(4) Rewrite Resistance Testing 5/20/11 – John Ainscough

Resistance Testing (as described in the IEEE – 1617 guide)

The IEEE – 1617 guide discusses a method for concentric neutral resistance measurement.

A measurement of the concentric neutral resistance is used to estimate the integrity of the neutral. The resistance of the cable neutral does not increase significantly due to reduced strand diameters in localized areas. When localized corrosion proceeds to the point creating breaks in neutral strands the neutral resistance may increase in increments corresponding to the number of broken strands.

The method discussed in the IEEE – 1617 guide for measuring neutral resistance involves injecting an alternating current (60 Hz) of up to 30 amps into the ground system at the neutral terminations. When the neutral is left connected to the system ground, a portion of the injected current will flow in the cable neutral and the remainder will flow through parallel ground paths. Measurements of the current flowing in the neutral, the voltage across the neutral terminations and the phase angle between the voltage and the neutral are used to calculate the neutral resistance.

A comparison is made of the resistance calculated from the test measurements to the calculated resistance of the neutral design if no corrosion was present.

An Ohm-Check Neutral Resistance Tester is the commercial product used to take measurements conforming to the neutral resistance measurement section of the IEEE – 1617 guide.

The Ohm-Check instrument provides an output measure of neutral resistance in ohms per 100 feet. A ratio of measured resistance to the calculated resistance of a new neutral of the same design is also reported.

The Ohm-check manual cautions that "When the neutral test current is very low (less than 1 Amperes), reliable resistance measurements are not possible."

The IEEE – 1617 guide does not provide support for any methods other than the Ohm-Check type of device for direct resistance measurements of cable concentric neutrals.

Megger Testing

The Megger company manufactures electrical testing equipment including equipment for performing some testing on cable systems. A Megger publication discusses the use of a particular line of test equipment in making some assessment of the neutral condition on bare concentric-type cable.

The neutral measurement procedure is given on page 4 of the 2003 Megger publication titled Fault Finding Solutions. The procedure specifies the use of a Megger Insulation Tester that has both megohm and an ohm (continuity) range. The procedure for testing the concentric neutral of an de-energized cable segment begins by connecting a short between the phase and neutral at the far end of the segment and doing a loop test for continuity at the near end of

the segment by setting the instrument to the ohms or continuity range and measuring across the open phase and neutral conductors. If the phase conductor is known to be good, a high resistance measurement suggests damage of the neutral. The Megger procedure states: "A reading in the hundreds of ohms is a good indication of corroded neutral if working on bare concentric-type cable."

Page 5 of the Megger publication includes the statement: "If the loop test indicates a resistance reading in the 10 to 1000 ohm range and particularly if the reading varies during the measurement, there is very likely neutral corrosion on the cable."

The Megger technical support group pointed to the Megger model MIT400 series of Insulation Resistance and Continuity Testers instruments as the equipment that would meet the instrument qualifications given on page 4 of the Fault Finding Solutions publication.

The data sheet for the MIT400 series indicates the largest Continuity test current levels are about 200 milliamps (0.20 amps). Note that this level of test current is in the less than the 1 Ampere range where the Ohm-Check documentation considers resistance testing to be not reliable. This type of testing cannot be expected to provide an accurate neutral resistance measurement. Such testing only gives some rough indication of the potential presence of a concentric neutral continuity issue. Measurement results with low current testing may be significantly affected by other currents and differences in voltage potential in the environment surrounding the buried cable. Test results may be inaccurate and highly variable depending on environmental conditions at the time of the testing.

Appropriate safety procedures must be followed during all testing activity when applying the procedure used in the Megger publication.

Testing With Other Multi-meters

Testing similar to the preceding discussion of Megger testing may be attempted with a digital multi-meter. Measurement results with low current testing may be significantly affected by other currents and differences in voltage potential in the environment surrounding the cable. Test results may be inaccurate and highly variable depending on environmental conditions at the time of the testing.

Pursuant to Interim PUC ALJ Order: Section II.A.2 Second Phase of Mitigation Plan Testing

1) Testing consisting of conducting Ohm Check, Megger, and digital multi-meter tests on one section of B-phase cable from switch cabinet 45/71 to transformer 329/537*.
2) Testing consisting of conducting Ohm Check, Megger, and digital multi-meter tests on three sections of B-phase cable from switch cabinet 45/71 to transformer 592/017, from transformer 592/017 to transformer 361/775, from transformer 361/775 to transformer 614/619*.

*Ohm-Check off-line testing by Xcel Energy contractor (NPL) and NEETRAC / Georgia Tech Research Corporation in accordance with a service agreement. Loop resistance testing by Xcel Energy contractor (NPL) using a Megger model MIT 400 series meter recommended by the Megger technical support group. Digital multi-meter loop resistance measurements by Xcel

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Energy contractor NPL using the Greenlee CMI-200 previously used for testing November 15-18, 2011.

Measuring Neutral and Phase Currents
By Kerry McBee

Test: Neutral and phase current measurements.

Reference: 6d of Interim Order of Administrative Law Judge

Purpose:

The purpose of this test is to determine how much current is flowing through the neutral conductors of phase B and C as compared to the amount of current flowing in the phase conductor of B and C. The test can determine approximately how much current is flowing through the ground. The test will not indicate the exact paths of the ground currents. Phase angle measurements are required to accurately compare phase and neutral currents.

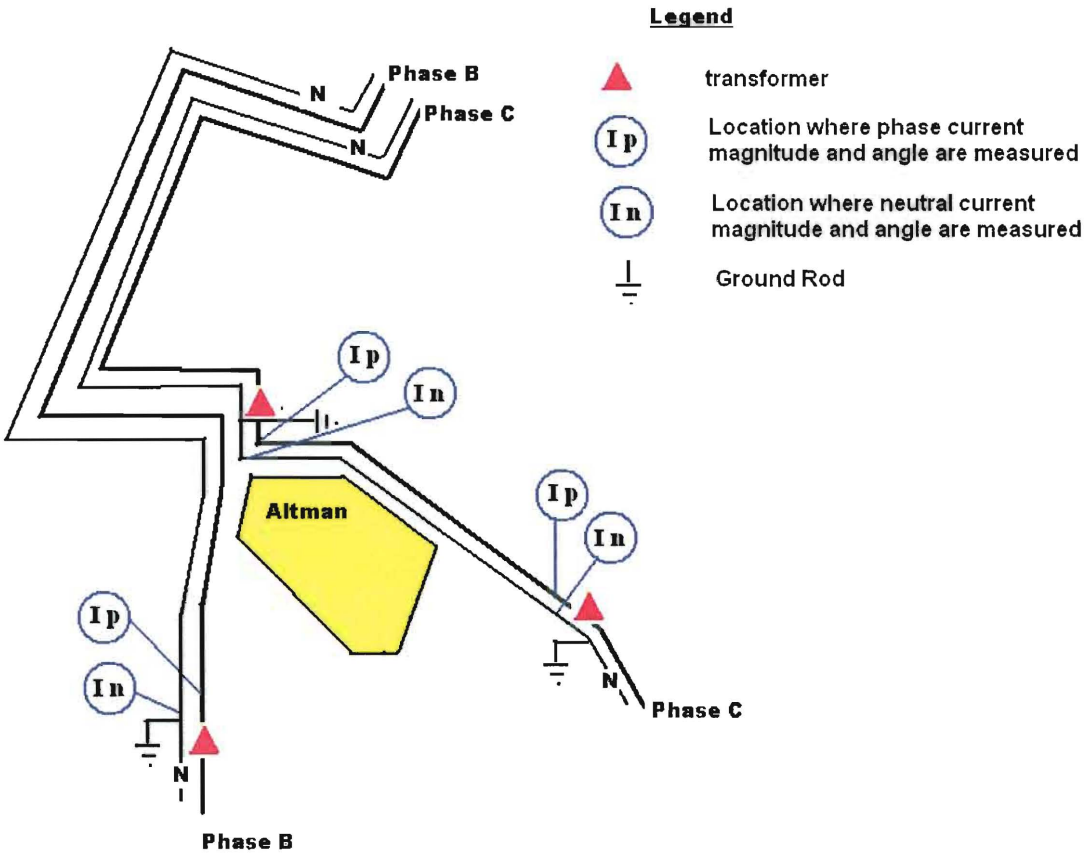
General Test Description:

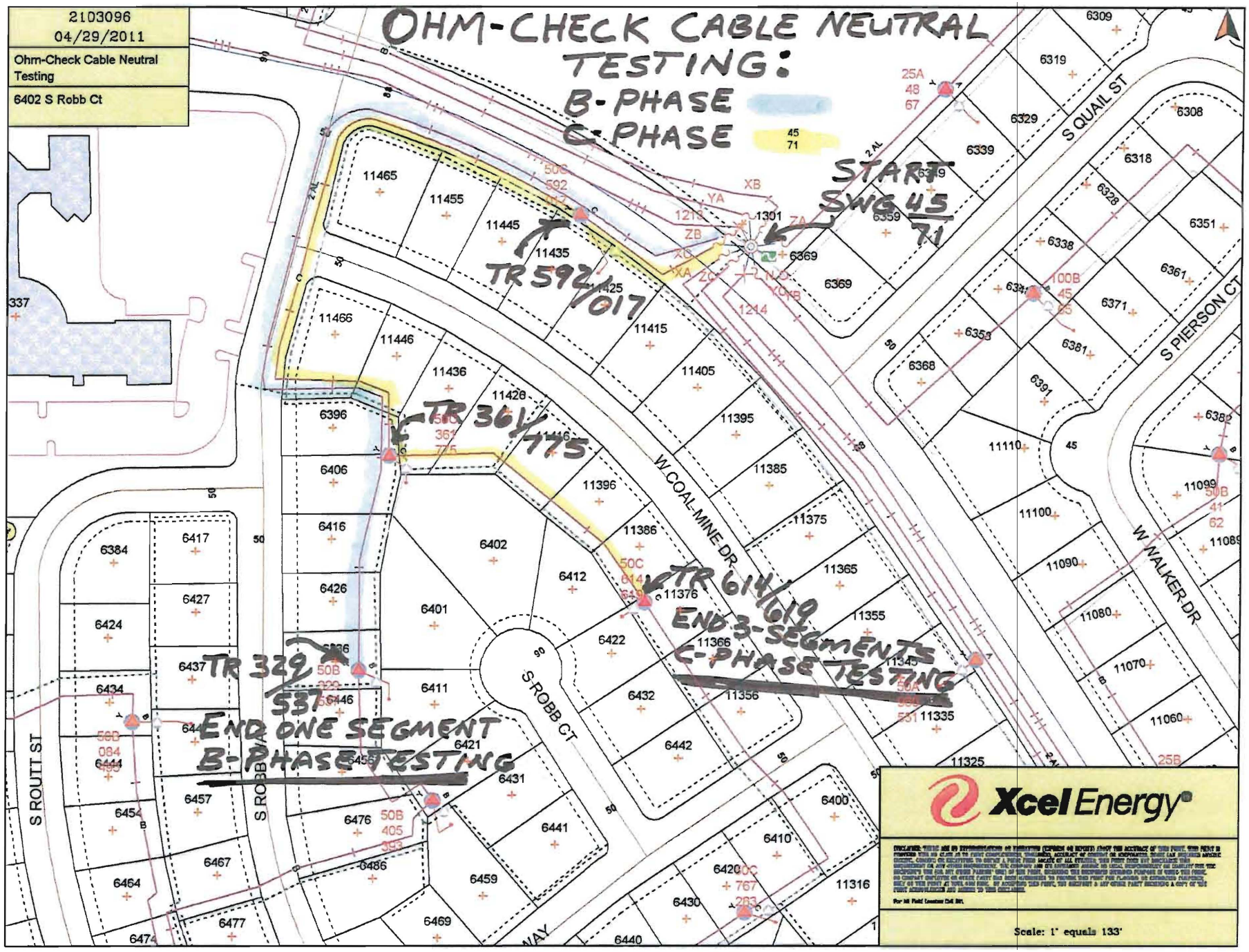
Install power quality recorders at transformers 361/775, 614/219, and 329/537. At each location, the recorders will measure magnitude and phase angle of the current flowing through the phase conductor and neutral conductors. All measurements shall be time stamped.

I. Required Equipment:
Three PM7000 power quality recorders

II. Test Procedure:
a. Install one power quality recorder at transformer 361/775. One sensor shall be connected to the concentric neutrals that serve transformer 614/619. One sensor shall be connected to the phase conductor that serves transformer 614/619
b. Install one power quality recorder at transformer 614/619. One sensor shall be connected to the concentric neutrals that serves transformer 361/775. One sensor shall be connected to the phase conductor that serves transformer 361/775.
c. Install one power quality recorder at transformer 329/537. One sensor shall be connected to the concentric neutrals that are connected to switch cabinet 45/71. One sensor shall be connected to the phase conductor that is served from switch cabinet 45/71.
d. Recorders shall retrieve measurements for a period of 10 days.

III. Diagram illustrating test locations:

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04/29/2011
Ohm-Check Cable Neutral Testing
6402 S Robb Ct
OHM-CHECK CABLE NEUTRAL TESTING:
B-PHASE
C-PHASE
START SWG 45/71
TR 592/017
TR 361/775
TR 614/619
END 3-SEGMENTS C-PHASE TESTING
TR 329/537
END ONE SEGMENT B-PHASE TESTING
W COAL MINE DR
S QUAIL ST
S PIERSON CT
W WALKER DR
S ROUTT ST
S ROBB CT
Xcel Energy
Scale: 1" equals 133'