Distribution Circuit Phasing

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Agenda

- Importance of Distribution Circuit Phasing
- Distribution Circuit Phasing Standards
- Recloser Phasor HMI Demonstration
- Overview of GPS/Cell Phasing Systems

- Break (3:00 – 3:10)

- Outdoor Demonstration (weather dependent)
Why Does Circuit Phasing Matter?

- **Yesterday...**
  - Circuit phasing didn’t really matter too much:
    - Feeder metering only at the substation
    - Fault targeting only at the substation (e.g. no phase targets on a hydraulic line recloser)
    - Simple overcurrent protection
    - Customer swapped phases around to achieve the desired rotation
  - Only significant concern:
    - Out-of-phase situations at normally open tie points

- **Today...**
  - Correct circuit phasing is critical:
    - Consistent fault identification
    - Directional overcurrent protection
    - Negative sequence overcurrent protection
    - Power quality analysis
    - Distribution automation
Phasing Issues

- Assuming we want A-B-C…
  - there are 6 configurations we could get:

- B-C-A and C-A-B are “Phase Offsets”
  - Okay for directional and negative sequence overcurrent
  - Okay for customer rotation
  - Challenges for targeting and event analysis
  - Challenges for distribution automation

- A-C-B, C-B-A, and B-A-C are “Phase Swaps”
  - Not okay for directional or negative sequence overcurrent
  - Challenges for customer rotation
  - Challenges for targeting and event analysis
  - Challenges for distribution automation
Impact of Phasing Issues

Review of Symmetrical Components

- **Normal Balanced**
  - 100A per Phase
- **Positive Sequence**
  - 100A<0
- **Negative Sequence**
  - 0A
- **Zero Sequence**
  - 0A
Impact of Phasing Issues

Symmetrical Components with Load Imbalance

Slight Imbalance
IA = 80A
IB = 90A
IC = 100A

Positive Sequence
I1 = 90A<0

Negative Sequence
I2 = 5.8A<-150

Zero Sequence
I0 = 5.8A<150
Impact of Phasing Issues
Symmetrical Components with Load Imbalance

Huge Imbalance
IA = 33A
IB = 67A
IC = 100A

Positive Sequence
I1 = 66.7A<0

Negative Sequence
I2 = 19.3A<-150

Zero Sequence
I0 = 19.3A<150
Impact of Phasing Issues

Symmetrical Components with Load Imbalance – and Phase Offset

Huge Imbalance
IA = 33A
IB = 67A
IC = 100A

Positive Sequence
I1 = 66.7A<0

Negative Sequence
I2 = 19.3A<-30

Zero Sequence
I0 = 19.3A<30

But instead of A-B-C, it is actually B-C-A
Impact of Phasing Issues

Symmetrical Components with Phase Swap

But instead of A-B-C, it is actually C-B-A
How to get Correct Phasing

Option 1 – Drive out the circuit
   *Time consuming and problematic.*

Option 2 – Design and construction standards
   *Works if everyone uses it, but what are the chances of that.*

Option 3 – Tools built into reclosers
   *Very effective for phase swaps; not so effective for phase offsets.*
   *Must have load current (in-service check).*

Option 4 – New tools using GPS and cellular data
   *Solves both offsets and swaps.* *Total solution.*
This standard explains the typical phasing arrangement that should be used on overhead distribution lines.

Overhead distribution lines in Puget Sound Energy’s system should be phased as shown in Figure 1. A-phase should always be located on the southern or western side of a pole and C-phase should be located on the northern or eastern side of a pole.

If the distribution neutral is on the primary crossarm it should be positioned as shown in Figure 1.

NOTE: At PSE it is traditional to refer to C-Phase as O-Phase.
Circuit Phasing Standards

Utility #1  A-B-C South to North
            A-B-C West to East

Utility #2  A-B-C North to South
            A-B-C West to East

Utility #3  A-B-C North to South
            A-B-C East to West
Circuit Phasing Standards

Color Codes:
- A-phase = Red
- B-phase = White
- C-phase = Blue

Utility #1    Red-White-Blue
Utility #2    Red-Yellow-Blue
Utility #3    Yellow-Red-Blue

**Side bar comment: Color coding for low-voltage NEC is often an issue:**
- Current Code does not specify color (except limiting use of white and gray to neutral, limiting green to ground, and requiring orange for a wild leg)
- In the 1970’s, the Code did include color requirements; some jurisdictions still require specific color codes. But different jurisdictions may use different colors.
Circuit Phasing Standards

Standards work great…
until you actually build something

Standards fall apart with:
  - Contractors
  - Storm restoration (mutual aid from foreign crews)
  - New employees