

-The data bases we are creating are also on a smaller scale

-This is giving an example of what can be done with the load flow/ fault databases

Regulations and Standards that must be taken into consideration:

- Western Electricity Coordinating Council (WECC) Standard VAR- STD-002b-1 Power System Stabilizer
- North American Electric Reliability Corporation (NERC)
- Federal Energy Regulatory Commission (FERC)

- California Public Utility Council (CPUC)

3. Current Status of Art

In order for us to complete this project we must first understand the current approaches that are being made by industry to deal with this problem. Around the world there are various approaches to locating faults on a distribution line. We are utilizing those approaches as well as creating a few of our own simply because our system is much smaller than that of an actual power utility. However, our focus is not as much on the fault locating approaches as it is on the system that is being used to make this location available. One of the main issues for the utility and the issue that we are attacking is that the system to make an accurate location available in a short amount of time is no longer desired, but new technology approaches alone are not reliable. Two major utility companies in the United States; Con Edison and Progress Carolina have large scale systems in place that have been successful in accurately locating faults. EPRI is in the process of working on various approaches as well as systems that will work universally to make accurate and timely fault detection a reality. EPRI's ongoing projects to better locate faults includes: gathering fault data from different sources, using lessons learned for Con Edison and Progress Carolina to advance their approaches and systems, and find out which fault data approaches work best with all types of faults.

The following are some approaches to fault locating that EPRI, various utilities and others are being implemented as well as tested depending on their reliability:

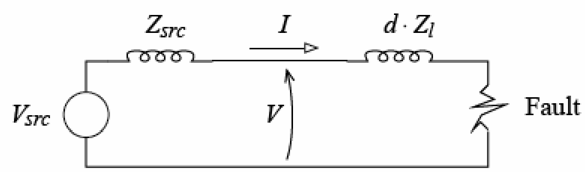
The Supervisory Control Data acquisition or SCADA is a system that collects data from various sensors or other remote locations and sends the data to a central computer that manages and controls the data. A SCADA system usually consists of a Human Machine Interface (HMI) that presents processed data to a human operator and is monitored and controlled by a human; a Remote Terminal Unit (RTU) which are connected to the sensors converting the sensor signals to digital data sending that data to the supervisory system; and a communication infrastructure connecting the supervisory system to the RTUs. This system collects a large amount of power flow data from the transmission and distribution system including fault data. Many approaches may fall under the SCADA category if they meet the mentioned criteria. This data would be beneficial in a Distribution Fault Location System because it would provide vital fault data.

Fault indicators are devices that indicate fault current by sensing the magnetic field caused by current flowing through the conductor. Fault indicators help reduce the outage duration because they narrow down the location of the fault. Fault indicators will "trip" whenever the current reaches a set trip level. After the trip the indicator resets. There are time-reset fault indicators and voltage-reset indicators. The time-reset indicator goes from a tripped status to a normal status when the voltage line is restored.

A Geographic Information System (GIS) integrates hardware, software, and data for analyzing and displaying information, most commonly in map form. Currently in the power industry, GIS is being used to map out all aspects of the power systems with physical locations of the utilities assets, to include transformers, substations, power lines etc. Within the utility companies this technology can possibly be used to show fault locations in the future. The capabilities of the GIS are expanding all the time.

There are several algorithms that can be applied to locating a fault distance. A few example algorithms that can be used to obtain are: the reactance algorithm, the Takagi algorithm, or the differential equation approach. These algorithms can be tested to see which one will work best within a given fault locating system by testing on known fault locations.

EPRI uses the Ohms-Law Algorithm as well as Arc Voltage Estimation to come up with their fault distances. The Ohms-Law Algorithm is:

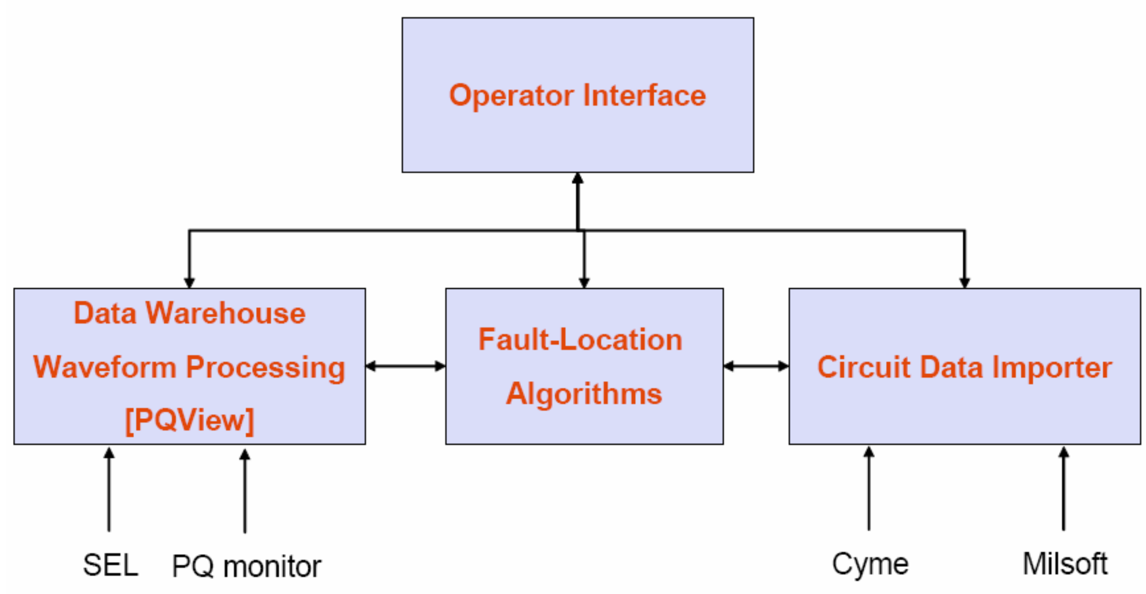


$$d = \frac{V}{I \cdot Z_l}$$

Where d is the distance to the fault, Z is the impedance value, I is the current and V is the voltage. The Arc Voltage Estimation consists of the fault location, the estimated fault type, and estimating the arc power and energy.

PQView was created by EPRI and Electrotek. They have a system that collects data from sensors (something similar to a SCADA system) the data is analyzed for faults and through a web-based mapping system fault locations are made available. The only issue with this system is that the locations are often incorrect, making them unreliable.

“Fault-location algorithms are only one component of an integrated system to locate faults. In fact, the algorithms may be the easiest part. A fault location system must be integrated with the monitoring event database and the system circuit information. This must be brought together and presented to the operator. The event data must be made available within minutes to be most useful to dispatchers.”-EPRI



EPRI diagram of an integrated fault location system

Individually, each method is not reliable enough to stand alone and accurately locate a fault, however, bringing real-time data together will allow SDG&E or any other utility and its operators to comfortably say, this is the accurate location we have provided. If the data gathered from these various devices and software were used together properly and applied to a working system, many of them would no longer have to be in testing stages but could be in implementation stages, saving the utilities money with less down time and more reliable assets.

4. Engineering Approach

Our project will utilize all of the fault data from our various sources available and integrate it into one simple interface to be easily accessible in a web based format. Our final product will be a web page that shows a fault map with the fault location clearly indicated, a table with the time, voltage, current, reactance and X-Y coordinates for the fault on the map. There will also be a graphical representation of the voltage and current of each line being polled at that time. This whole page will be working in real time. There are different types of faults that occur and need to be determined for a fully automated fault location system to be complete, however, for our project we will focus on locating single phase-to-ground faults.

In designing a DFL system that will perform this function we will first start with simulating a fault on a single phase distribution line in a network. The simulation will be performed in Simulink using the SimPowerSystems toolbox as well as PSAT to give us a variety of data to look at. This simulation will be the start to the process of totally integrating a complete fault location system. After the simulation is performed we will create a small scale power system that will provide us with the voltage and current data need for fault analysis. The data obtained from the power system will go to various fault detection sources that will give location references.

The first source is an algorithm that will calculate the fault distance from the voltage source (substation). This data will be analyzed and made available in the table and graph through the web site.

Our second source will obtain the specific line in which the fault has occurred. Used an FPGA board and VHDL code this will be made possible. This digital system will be a big factor in what eliminates different possible fault locations from the system. The information gathered from this will also be transferred to the map to give an actual fault location.

Alternate solution ideas and components are to implement fault indicators on the distribution lines. These indicators would be able to read voltage and current in the line and flash when a fault is read. This would give crews a visual indication when trying to locate faults. There are many different algorithms that can be used to locate faults. Two ended methods, impedance based methods and traveling wave methods are all different ways to use data in determining a fault location. An alternate solution for our project could be to use the two ended method. In the two ended method data is collected from two ends of a distribution line instead of just one. Data must be collected simultaneously from both ends of the line. GPS is used to sync the clocks of the data collection. The theory behind this is that when a fault occurs at a certain distance on a line the result produces traveling waves. These transients work toward the ends of the line at the speed of light. When data is collected it tags the time the wave reaches the ends of the line. This has to be done with microsecond accuracy in time. GPS makes this possible. This method gives a fault location with an accuracy 300 meters or less. This method for finding the distance of the fault could be used in place of our reactance based solution and would be a good alternate solution to our problem. The only issue with this solution is the costs of implementation.

5. Tasks and Deliverables

Tasks:

November/ December

- Simulations and testing of single and three phase power systems with faults in Simulink and Labview

November / December

- Research integration options for all fault detection components

January

- Get approval to begin building small scale power system

January/ February

- Creation of the three- phase network with phase to ground faults

January/ February

- Create digital system using FPGA board and VHDL code
- Create XY node mapping system

February/ March

- Combine all components to create web-based DFL System

Tasks assigned by team members:

Bill

1. Simulations and testing of single and three phase power systems with faults in Simulink
2. Creation of the three- phase network with phase to ground faults

Henry

1. Simulations and testing of single and three phase power systems with faults in Simulink
2. Creation of the three- phase network with phase to ground faults

Tracy

1. Create digital system approach using FPGA board and VHDL code

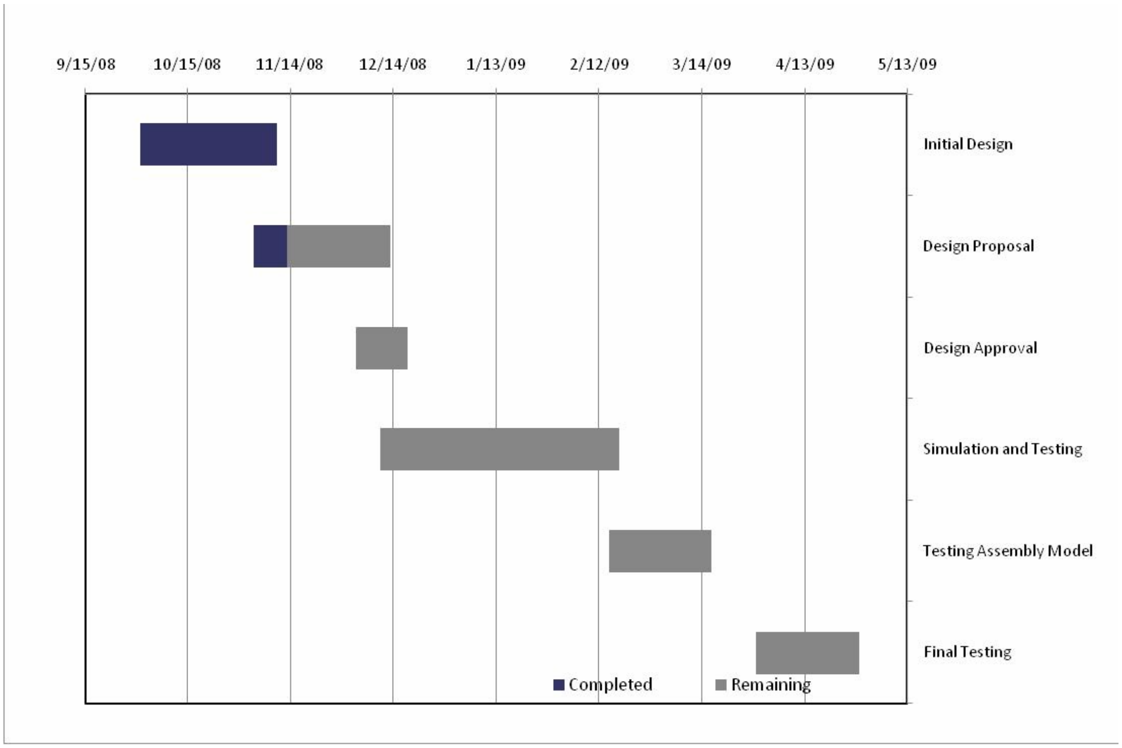
Tierra

1. Create the XY node mapping system

Hassan

1. Research integrating possibilities or all approaches

Deliverables:



Budget:

The tentative budget for this project is $2,177.00. This is necessary to simulate and build components of our Distribution Fault Location System. The projected costs for each component are as follows:

- Matlab and Simulink Student Version $99.00
- Simpower Systems Toolbox $59.00
- PSAT Free Download
- Labview $1249.00
- Power System Equipment $150.00
- FPGA Board $120.00
- Misc. $500.00

6. Conclusion

Fault location has been researched extensively in the past couple of decades. The importance of an efficient outage management system has become a priority for the power industry. This project is very relevant to SDG&E's efforts as well as the efforts of the Department of Energy to create a greener, smart power grid. We hope that once we finish our senior design we will be able to actively contribute in the improvement of the Nations power grid's stability. Our final senior design deliverable will consist of a functioning Distribution Fault Locating System with phase-ground fault detection capabilities.

7. Reference

1. Short, Tom. "Fault Location on Distribution Systems: An Update on EPRI and DOE Research," IEEE Distribution Subcommittee presentation. Orlando, FL. January 10, 2007.

2. Dr. Charles Kim. "Distribution Fault Location Studies." PowerPoint presentation. San Diego Gas and Electric, San Diego, CA. August 2007.

3. Electric Power Research Institute, "Distribution Fault Location: Field Data and Analysis," online: www.EPRI.com.

4. T. Venseth, E. Bejerken. "Locating Earth Faults in Compensated Distribution Networks by Means of Fault Indicators," International Conference on Power System Transients. Montreal, Canada. June 2005.

5. Clegg, Barry. Underground Cable Fault Location. England: McGraw-Hill Book Company Europe, 1993.