Voltage Optimization: Distribution Planning Considerations and Demand Savings Potential for an Emerging IDSM Technology

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Agenda

1) Ameren Illinois Company (AIC)

2) Voltage Optimization (VO) Technology & Implementation

3) AIC VO Programs

4) Evaluation Approaches and Findings
Ameren Illinois Company (AIC)

- AIC is a diversified regional electric and natural gas utility that serves 1.2 million electric and 816,000 gas customers
  - Service territory includes over 1,200 communities and spans more than 43,700 square miles

- AIC operates and maintains:
  - 4,500 miles of electric transmission lines
  - 46,000 miles of electric distribution lines
  - 18,200 miles of natural gas transmission and distribution mains
  - 12 underground natural gas storage fields

- Employs more than 3,300 personnel
Voltage Optimization Overview

- Voltage Optimization (VO) is a distribution system optimization technology that improves power system operations and saves energy.

- There are two main technologies collectively referred to as VO:

<table>
<thead>
<tr>
<th>Volt-VAR Optimization (VVO)</th>
<th>Conservation Voltage Reduction (CVR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improves power factor to reduce line loses</td>
<td>Reduces distribution line voltage to reduce customer energy consumption</td>
</tr>
</tbody>
</table>
CVR technologies reduce distribution line voltage by regulating voltage in the lower portion of the allowable range.

Historically, utilities have regulated voltage in the upper portion of the range to avoid low voltage violations.

Regulating voltage in the lower portion of the range does not compromise power quality.

Most end-uses use less energy at lower voltages.

Voltage Optimization Overview

Voltage (volts)

Before VO  After VO

127
113
## Voltage Regulation and Monitoring Devices

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Location</th>
<th>Regulation</th>
<th>Monitoring</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Tap Changer (LTC)</td>
<td>Substation</td>
<td>✓</td>
<td>✓</td>
<td>Raise or lower voltage</td>
</tr>
<tr>
<td>Voltage Regulator</td>
<td>Substation or Feeders</td>
<td>✓</td>
<td>✓</td>
<td>Raise or lower voltage</td>
</tr>
<tr>
<td>Capacitor Bank</td>
<td>Substation or Feeders</td>
<td>✓</td>
<td>✓</td>
<td>Voltage and VAR support</td>
</tr>
<tr>
<td>Advanced Metering Infrastructure (AMI)</td>
<td>Customer Residence</td>
<td></td>
<td>✓</td>
<td>Granular and continuous monitoring</td>
</tr>
</tbody>
</table>

Implementation Considerations

- Substation and circuit-level characteristics must be carefully considered so that necessary modifications and upgrades can be installed
  - Modifications required to maximize VO energy savings differs on a case-by-case basis
- VO can be deployed and operated to meet specific program objectives

<table>
<thead>
<tr>
<th>Existing Infrastructure</th>
<th>Circuit Characteristics</th>
<th>VO Vendor Technology</th>
<th>Program Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Existing grid infrastructure must be conducive to VO implementation</td>
<td>• Number of customers</td>
<td>• Technologies have different data requirements, distribution circuit models, and optimization algorithms</td>
<td>• VO is used to reduce: energy consumption, peak demand, and distribution line losses</td>
</tr>
<tr>
<td>• Number of automated voltage sensors – upgrades and additions to improve monitoring capability</td>
<td>• Proportion of residential customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Length of circuit - voltage regulator additions possible to maintain line voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• DERs - smart inverters to optimize voltage and VAR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Implementation and Evaluation Metrics

• Although the primary objective of the AIC VO program is to achieve energy savings, both implementation and evaluation metrics are important indicators of VO program success.

<table>
<thead>
<tr>
<th>Implementation Metrics</th>
<th>Evaluation Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Reduction</td>
<td>Conservation Voltage Reduction Factor (CVR_f)</td>
</tr>
<tr>
<td>Upgrade Costs</td>
<td>% Change Usage</td>
</tr>
<tr>
<td>Deployment Difficulty</td>
<td>% Change Voltage</td>
</tr>
<tr>
<td>Deployment Scalability</td>
<td>National Average = 0.80</td>
</tr>
</tbody>
</table>
AIC VO Pilot Program (2012)

Pilot Characteristics:
- 1 urban substation with 3 feeders
- 1 rural/urban substation with 1 feeder
- Voltage reduction at the LTC - LTC set point on pilot feeders of 0%, 2%, 4% for 24 hour periods

System Enhancements:
- New regulator controllers with two-way communication
- End-of-Line voltage sensors
- LTC controller modifications for remote control capabilities
- Implementation of automatic voltage control using Ameren’s ABB ADMS system

Results:

<table>
<thead>
<tr>
<th>Feeder</th>
<th>CVR_f</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>0.78</td>
<td>1.24</td>
<td></td>
</tr>
<tr>
<td>Rural/Urban</td>
<td>0.97</td>
<td>0.44</td>
<td></td>
</tr>
</tbody>
</table>

Lessons Learned:
- Data retention
- SCADA control
- Control logic
- Value of voltage sensing
AIC VO Program (2017 - 2018)

- AIC launched its VO program in 2017 and is using the first few program years to better understand current marketed VO technologies and solutions

- There are 14 VO-implemented circuits currently deployed and operational

- 10 additional circuits are in the engineering test phase

<table>
<thead>
<tr>
<th>VO Technology</th>
<th>Circuit Count</th>
<th>Voltage Regulation</th>
<th>AMI</th>
<th>Deployed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilidata</td>
<td>4</td>
<td>Feeder Head and Line</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>DVI</td>
<td>4</td>
<td>Feeder Head and Line</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>OSI</td>
<td>1</td>
<td>Feeder Head and Line</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>ABB</td>
<td>5</td>
<td>Feeder Head and Line</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

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• 10 additional circuits are in the engineering test phase
AIC VO Program (2018 - 2025)

- AIC plans to implement VO on 1,047 VO circuits by the end of 2024

- Circuits were selected for the VO Program mainly based on voltage level, energy consumption, potential savings, and total resource cost (TRC)

- Large change management effort required to support the program

- Total projected savings of over 400 GWh over 7 years

- Starting in 2019, AIC will switch VO technology on and off on a subset of VO-implemented circuits to support evaluation efforts
Evaluation Approaches

• Opinion Dynamics will evaluate the energy and demand savings of AIC’s VO program starting in 2019 using two different approaches:

<table>
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<tr>
<th>Algorithmic Approach</th>
<th>On/Off Regression Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deemed savings approach based on results from AIC’s pilot study and a survey of the literature that assumes a CVR_f of 0.80</td>
<td>Regression model using VO on and VO off testing data that will be used to obtain seasonal and annualized savings estimates</td>
</tr>
</tbody>
</table>

• The results of the two approaches will be compared and the on/off regression approach results will be used to validate the algorithmic approach.
Results from Existing Programs

• VO programs implemented nationwide have shown that energy reductions of between 1% and 4% are achievable.

• CVR_f values for energy and demand savings range from between 0.10 and 1 where a higher value indicates more energy savings and 1 is a 1:1 relationship between voltage and energy levels.

• Generally, VO has been found to produce larger energy savings on residential loads and in the summer season.
Conclusions and VO Program Next Steps

Conclusions
• VO is an emerging technology with considerable energy and peak demand reduction potential
• To successfully implement VO, individual substation and circuit characteristics must be considered to make informed upgrade and grid modification decisions

Next Steps
• AIC:
  • Continue to deploy VO on target circuits
  • Study and analyze the effect of DER penetration on VO savings
  • Institute thoughtful change management to ensure successful implementation of large VO program
• Opinion Dynamics:
  • Evaluate the energy and demand savings from the VO program
  • Contribute to industry understanding of best VO evaluation methodologies
Contact Information

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