Designing For a Critical Load using a Spot Network

Tony Oruga, P.E. – Product and Sales Manager
Network Protectors
Network Systems

- Who?
- When?
- What?
- How?
- Why?
- Where?
Network Systems

- Who knows what distribution network systems are?
- When?
- What?
- How?
- Why?
- Where?
Network Systems

- Who?
- When were they first used?
- What?
- How?
  - 1882 – DC networks
- Why?
  - 1907 – Memphis; AC network
  - 1921 – Seattle
  - 1922 – NY; first system
- Where?
When were they first used?

- **1922**
  Westinghouse Electric developed first Network System
  Union Electric in New York, now called Consolidated Edison.
  Con Ed - 25,000 Network Protectors on their system.
  85% of Con Ed load supplied by Networks.

- **Today**
  Commercial areas of most major cities over 200,000 have network systems.

- Secondary Network voltages are 216, 480, and 600VAC
When were they first used?

Type CM-1 Produced 1925
Type CM-22 Produced 1934
First Type CM-22 Produced

First CMD Network Produced 1968 1975
First CMD 1991 2000

First Spring Close Networks offered
CMD offered with a Capacitor Trip Device

1922
Type CM First Network Protector offered
1927
Type CM-2 Produced

19
Network Systems

- Who?
- When?
- What is a Network System?
- How?
- Why?
- Where?
What is a Network System?

Alternative to traditional power distribution topologies

- Radial
- Primary Selective
- Secondary Selective
- Network System
  - Spot
  - Grid

“That’s the way we have always done it…”
What is a Network System?

*2 or more parallel feeders to a load supply allow uninterrupted power during contingency
What is a Network System?
What is a Network System?
What is a Network System?

- Highest level of reliability for power distribution systems
- Most desirable for critical loads
- Two main topologies:
  - Spot – One dedicated customer
  - Grid – Several customers; i.e. City block…

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Radial 1 Primary Source 1 Transformer 1 Secondary Path</th>
<th>Primary Selective 2 Primary Sources 2 Transformers 1 Secondary Path</th>
<th>Secondary Selective 2 Primary Sources 2 Transformers 1 Secondary Path</th>
<th>Spot Network 2 Primary Sources 2 Transformers 2 Secondary Paths</th>
<th>Grid Network Plurality of Sources Plurality of Transformers Plurality of Secondary Paths</th>
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</thead>
<tbody>
<tr>
<td># of Outages Per Year</td>
<td>1.14</td>
<td>0.1405</td>
<td>0.1007</td>
<td>0.000705</td>
<td>Approaching zero</td>
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<tr>
<td>Total Hours of Downtime Per Year</td>
<td>3.06</td>
<td>1.0605</td>
<td>0.101</td>
<td>0.001</td>
<td>Approaching zero</td>
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</tbody>
</table>
What is a Network System?

Substation and Primary Feeders
- Nominal Voltages 4.16 kV to 34.5 kV
- Dedicated primary feeders - supply only network transformers
Network Systems

- Who?
- When?
- What?
- How does it work?
- Why?
- Where?
How does it work? Spot Network

Fault on Primary side which causes breaker to open

**Spot Network - Fault on Primary Feeder**

1. Network Transformer
2. Network protector
3. Network breaker fuse

Cable Limiters
How does it work? Spot Network

Station Breaker opens which causes NP to open

Spot Network - Station Breaker “1” is Opened

Network Relay Trips Upon the Flow of Reverse Magnetizing Current of its Associated Network Transformer.
How does it work? Spot Network

Station Breaker opens which causes NP to open

Spot Network – **Continues operation at N-1 contingency**

Customer never experiences interruption of service

Collector Bus
MPCV Relay Family

- Robust design for extreme temperatures (-40C to 125C)
- .25" Thick Solid Brass Case
- Submersible
- Communication activated
- Advanced Safety Algorithms
- Only sequence based relay
- Replaces any Electro-Mechanical Network relay, solid state, or digital relays regardless of vintage or protector type.
- Specification preferred for foreign and domestic utilities
LV Secondary Network System Philosophy

- *Underground Systems Reference Book, EEI T&D Committee (1957)*
  - Page 5-2: Operation is based on 3 principles:

  1. The self-clearing of faults on the secondary grid either by burning-off faults or clearing by use of limiters.

  2. Automatic opening of network protectors when a feeder breaker is opened or in event of a fault on a primary feeder cable or in a network transformer.

  3. Automatic closing of network protectors to connect the network transformers to the secondary grid when the primary feeder is energized.


  Network Protector Fuses—The network protector is equipped with a set of fuses, one in each phase, electrically located between the circuit breaker and the terminals for connection to the system secondary-voltage grid. The primary function of the network-protector fuses is to provide back-up protection for the protector. The fuses should promptly and definitely open the circuit, if the protector fails to trip on a fault causing a reversal of power, such as a fault in a transformer, on a primary feeder, or in the secondary connections between the protector and its associated transformer. The blowing time of the fuses should not be so short, however, that the network master relay does not have ample time to operate and trip the protector when it is functioning normally. Also, the blowing time of the fuses should be long enough to allow network faults sufficient time to burn clear, or be cleared by limiters if they are used, before the fuses blow. Thus the overall tripping time of the network-protector circuit breaker under fault conditions, and the time required to clear secondary faults, are the factors establishing the lower time limit for the current-time curves of the fuses.

  The upper time limit for the current-time curves of the fuses is governed by the following factors: It is desirable to have the fuses protect the network transformer against dangerous temperatures due to high values of current over as wide a range of overload and fault currents as possible. Fuse blowing time should also be coordinated with the tripping time of the associated primary-feeder circuit breaker under fault conditions on the secondary grid, or on another feeder.

  The ideal coordination of secondary-network protective equipment is illustrated in Fig 18. Because of practical design limitations of cable insulation and limiters, such ideal protection cannot be achieved, and typical protective coordination is illustrated in Fig. 19.
Sample – SLD 2-Unit Spot Network

Primary Medium Voltage Devices

Two Position Fusible Primary Switch

1000/1500 kVA Dry Transformer

1875A CMD Non-Fused Protector

65E CLE Fuse

50/51

2000A

Tie NC

Typical DS or DSL Feeders
Sample – Network Floor Plan (Switchgear)
Sample – Network Floor Plan (Switchgear)
Sample – Profile Network view (submersible)

- Collector Bus
- Sudden Pressure Relay
- Visual Disconnect
- Network Transformer
- Visual Status Indicator
- Network Protector
- Bulkhead
- Source Bus
- Primary Disconnect Switch

*Throat or Wall mount*
Vault Vision

- Vault protection
- Family of sensors that seamlessly integrate into communication platform
- Multi-platform communication
- Heat detection systems
Today’s Product Suite for Underground
How does it work? Spot Network

Submersible model CM-52 shown

Switchgear Line-Up
Network Systems

• Who?
• When?
• What?
• How?
• Why use a Network System?
• Where?
Advantages of Network System Design

• Outage on primary feeder does NOT cause customer outage
Advantages of Network System Design

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- **Less transformer capacity is required**
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• **Less voltage sag on Motor starting (up to 70% less than a radial system)**
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- Less transformer capacity is required
- Lower peak loads on transformers - diversity of demand
- Transformer losses are typically less
- Protectors assure positive power into load
- System provides improved voltage regulation
- Less voltage sag on Motor starting (up to 70% less than a radial system)
- Automatic open and close operation

**LV Network Customer outage rate**
- Approaching zero
- Radial systems – once every year.

BEST SOLUTION FOR CRITICAL LOAD APPLICATIONS!
Design Considerations

Reliability vs. Investment Cost
- Radial
- Primary Selective
- Primary Loop
- Double-Ended
- Spot Network

Number of Outages vs. Costs associate with outages
- Radial
- Primary Selective
- Primary Loop
- Double-Ended
- Spot Network
Network Systems

- Who?
- When?
- What?
- How?
- Why?
- Where are they used today?
Where are they used today?
Where are they used today?

*Selected example utilities
Where are they used today?

Network Systems are also widely used in other parts of the world such as:

• Canada

• Asia and Asia Pacific
  
  Philippines  
  Thailand  
  South Korea

• Australia

• Latin America – Central and South America
  
  Mexico  
  Columbia  
  Brazil  
  Venezuela
Example Installations

Electrical Room Installation

Subsurface Vault Installation
Example Installations

Platform installation

Roof installation
Example Installations

Detroit Edison Design
Example Installations

Subsurface Vault Installation
Example Installations

3 Unit 480Y/277 V Spot Network- Seattle, WA- Building Vault
480V Spot Network Example
(1-4 Feeders at 12.47 kV)

- Load Estimation Study
  - Maximum Short Term Peak Load: 1250 kVA
  - Continuous Average Load: 800 kVA
  - Minimum Baseline Load: 275 kVA
  - All above loading conditions at 0.87 Lagging PF

- 3 Standardized 480V Transformer Options
  - 1000 kVA (1200A)
  - 1500 kVA (1800A)
  - 2500 kVA (3000A)

- Network Unit Options
  - 2-Unit through 6-Unit Spot Networks
Optimal Transformer / “#-Unit” Combination (N-1 Contingency)?

<table>
<thead>
<tr>
<th>Units</th>
<th>(N-1)</th>
<th>1000 kVA Transformers</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td>1250</td>
<td>2000</td>
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<tr>
<td></td>
<td></td>
<td>62.5% Max Peak Load</td>
</tr>
<tr>
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<td>800</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>275</td>
<td>2000</td>
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<tr>
<td></td>
<td></td>
<td>40.0% Max Cont Load</td>
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<td></td>
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<td>13.8% Min Load</td>
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<table>
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<td>83.3% Max Peak Load</td>
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<td>800</td>
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<td>53.3% Max Cont Load</td>
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<td></td>
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<td>18.3% Min Load</td>
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<th>Units</th>
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<td>125.0% Max Peak Load</td>
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<tr>
<td></td>
<td></td>
<td>80.0% Max Cont Load</td>
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<tr>
<td></td>
<td></td>
<td>27.5% Min Load</td>
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</tbody>
</table>

3-Unit $ > 2-Unit $ & Min Load concern?
2-Unit 1500 kVA $ > 1000 kVA, also Min Load concern?
2-Unit 1000 kVA: Least $, Best "Sweet Spot" Loading.
## Transformer Calculations

<table>
<thead>
<tr>
<th>Transformer kVA</th>
<th>12.47 kV</th>
<th>216 V</th>
<th>480 V</th>
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<tbody>
<tr>
<td>Transformer</td>
<td>Nameplate 100% Amps</td>
<td>Max 100% Amps</td>
<td>Nameplate 100% Amps</td>
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<td>300</td>
<td>13.9</td>
<td>278</td>
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<tr>
<td>3000</td>
<td>138.9</td>
<td>1984</td>
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</table>

n/a = Outside NWP Amperage Range

\[
VA = E_{LN} \times I \times 3_{PHASES}
\]
\[
VA = \frac{E_{LL}}{\sqrt{3}} \times I \times 3_{PHASES}
\]
\[
VA = \sqrt{3} \times E_{LL} \times I
\]
\[
KVA = \frac{\sqrt{3} \times E_{LL} \times I}{1000}
\]
\[
I = \frac{KVA \times 1000}{\sqrt{3} \times E_{LL}}
\]

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## Network Protector Selection

<table>
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<tr>
<th>216 Volts</th>
<th>IEEE Std C57.12.44-2005</th>
<th>CM52 (IB 52-01-TE)</th>
<th>CM22 (IB 35-500-1E)</th>
<th>CMD (DB 35-552B)</th>
<th>CMR8 (IB 35-575-B)</th>
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<td>NP Amps</td>
<td>Interrupt Xfmr kVA</td>
<td>Xfmr Amp</td>
<td>NP/Xfmr %</td>
<td>kA</td>
<td>kVA</td>
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**EATON**

Powering Business Worldwide
Network Protector Selection Rationale

• Choose 1000kVA 5% Impedance Transformers (125% Maximum Short Term = 1504A)

• 1600A NWP Rating Provides 133% Transformer Nameplate Overload Margin, a good fit.

• 1875A NWP 156% Rating also utilizes 1600:5 CTs but unnecessary higher amperage fuses.

• Select 1600A CM52 NWP for a 2-Unit 1000kVA Spot Network.

• Notice that a 2-Unit 1500kVA Spot would yield: Higher Transformer $, Higher NWP $ (4-Pole CM52), for undesired excess load capacity.
IEEE Standards & References

- IEEE – C57.12.40
  Secondary Network Transformers Subway and Vault Type (Liquid Immersed) – Requirements

- IEEE – C57.12.44.2014
  Standard Requirement for Secondary Network Protectors

- EPRI Bronze Book – Underground Distribution Systems Reference Book
Additional Network System Training

• Electrical Networks Systems Conference (ENSC)
  • Annual Conference
  • Guest Speakers and Vendor Trade Show
    16th Annual ENSC
    Tempe, AZ
    March 30th to April 2nd 2015

• Troubleshooting Training (3-day)- covers all brands of NWPs
  • Factory or Onsite Classes are available
  • Greenwood Seminar to be held 2x per year, 4.0 CEU credits awarded

• NWP Engineer Application Training (2 days)
  Greenwood and On-Site
Questions?