Automated Phase Identification System for Power Distribution Systems

A Revised Final Report Submitted to Dr. Miu and the Senior Design Project Committee
of the
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Team Number: ECE-08

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Abstract

Power distribution systems are complex networks of equipment and cable, usually in a two or three phase configuration. Over time, cables deteriorate along with their respective labels making it difficult for utility companies to confirm the phase during maintenance and repair. The current methods used to identify the phase of a cable require the cable to be de-energized. This problem leads to intentional customer outages and revenue losses for the utility company. To improve reliability and efficiency of the system, utility companies need a device that has the ability to detect the voltage magnitude and phase angle of an unidentified energized cable. By determining the cable's phase properly this can increase utilities' revenue, reduce equipment failures, and reduce intentional customer interruptions.

This project has been successfully designed and developed to automatically determine the electrical phase of energized power distribution cables using Synchronized Phasor (Synchrophasor) technology. This system uses a known phase angle as a reference point and compares the unknown phase angle in real time via a wireless communication network. GPS clocks are used to time stamp data for accurate comparison. This automatic phase identification system has been successfully tested in laboratory on 3 phase wye, 3 phase delta, and 2 phase Scott-T connected loads.

For our project we stayed very close to our schedule and completed most tasks on time or early. The labor costs for this project were over budget, because more time was needed to complete the project than expected. However, all of our other costs were under budget and the overall project cost was under budget.

Results from successful laboratory and field tests have been obtained and documented. Test procedures and a user manual have been created for power distribution personnel. The final product includes user manuals and two portable phase identification units along with a communication system that can automatically and correctly identify the phase of 3 phase wye, 3 phase delta, and 2 phase Scott-T connected loads.

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Table of Contents

List of Figures

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1. Problem Description

An issue that arises with power utility companies is trying to identify the phase of a customer on a two or three-phase power system. Failure to properly identify the phase of a cable may lead to unbalanced loading on the phase and possible overloads which can lead to equipment damage and service interruption. Service interruption could be lengthy if the distribution system is underground. Utility companies currently address this problem using test methods requiring the cable to be de-energized. This causes a service interruption to the customer which is it be avoided whenever possible, as they can lead to customer inconvenience and customers' loss of revenue. Also, there may be additional costs incurred if the secondary cables from the transformer are underground and difficult to access. Thus, there exist several advantages to identify the correct phase of the cable fed to the customer while still energized.

Currently in the United States electric power is generated and distributed in the form of 60-Hz-polyphase Alternating Current (AC). In most cases, there are three phases, A, B, and C, each displaced by 120 degrees from each other (Figure 1). The power from generating stations is transformed to high voltages for transmission in order to reduce voltage drop and power losses. High voltage Transmission lines, normally operating at 230, 345 and 500 and 765 KV phase to phase, connect the generating stations to the switching and distribution substations. At the distribution substations, the voltage is transformed down to primary distribution voltage levels of 4, 13, and 34 KV phase-to-phase. Then, distribution lines run underground or aerial along roadways or railroad tracks to residential, industrial, and commercial customers. This whole process can be seen in Figure 2.

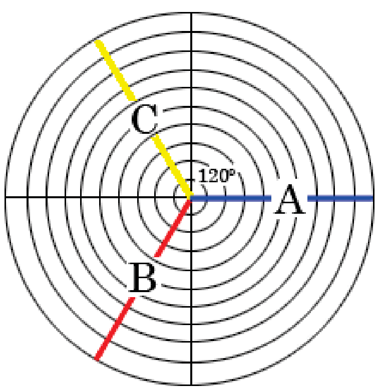

Figure 1: Three-Phase Phasor Diagram

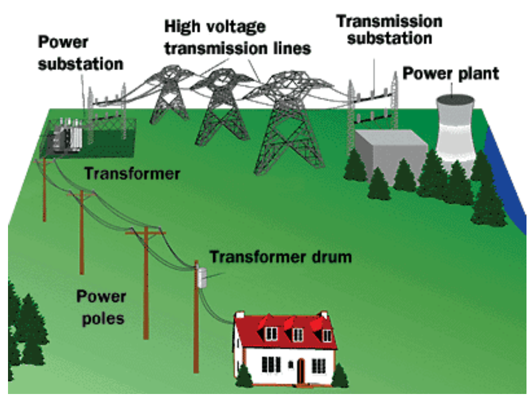

Figure 2: Overall Power System[1]

On the distribution level, three-phase-wye (Appendix G, pg G-3) and three-phase-delta (Appendix G, pg G-3) transformer winding configurations are commonly used. A delta winding configuration eliminates the need for a neutral and is primarily used to serve large polyphase industrial or commercial loads who accept their electrical service at primary distribution voltages. Wye-connected transformers are ideal for residential and small commercial loads because they can serve both single-phase and three-phase customers.

A Scott-T configuration is used when a utility needs to feed older two-phase customers from the newer style three-phase configuration mentioned above. A Scott-T transformer bank requires A, B, and C phases on the primary side, each displaced by 120 degrees, and outputs A and C-phase (displaced 90 degrees) and a neutral. In this 5 wire system, A-phase polarities (A1 and A2) and C-phase polarities (C1 and C2) each constitute a 240/120 Volt where both A1 and A2 or C1 and C2 must be fed to the load to provide 120V line-to-neutral or 240V line-to-line as shown in Appendix G, pg G-3. On a two-phase system, the two components of a phase, A1 and A2, or C1, and C2 are 180 degrees out of phase from each other[2]. The two-phases are 90 degrees displaced in phase from each other (Figure 3).

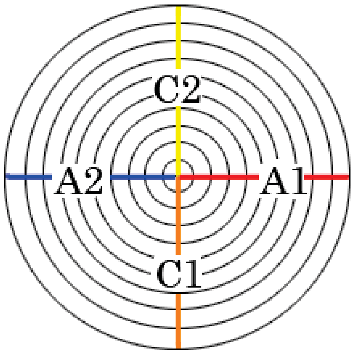

Figure 3: Two-Phase Phasor Diagram

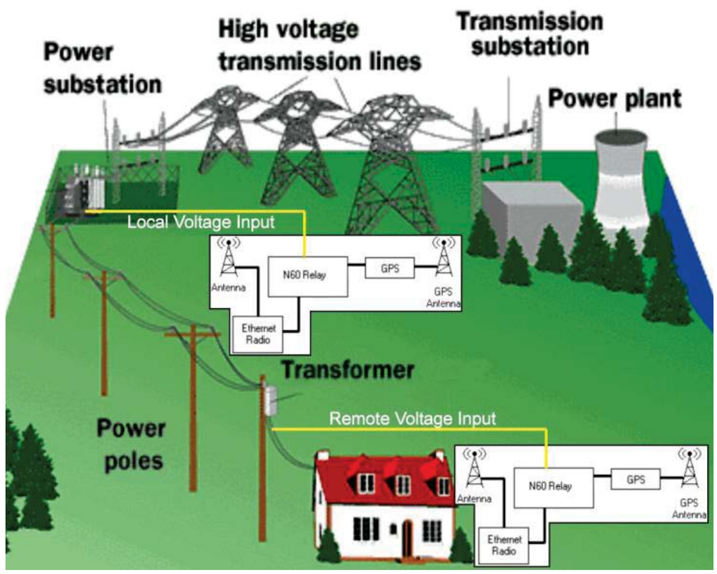

Figure 4: Working Block Diagram

In order to reach a proper solution to correctly and automatically identify a phase of a cable, we divided the project into the following tasks:

- Power Hardware and System Design
- Communication Hardware
- Integrated Power and Communication Systems
- Phase Identification Algorithm and Implementation
- Lab Testing
- Field Testing