Walk-through of long-term utility distribution plans:

Part 1 - Traditional Distribution Planning

Lavelle Freeman
GE Energy Consulting
Distribution Systems and Planning Training for Western States, May 2-3, 2018
Goal of distribution planning

► Provide orderly, economic expansion of equipment and facilities to meet future demand with acceptable system performance

• Deliver power with required frequency (60Hz)
• Satisfy voltage requirements (within ±5%)
• Deliver adequate availability (<2 hours out/yr)
• Have capacity to meet instantaneous demand
• Reach all customers wherever they exist

… and do it all for the lowest possible cost
Need to plan because it takes time to build capacity

- Effective minimum-cost planning accounts for lead time to deploy T&D assets in developing reasonable alternatives

<table>
<thead>
<tr>
<th>T&amp;D Level</th>
<th>Lead Time (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>13</td>
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<tr>
<td>EHV Transmission</td>
<td>9</td>
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<tr>
<td>Transmission</td>
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<tr>
<td>Sub-transmission</td>
<td>7</td>
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<tr>
<td>Substation</td>
<td>6</td>
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<tr>
<td>Feeder</td>
<td>3</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.5</td>
</tr>
<tr>
<td>Service</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Loads and demand drive distribution planning

- Loads vary over time

Typical Feeder Load

Typical Customer Load

Perceived variability depends on level of aggregation and resolution
Loads Vary by Customer Class

“Class” is any distinction that is useful for segmentation

- Residential
- Commercial
- Industrial
- Agricultural
- Institutional
- Resort
- Storage
Demand is average value of load over a period

Most distribution utilities sample demand on a 15-60 minute basis

165 kW used in this one-hour period

The longer the sampling period the more likely the peak is under-estimated
Individual Customer Load

► As number of customer loads in group increases:
  • Peak demand per customer drops
  • Load profile curve becomes smoother
  • Load factor (LF) increases
  • Coincidence factor (CF) decreases

LF = 0.2
CF = 1

Groups of customer loads

Planners typically develop coincidence curves for various customer types based on load research data.

Example of coincidence data from a utility in the Southeastern U.S.
Coincidence application to capacity planning

Planners use coincidence curves to determine load = coincidence * number of customers downstream

Two main methods for reliability assessment

- **Historical**: compute reliability indices using archived data on outages and interruptions
  - Can determine the current system performance
  - May (*carefully*) be used to project future performance
  - Cannot be used for multiple-scenario analysis

- **Predictive**: assess system reliability using a connectivity model with component reliability data
  - Usually calibrated using historical reliability indices
  - Historical interruption data may be used to represent component reliability
  - Excellent for “what-if” scenarios and project justification
Predictive Reliability Model

► **Connectivity** is a functionally accurate description of the topographical arrangement capturing diversity of supply, equipment redundancies, remedial actions and mitigating measures.

  Sources: system maps and one-line diagrams, GIS databases, drawing files

► **Component data** describes the failure, repair and remedial characteristics of individual system components
  - Failure rates, repair times, switching times
  - Sources: utility archives, databases, industry sources such as IEEE standards, papers, and publications

Excellent for developing and evaluating reliability improvement strategies
Example Plan:
Consumers Energy, Michigan

Electric Distribution Infrastructure
Investment Plan (2018-22)
Michigan Public Service Commission Order for Case No. U-18014

Requires a **five-year distribution investment and maintenance plan** that contains:

1. **Current state of the electric distribution system**: a detailed description, with supporting data, on distribution system conditions, including age of equipment, useful life, ratings, loadings, and other characteristics
2. **System goals and related reliability metrics**: assessment of performance using industry standards and metrics such as SAIDI, SAIFI, CAIDI
3. **Local system load forecasts**: forecasts of load at the system, area and local levels
4. **Maintenance and upgrade plans**: project categories including drivers, timing, cost estimates, work scope, prioritization and sequencing with other upgrades, analysis of alternatives
5. **Cost / benefit analysis**: analysis considering both capital and O&M costs and benefits

Consumers filed their draft Plan on Aug 1, 2017; Final Plan was filed on April 13, 2018
Trends in Consumers Energy customer expectations

► Reliability and resiliency
Customers increasingly focus on reliability and resiliency in assessment of utility service

► Security
Customers, governments, and utility executives are increasingly focusing on security threats, especially cybersecurity

► Distributed energy resources (DERs)
Customers will continue to pursue adoption

► Renewable generation
C&I customers will continue to desire expanded renewable generation

► Data proliferation
Customers have more access to big data and are making more new, real-time decisions

“meaningfully affect ... assets and capabilities required to operate [the distribution system] successfully”

Distribution Investment and Grid Modernization Focus Over next Five years

► **Reliability** – Automated re-routing of power flows around an outage and restoration following an outage through FLISR.

► **Sustainability** – Energy efficiency gains and peak reduction through VVO.

► **Controls** – Enabling increased utility- and customer-owned DERs such as DG and energy storage systems.
System Information

Serves 1.8 million customers in the north, central, and western MI

Average age of Consumers Energy distribution assets

Compared to other major U.S. utilities, the age of CE infrastructure is in the third quartile

Trend in Consumers Energy SAIFI with and without Major Events

Based on data from Consumers Energy’s Electric Distribution Infrastructure Investment Plan (2018-22), 8/1/17,
https://mi-psc.force.com/s/ Filing U-17990-0416
Trend in Consumers Energy SAIDI with and without Major Events

Reliability Statistics by Operating Region

Impact of Regional Performance on System Metrics

Additional Measures of Customer Experience

**SERVICE REGION**

**AVERAGE PERCENT OF CUSTOMERS WITH ≥3 INTERRUPTIONS PER YEAR**

**SERVICE REGION**

**AVERAGE PERCENT OF CUSTOMERS WITH ONE OR MORE ≥5 HOUR INTERRUPTION**

Based on data from *Consumers Energy’s Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17, [https://mi-psc.force.com/s/Filing U-17990-0416](https://mi-psc.force.com/s/Filing U-17990-0416)
Common causes of interruptions for Consumers Energy

- Trees and weather account for 75% of LVD outages
- Equipment failures and weather account for over 50% on HVD
Root Causes of Outages by Region

SAIFI Contribution by Incident Cause
(2013-2017 Avg; MED Excluded)

Based on data from Consumers Energy’s Electric Distribution Infrastructure Investment Plan (2018-22), 8/1/17,
https://mi-psc.force.com/s/ Filing U-17990-0416
Consumers Energy **Five-Year Electric Distribution Infrastructure Investment Plan (2018-22)**

**Plan**

Develop circuit-level system planning to better integrate DERs and renewables in order to maximize customer value and control, increase reliability, resiliency and security, and reduce CE’s carbon footprint.

<table>
<thead>
<tr>
<th>Build</th>
<th>Maintain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tune investment options to meet future capacity needs</td>
<td>Maintain, repair, and replace grid infrastructure using future technologies to lower costs</td>
</tr>
<tr>
<td><strong>Wires</strong></td>
<td><strong>Preventative maintenance</strong></td>
</tr>
<tr>
<td>Build substations and lines to meet capacity needs</td>
<td>Ensure system reliability through predictive maintenance</td>
</tr>
<tr>
<td><strong>Non-wires alternatives</strong></td>
<td><strong>Outage response</strong></td>
</tr>
<tr>
<td>Deploy non-wires alternatives to meet and/or mitigate capacity needs</td>
<td>Respond to outages while building predictive capabilities</td>
</tr>
</tbody>
</table>

**Operate**

Foster next generation distribution operations capabilities to meet future customer needs and desires.

Bridges Phase 1 and phase 2 of Consumers’ 15-year plan
**First Role: Plan**

**Plan**

Develop circuit-level system planning to better integrate DERs and renewables in order to maximize customer value and control; increase reliability, resiliency and security; and reduce CE’s carbon footprint.

- Identify future infrastructure needs to ensure that the system
  - Has adequate distribution capacity
  - Can effectively integrate DERs where most beneficial
  - Can effectively manage frequency and voltage regulation
  - Is able to proactively adapt to ensure reliability, resiliency, and safety

- Process relies on load forecasts as primary input
Current Approach to System Planning

- Identify future supply-side and demand-side resource needs based on load forecasts and the acquisition of various resources

**Build HVD system peak load forecast**
- Using historical data, economic forecasts and weather data
- 65% confidence interval

**Allocate forecast to planning areas**
- Allocated based on historical growth within each area
- Load flow model developed for HVD system

**Build LVD system peak load forecast**
- Allocated based on local substation peak*
- Local load flow model developed in CYME

*Real-time data (SCADA or Distribution SCADA -- DSCADA) is used where available. Otherwise, historical data from manual readings is used
Key planning related expenses

► Future investments to improve planning capabilities:

• **System Modeling Tools**: Tools that help perform near-real time distribution power flow studies to help streamline interconnection requests for DERs

• **Data Lake**: Gather disparate data sources (asset, customer, outage, smart meter, DSCADA, etc.) into a single location to be used for advanced data processing and analytical techniques

• **Grid Analytics “Sprints”**: Develop analytical capabilities to perform feeder and circuit level analyses quickly

• **External Planning Services**: Offer DER planning services for customers and project developers
Electric Distribution Planning Process

Financial Planning
- Long term financial planning
  - Budget outlook

Planned Engineering Programs
- Load studies
- LVD capacity planning
- LVD reliability planning
- HVD capacity planning
- HVD reliability planning

Unplanned Engineering Programs
- Unplanned program budget forecasting

Monthly forecasting
- Project execution
- Operational Reviews

Demand failure response
- New business response
## Five-year Capital Investment Plan

### 5-Year Plan – Capital Programs

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<td>1.0 New Business</td>
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<td>2.0 Demand Failures</td>
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<td>145</td>
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<td>3.0 Asset Relocations</td>
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<td>226</td>
<td>281</td>
<td>267</td>
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<td>232</td>
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<td>5.0 Capacity</td>
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<td>6.0 Tools and Technology</td>
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<tr>
<td>Total Planned</td>
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<td>193</td>
<td>167</td>
<td>245</td>
<td>300</td>
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<td>7.0 Cost of Removals</td>
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<td>70</td>
<td>60</td>
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<td>58</td>
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<td><strong>Capital Plan</strong></td>
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<td><strong>603</strong></td>
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<tr>
<td>8.0 Demand Response</td>
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<td>7</td>
<td>9</td>
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<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

From Consumers Energy’s Electric Distribution Infrastructure Investment Plan (2018-22), 8/1/17
Second Role: Build

- Develop solutions to needs identified by system planning
- Incorporate both traditional assets and non-wires alternatives
Current Approach to System Building

► Determine Investment to ensure the entire system meets overall load and peak demand

Determine needs
- Conduct distribution studies
- Power flow analysis
- Reliability assessment
- Planning criteria violations

Identify Solutions
- Load transfer
- Capacity increase
- New LVD substation
- Alternate LVD substation connection
- Non-wires alternatives

Prioritize Projects
- Equipment loading compared to peak capability
- Performance on lines (SAIDI) and projected improvement
2. Build

System Modeling and Analysis

GIS

- Network topology
- Equipment
- Phase

Device monitoring & control

- Equipment status
- Control settings
- Load information
- Conductor type
- Device capacity

Customer information system

Equipment database

Planning model

- Single-phase unbalanced load flow model
- Reliability model

- CYMDIST, CYME
- SynerGEE, Advantica-Stoner
- WindMil, Milsoft
- PoweFactory, DlgSILENT
- DEW, EDD
- NEPLAN, Neplan AG

- ESRI ArcGIS
- Intergraph
- GE Small World
- Milsoft WindMiMap
- Schneider EcoStruxur
### Substation expansion

<table>
<thead>
<tr>
<th>Location</th>
<th>Deerfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major cause</td>
<td>Customer expansion</td>
</tr>
<tr>
<td>Local load</td>
<td>The existing transformer in the substation was loaded to approximately 86% of capability in 2016. The customer’s load addition of 1.8MW in late 2017 will place the transformer at 131% of capability in 2018.</td>
</tr>
</tbody>
</table>
| Primary options considered | Expand the existing substation  
Build a new substation  
Energy efficiency / demand response |
| Rationale   | The existing substation is a small substation that is group regulated. These substations were not built to the current minimum approach distance standards. Working in them without forcing an outage to customers is difficult. The substation expansion project will address the capacity the concerns and ultimately improves reliability to the area. The addition of a new substation was not necessary due to the relatively small nature of the load addition (about 1.5MW of peak load increase), but neither energy efficiency nor demand response were considered viable in this location to achieve sufficient peak load reduction. |
Non-Wires Alternatives (NWA)

Two Focus Programs

<table>
<thead>
<tr>
<th>Demand Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since 2010, we have partnered with more than 1,700 Michigan residences and businesses to reduce peak electric demand by approximately 52 MW (majority through our C&amp;I program)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since 2009, our portfolio of Energy Efficiency programs have saved customers more than $1B in reduced energy bills while reducing peak electric demand by approximately 400 MW</td>
</tr>
</tbody>
</table>

► Ongoing NWA project at the Swartz Creek substation to defer a capacity project

► Demand Response
  • AC cycling pilot with 1,754 customers, 2 MW in 2016
  • Two time of use (TOU) pilots with 37 employees, enrolling 0.0233 MWs in 2016
  • $20M investment to increase C&I demand response portfolio from 50 MW to 150 MW

► Future BESS Pilots
  • WMU Solar Farm (Kalamazoo) - 1MW/1MWhr
  • Circuit West BESS (Grand Rapids) - 0.25 to 0.75 MW

► NWA are now an integral part of the supply planning process and part of the Company’s supply plan.
<table>
<thead>
<tr>
<th>Non-wires alternative (Pilot)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
</tr>
<tr>
<td><strong>Major cause</strong></td>
</tr>
<tr>
<td><strong>Local load</strong></td>
</tr>
<tr>
<td><strong>Primary alternative considered</strong></td>
</tr>
</tbody>
</table>
| **Rationale**               | A traditional substation capacity increase would be implemented after an observed overload. Swartz Creek substation was chosen for the NWA (pilot) due to historical loads that have been observed close to capacity, but never over. Piloting an NWA at this location was an opportunity to test an NWA solution’s feasibility without risking the equipment or customer reliability due to an observed overload the prior year.  
The company’s NWA pilot at Swartz Creek substation will rely heavily on the existing Energy Efficiency and Demand Response programs in place. The pilot will also make use of the Time of Use and dynamic peak pricing rates that are offered. These programs and rates will be marketed in the community to show off the rebates and long-term cost savings that can be realized. The marketing plan utilized will reach both residential and business customers.  
The NWA pilot is being run in coordination with the Natural Resources Defense Council (NRDC). |
Third Role: **Maintain**

Consistently maintain distribution assets as they age.
Current Approach

Ensure all equipment is operating safely, effectively, and efficiently

- Repairing Assets
  - Multiple programs covering poles, lines, pole-top equipment, and substation equipment
  - Tree trimming and line clearing program
  - Programs to reduce customers’ average outage duration (SAIDI).

- Replacing Assets
  - Investments to upgrade deteriorated equipment, to reduce system outages
  - Investments for adverse weather
  - Investments to build for the future need and demands of our customers.

- Outage Restoration
  - Restoration management program
  - Storm restoration relies on
    - outage management system
    - resource management system
  - Continuous feedback loop to improve restoration program
Project Prioritization

► Evaluate reliability projects based on estimated avoidance of outage minutes for the customers impacted by the project

► Projects are prioritized using
  • Cost-benefit ratio analysis
  • Input by engineers and program managers based on experience and knowledge of the system
  • Availability and location of resources
  • Funding

► Reliability Analytics Engine (“RAE”) used to analyze outage data
  • Produces ranked list based on line performance and opportunity for improvement
Repair/Replacement Programs

- Pole inspection and replacement
- Line inspection and replacement
- Tree trimming
- System protection
- Substation inspection
- Substation maintenance and reliability
- Demand failures
- Storm restoration
### Five-Year O&M Plan

#### 5-Year Plan – O&M Programs

<table>
<thead>
<tr>
<th>All values in $ millions</th>
<th>Actual</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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<tbody>
<tr>
<td></td>
<td>2015</td>
<td>2016</td>
<td>2017 prelim</td>
<td></td>
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<tr>
<td>1.0 Net O&amp;M Assoc. with Construction</td>
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<td>1</td>
<td>-3</td>
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<tr>
<td>2.0 Reliability</td>
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<td>54</td>
<td>53</td>
<td>55</td>
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<td>3.0 Ops, Metering, Service Restoration</td>
<td>89</td>
<td>76</td>
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<td>69</td>
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<td>77</td>
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<td>4.0 Field Operations</td>
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<td>19</td>
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<td>5.0 Grid Management &amp; SEOC</td>
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<td>6.0 Planning &amp; Scheduling</td>
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<td>7.0 Operations Performance</td>
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<td>8.0 Operations Management</td>
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<td>9.0 Engineering &amp; Ops Support</td>
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<td>10.0 Engineering &amp; System Planning</td>
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<td>11.0 Joint Pole Rental</td>
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<tr>
<td>12.0 Energy Efficiency &amp; Demand Response</td>
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<td><strong>79</strong></td>
<td><strong>121</strong></td>
<td><strong>128</strong></td>
<td><strong>127</strong></td>
<td><strong>130</strong></td>
</tr>
</tbody>
</table>

From Consumers Energy’s Electric Distribution Infrastructure Investment Plan (2018-22), 8/1/17
Fourth Role: Operate

Foster **next generation distribution operations** capabilities to meet future customer needs and desires

- Actively manage the distribution system at all times to
  - Minimize cost
  - Ensure safety
  - Improve reliability and resiliency
  - Allow customers more control over their energy supply and consumption
Current and Future System Operations

Current System Operations
- Power flow analysis tools
- Customer call triangulation
- SCADA
- Four hours of analysis to run CYME report and interpret the results
- Limited capability to perform switching
- Limited interactions with DER

Future system operations
- Operations increasingly complex
- Digital capabilities enable real-time system view
- Integrated ADMS allows enhanced operations, better tools to assess, monitor, analyze and control
- Sensors and AMI increase situational awareness and system control

"Increase situational awareness and automate manual processes, shifting operations from being reactive to proactive"
Key operations investments

► **Grid Communication**: Reliable, high-speed, high-capacity, wired and wireless communications platform based on internet protocol to connect all substations and distribution grid devices

► **Substation and Line Automation**: DSCADA, distribution automation, device controllers, and line sensors to optimize power flow and performance and avoid outages

► **Unified System Control Center**: Consolidating System Control Center (SCC) personnel and developing a Distribution Control Center (DCC). Consolidating operations support functions such as Operating Technologies, Data Center, Security, Real-Time Engineering, Applications Support

► **Advanced Distribution Management System**: Consolidated grid management applications including Volt-VAR optimization; conservation voltage reduction; and fault location, isolation, and service restoration

► **Communications Device Management System**: Operational platform to enable system-wide communications by collecting information from multiple grid device technologies

► **Data Management**: Accurate system model and processes to maintain the integrity of model data provides the foundation for ADMS and other distribution applications
Key Take-Aways

► Almost $5 billion invested in electric distribution over past decade by Consumers Energy

► Investments in physical grid infrastructure (poles, wires, relays, transformers, etc.) provide the necessary foundation for upgrading grid capabilities

► Grid modernization goals cannot be met if new technology is deployed on existing aging infrastructure

► Must coordinate advanced capabilities with physical grid infrastructure upgrades

► This will allow advanced communications and intelligent applications to manage the grid as a fully integrated bi-directional system
Any Questions?

Contact Lavelle Freeman at 518-385-3335  
Lavelle.freeman@ge.com