Team Intelligent Howard University

Senior Design Project Proposal:

Expert Self-Healing Network with Automated Reconfiguration and Outage Management

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1. Introduction

1.1 Project Objective

The significance of this project is to propose a design of an intelligent switching system that can sense short circuit faults, and isolate them while minimizing the costumer outage area on a single and three phase power distribution network. The available technology is only limited to three phase networks. Our goal is to extend these capabilities to single phase loops which usually consist of residential complexes. It is at this level where most faults occur and the need for a reconfigurable network necessary to minimize the outage area and time experienced by customers.

1.2 Project Background

This project was inspired by the power industry's need for an intelligent switching system that is able to reconfigure a three or single phase electrical distribution network to minimize the affected area when faults occur on the network. The success of this project will not only save the utility companies money lost during long outage times, but it will also improve the reliability of the network; increasing the service quality of the utility company which translates to happier customers.

2. Problem

2.1 Problem Formulation

Faults (shorts) often occur on power distribution networks, which in turn, disrupt the customers' electricity supply. Power companies have managed to implement intelligent switching devices that isolate fault(s) while minimizing the customer outage area, but only on three phase power distribution networks. However, most faults occur on single phase (single loop) distribution lines connecting multiple customers such as residential, commercial and industrial sites. The limitations of the current technology make the network less efficient and less reliable.

To address the deficiencies of the available technology, a smarter self-reconfiguration scheme has to be developed. This new automated reconfigurable power management system will be designed to perform intelligent switching in response to faults that occur in both three and single phase distribution networks. These operations will minimize the outage areas triggered by the fault. The success of this scheme will increase the efficiency and reliability of the network electric supplies. Keeping customers secure and satisfied as utility companies strive to maintain a perfect supply.

2.2 Problem Definition

To design an intelligent switching system that can sense short circuit faults, and isolate them while minimizing the costumer outage area on a single and three phase power distribution network.

2.3 Design Requirements

For our proposed scheme to be approved by the power industry, it has to meet these minimum requirements. Meeting these requirements will ensure a fully functional device that would enhance a distribution grid, by increasing its efficiency and reliability. Our design will meet the following requirements:

- **Overall Function**
    1. Sense voltage, current, and phase.
    2. Perform programmed/automated switching to reconfigure network.
    3. Communication capability with other IEDs within the vicinity to perform automated switching.
    4. Communication capability to send alerts to dispatch unit and operator.
    5. Calculate and track the outage's area and duration.
- **User Interface**
    1. Wired USB computer interface for software and International Organization System (ISO) updates/configuration
    2. Wireless access computer interface for software and ISO updates/configuration
- **Performance**
    1. Sensor reacts to unbounded changes in line voltage, current, and phase within about the first 5 milliseconds.
    2. Micro processor send signals to its connected switches and other (Intelligent Electronic Devices) IEDs involved to carry out coordinated/automated switching operations that would reconfigure the grid within the next 2-5 seconds depending on how many IEDs are involved in the reconfiguration process.
    3. Send alert message to the control station (operator) /dispatch unit within 2 minutes with information on outage areas (location, time, possible cause(s) thus reducing the amount of time for locate the fault.
- **Aesthetics**
    1. The casing of the device will be 10x7x10 inches in dimension.
    2. The device will weigh less than 10 lbs.
    3. The casing of this device will be able to withstand the four climates.

- **Power**
    1. Device should be powered through the power line.
    2. Device shall be protected from lightning strikes and over voltages.

- **Compliance**

1. The FCC rules and regulations part 24 (As regards GSM modem for internet access)
2. ADA regulations (Entire system)
3. FCC regulations on Specific Absorption Rate (SAR) of electronic devices (GSM Modem, Bluetooth Earpiece, Electromagnetic Radiation from the Intel Atom Board)
4. IEC (International Electrotechincal Commission) non-governmental agency that “prepares and publishes” the international standards for all electro technology (all electrical, electronic and related technologies)

3. Current Status of Art

With the use of auto-reclosing at the individual feeder level, reconfiguration in power distribution has been around for quite some time. Currently, there are many transmission grid self-healing techniques in use that bring the advantages of digital technology to modernize the electric power grid, and improve efficiency, reliability and performance. The realization of reconfiguration networks includes “timely recognition of impending problems; redeployment of resources to minimize adverse impacts; a fast and coordinated response to evolving disturbances; minimization of loss of service under any circumstances; minimization of time to reconfigure and restore service.” [1] The present mesh networking topology is used where each node not only captures and spread its data, but also serves as a relay in propagating the data;[2] communicating information between nodes by intelligent electronic devices. However, these are somewhat limited, in that they neglect one-phase outages in complex networks.

Duke Energy announced their first self-healing network implementation in June 2009. This features mesh networking, consisting of intelligent switches and line sensors. In the event of a fault occurrence in the system, the network notices an abnormality in the power flow, diagnoses the issue and reroutes to island, isolate or sectionalize the problem. This involves real-time communication between the smart sensors and switches to assume the necessary actions, best-fit to reduce affected area. Because of this implementation, 1,500 customers were spared from experiencing a significant outage; only seeing brief interruptions and flickering as the self-healing network activated itself instantaneously. Customers that were being served directly by that line remained without power until service workers could address the fault. Self healing networks, such as, have the immediate benefits of lower congestion leading to improved economics and un-served energy resulting from relieving operational limits and reducing interruptions. [1] Duke Energy states “ …the installation of 17 self-healing teams in Ohio has helped avoid over 1.1 million outage minutes for more than 20,000 customers” [3]

This strategic solution has been adapted by many utility companies; however, it is limited to three phase networks. There are many single phase loops, underground and overhead, in the distribution of power in suburban communities. Because there has yet to be an intelligent system implemented for these configurations, operators and responders first must pinpoint the fault and then perform switching to isolate and minimize outage spans. This successive reclosing method uses no communication link and can take a considerable amount of time, much more than an automated self-healing system in place for three phase networks.

Another potential drawback in the current state of self-healing networks on the distribution level is proper load management of a reconfigured network. The load on any one power supply should be accounted for to ensure that not only do customers avoid a black-out but that the quality of power being provided is sufficient. Reconfiguring a network from its original structure can also require voltage and VAR management and auto demand response to bridge the supply-demand gap in a Smart grid network. We see that this current self healing technology needs some improvements, and this is what the next section covers.

3.1 Available Approach

Distribution Network Zoning - Dividing distribution networks into zones – separated by active and intelligent components – provides a way to handle fault situations in the most efficient way (where the fewest amount of consumers are affected, fast restoration and few personnel)These zones are defined by the consumption criticality and the vulnerability to disturbance. . Zones are divided by circuit breakers, LBSs or disconnections with remote communication and varying degrees of intelligence for protection, measurement and control.

Mesh Networking – Mesh networking is a type of networking used in a variety of fields. A node, or communication point, does not only capture and disseminate its own data, but serves as a relay for other nodes. It must collaborate to propagate the data in the network. A mesh network can be designed using a *routing* technique. When using a routing technique, the message propagates along a path, by *hopping* from node to node until the destination is reached. To ensure all its paths' availability, a routing network must allow for continuous connections and reconfiguration around broken or blocked paths, using *self-healing* algorithms.

3.2 Drawback on available devices

The main drawback of the available devices is its incapability to perform automated configuration on both three and single phase distribution networks. Not only does out proposed design eliminate this drawback, it would also be able to communicate with other IEDs within the vicinity to perform automated switching, and send alert messages to dispatch units/ operators.

4. Solution Approach

4.1 Solutions Description and Expectation

The team's proposed solutions to the drawbacks of current network reconfigurable IEDs is to design the state of the art network reconfigurable IEDs (NRIs) that can function on both single and three phase distribution networks. The buy products of this new system in the enhancement of the distribution network by increasing its efficiency and reliability.

This would save the utility industry money and promote great reputation and credibility. As a whole the proposed design would be both the customer and utility side through shared outcomes of investment gain and service reliability.

4.2 Primary Solution

The Self-Reconfiguration Network will integrate electricity delivery systems with modern interactive digital technology to offer an intelligent, less costly and more reliable delivery of electricity from supplier to consumer. Without smart grid, a utility sometimes may not discover local substation breakdowns until customers call to complain. Our network architecture includes network sensors inside a transformer or along wires that can immediately locate, isolate and report a problem or can even prevent it from happening in the first place.

Because the Smart Grid is an aggregate of several components of a Utility's electrical delivery system, a single, integrated communications infrastructure is essential. The communications infrastructure must be fast, reliable, secure and support both existing legacy functions and future networking requirements. Moreover, the communications infrastructure must support backbone network and sub-network communications on one platform.

The focus of our solution implementation will be on the speed of our single integrated communication. Our single integrated communication will be composed of relays and sensors at each substation to ensure power is flowing normally. A microprocessor will monitor all the sensors. If a problem occurs, the microprocessor will order the Normally Open (NO) switch, in that particular point to close in order to reconfigure the system. The microprocessor will also notify the utility company about the break down. This communication will be done in less than 10 seconds.

4.3 Communication Link

Traditionally, Synchronous Optical Networking/ Synchronous Digital Hierarchy (SONET/SDH) systems have been the technology of choice for communication networks. However, Ethernet-based backbone networks with sophisticated management systems that reliably address critical issues such as bandwidth optimization, Quality of Service (QoS) and security, are rapidly replacing costly SONET/SDH based solutions.

Our network will communicate using Ethernet-based backborn because it is cheaper and very reliable.

4.4 Testing and Verification

Once the design has been built, it will be test to see if it meets the proposed requirements.

Function Test	Passing Requirement
• Sensor Operations	• Detects unbounded voltage /current/phase with 10millisecond
• Microprocessor Operations	• Analysis data from relays, sensors and carries out signal commands to activate switching of its SSRs and other IEDs, within 2 to 5 seconds. Sends alert message to dispatch unit/operator
• Switch Operations	• Switches activated by microprocessor to reconfigure network within 1 to 5 seconds of instability sensing
• Data Acquisition	• Microprocessor keeps record of date, time and proximate location of fault
• Communication Operations	• Transmit and receive signals from linked IEDs to perform automated switching

5 Team Member task

It takes a team of a lot of strengths to carefully analysis a problem and come up with the optimal solution. The strengths of each member is put to the test with Mr. Goddard serving as Project manager, Mr. Bassene; Technical Specialist, Mr. Watson; Coordinator, Mr. Olusanya ;Researcher, and Ms. Ononiwu; Data management. However, these roles do not imply or restrict tasks. From this project, we all plan to achieve a better knowledge of the project and enhance our teamwork and leadership skills in engineering.

6 Deliverables

The team plans on having a functioning prototype by mid April. This prototype will adequately perform operations demonstrating its capabilities of handle faults on both a single and three phase distribution network.

7 Project Management

7.1 Solution Implementation Plan

The execution of the project will be divided into five different phases mentioned below.

Phase	Description
1	Gathering of information (research, requirements, possible improvements)
2	Solution formulation using Engineering Approach
3	Familiarize with working tools (microprocessor, solid state relays, sensors etc)
4	Build, test, modify
5	Presentation

7.2 Timeline and Milestones

Milestone	Sep	Oct	Nov	Dec 2012	Jan 2013	Feb	Mar	Apr	May
Brainstorm	X								
Initial Proposal		X							
Written Proposals: Version I		X							
Written Proposals: Version II		X							
Final Proposal Presentation		X							
Evaluation/Selection of Design		X							
Final Proposal Presentation			X						
Final Written Proposal				X					
Learn about atom processor				X					
Plan and develop functional blocks					X				
Order components and test components					X				
Begin System integration						X			
Complete system integration							X		
Test device and modify								X	
Project Presentation – EECE day									X

7.3 Resources and Budget

Item Description	Qty.	Cost ($)
Intel Atom Board	1	200.00 (provided)
Sensors		
Solid State relays		

8. Conclusion

For many decades utility companies have been dealing with numerous problems. One of the main problems these companies have been facing is communication. Before the invention of Smart Grid, companies would rely on customers to alert them of a fault in the system. Because of the lack of intelligent communication systems, it takes these companies longer time to respond. Our Self-Reconfiguration Network (SRN) will not only resolve that issue, but do it in the most efficient way and be implemented in a single phase system. The SRN will detect a fault and optimally reconfigure the system to minimize the number of affected customers and report the problem in about 10 seconds.

9. References

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10. Appendix

10.1 Feasibility of the Project

The current art of status of our project leads us to believe that our project is feasible. Due to the fact that smart grids have been implemented for a while now, the question is not how will this project work but how will we make it more efficient. We also looked at some reliability analysis concepts using the reliability function R (t), the probability density function (pdf), and the cumulative distribution function (cdf) to determine the reliability function (survival function). After exploring the current art of status of our project, we created a timeline to meet all our deadlines.

Moreover, we believe that the following points are key to our project:

- our ability to identify the need of more relays and sensors on a single phase to reduce, drastically
- the amount of affected customers
- the efficiency of the integrated communication system
- the reconfiguration based on prioritized customers, such as hospital, airports, business areas etc.

We believe that without these points, we will not be able provide a convincing proposal.

It costs utility companies more money to supply and maintain residential areas due to the fact that many residential customers are connected to a single line. By placing multiple switches and relays on these single lines, we will make it easier for utility companies to identify the faults and at the same time reconfigure their networks1.

Although this may require some initial costs, it is a great investment that will not only reduce the amount of affected customers, but also maintain over 90% percent of continuous power flow in the network

10.2 Reliability Analysis Concepts

The reliability is depicted as the ability of our SRN to maintain operation over a period of time t, and is defined by the cumulative distribution function (cdf).

$$F(t) = \int_0^t f(t)dt$$

Where f(t) is the pdf.

The probability that our Self-Reconfiguration Network survives to time t is the reliability function and can be defined as follows:

R(t) = 1 – F(t), assuming at t=0 there are no faults.

The reliability functions, as well as, the time between failures are all a part of the reliability analysis.