Distribution Automation for electrical grids
Volt-VAr management

Alain Aurus, Theodoros Oikonomou, Yasmine Vögele
Introduction
Facility Management

Use the “detach” button to detach the question panel. It will come up as a larger window.

When you do not need the questions anymore. Use the “attach” button to bring it back to the panel. (Do not use the little “x”).
Introduction of the team

Theo Oikonomou  
Global Product Manager  
Distribution Automation

Yasmine Vögele  
Marketing Manager  
Substation Automation

Alain Aurus  
Distribution Automation Initiative owner
**Grid Automation**

Leading the way within the Power Grids division

**Worldwide presence**

**ABB**
- 132,000 employees
- $34B revenue

**ABB Power Grids**
- 39,000 employees
- $11B revenue
- 100 countries

**ABB Grid Automation**
- 6,000 employees
Distribution Automation
Enabling you to see inside your grid
Trends and Challenges
Trends

- Increased Investment focused on Energy Efficiency improvement.
- Energy Consumption is still growing.
  - Infrastructure addition Vs Optimizing utilization of Existing Infrastructure
- Grid modernization trends enabling to see in real time into the Grid
  - Moving from a Reactive operating mode to Proactive and Prescriptive operating mode
- Increasing penetration of Distributed Energy Resources in the Low Voltage and Medium Voltage Network
- Move from Local Control to Model Based Volt/Var optimization

Keeping the voltages within the limits for reduced power losses and increased grid efficiency
## Distribution Automation

**Environment, Quality, Efficiency, Reliability**

### Challenges

<table>
<thead>
<tr>
<th>Quality of power supply</th>
<th>Operational efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Legislation and regulator demands</td>
<td>– Minimize the network losses</td>
</tr>
<tr>
<td>– Customer requirements</td>
<td>– Optimise Network Utilisation</td>
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<tr>
<td>– Less and shorter outages</td>
<td></td>
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<tr>
<td>– Voltage quality</td>
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### Challenges

<table>
<thead>
<tr>
<th>Distributed Energy Resources (DER)</th>
<th>Environmental Impact</th>
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<tbody>
<tr>
<td>– Increased need to measure power flows and quality due to increased distributed generation</td>
<td>- Reduction of CO2</td>
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<tr>
<td></td>
<td>- Increased Ability to host DER</td>
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</table>
# Distribution Automation Systems

## Application overview

<table>
<thead>
<tr>
<th>Basic applications</th>
<th>Advanced applications</th>
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<tbody>
<tr>
<td>Monitoring, Control and Measurement</td>
<td>Volt-Var Management</td>
</tr>
<tr>
<td>System Protection</td>
<td>Fault &amp; Outage Management</td>
</tr>
</tbody>
</table>
## Distribution Automation

### Portfolio

<table>
<thead>
<tr>
<th>Systems</th>
<th>Engineered packages/DA solutions</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered Distribution Automation Systems, from control center, to primary, down to secondary substation automation.</td>
<td>Secondary and communication equipment packaged together and factory tested</td>
<td>All the essential distribution automation products for medium to low voltage</td>
</tr>
<tr>
<td><img src="image1" alt="Systems Image" /></td>
<td><img src="image2" alt="Engineered packages/DA solutions Image" /></td>
<td><img src="image3" alt="Products Image" /></td>
</tr>
<tr>
<td>Primary equipment packaged with automation fully integrated and factory tested</td>
<td>All the essential distribution apparatus products for medium to low voltage</td>
<td></td>
</tr>
</tbody>
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Volt-VAr management

Introduction and concepts
Energy efficiency
Losses in a typical distribution grid (technical and non-technical)
Energy efficiency

Reactive power
Energy efficiency
Power factor correction

Restore the power factor as close to unity as is economically viable

Advantages
- Reduction of power consumption due to improved energy efficiency
- Reduction of electricity bills
- Reduction of Ohmic losses in transformers and distribution equipment
- Reduction of voltage drop in long cables

Power Factor $= \frac{P}{S}$
**Volt-VAr Management**

Traditional Volt-VAr control strategies

**Distribution Utilities**

- Deploy fixed and switched capacitors to reduce VAR flow losses and maintain acceptable voltage levels
- Install on-load tap changing transformers
- Install single and three-phase line voltage regulators (LVR)
- Employ simple one-way communications systems: like radio or PLC (power line carrier)
- Results could only be measured back at the substation and voltages out on the feeder could only be estimated through system models
Volt-VAr Management
Increase grid’s hosting capacity

Line Voltage Regulator (LVR)
Installation next to an existing secondary substation or supplied as an integrated part of a new substation

Advantages
- Limiting the voltage rise enables integration larger amount of renewables
- MV and LV grid hosting capacity improvement
- Avoids or reduces the need for grid expansion
- Regulation device can be relocated
- Fast and simple solution with low Capex
Volt-VAr Management
Control and Optimization through automation

1) CVR: conservative Voltage Reduction
2) VVO: Volt/VAr Optimization
3) VVC: Volt/VAr Control
Volt-VAr Management
Three levels of Volt-VAr efficiency

- **Centralized / Integrated**
  - Single solution for entire grid
  - Standardized field devices
  - Advanced DMS functionality

- **Semi-centralized / Coordinated**
  - Combination of conventional SCADA and flexibility of de-centralized solution
  - Modular step-wise approach

- **De-centralized / Local**
  - Quick response to problematic feeders (e.g. LVR)
  - Easy and flexible step-wise approach
Volt-VAr Management
De-centralized concept

Automation logic is running locally e.g. at Line Voltage Regulator and secondary substation level.

SCADA is just informed.

Tier 1
Control center
SCADA/DMS

Tier 2
Primary distribution substations

Tier 3
Secondary distribution substations and Line Voltage Regulators

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Communication
Voltage Control
De-centralized concept
Feeder level VVC

Local Volt-VAr control
Capacitor bank control based on local voltage, current, temperature and time of day

Advantages
- Limited – changes must be made manually or remotely at the capacitor banks
- Least expensive alternative to implement

Disadvantages
- A capacitor bank either supplies zero reactive power (off state) or 100% of its capacity (on state)
- Power factor correction and voltage reduction often inconsistent with loss or demand reduction
Volt-VAr Management

Semi-centralized concept

Automation logic is running at primary substation level. SCADA is just informed.

Tier 1
Control center
SCADA/DMS

Tier 2
Primary distribution substations

Tier 3
Secondary distribution substations and Line Voltage Regulators

Control
Information

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Semi-centralized concept
Primary distribution substation

Coordinated Volt-VAr control
Adding two-way communications and Volt-VAr software to coordinate and control capacitors, voltage regulators and load tap changers in real time at primary substation level

Advantages
– Near real-time adjustment of power settings
– Up to 3.5% improvement in grid efficiency
– Increases line capacity and reduces capital expenses
– Improves asset utilization
– Confirms cap bank is operational and gives indication of asset health
Volt-Var Management
Centralized concept

Automation logic is running at control center level.

Tier 1
Control center
SCADA/DMS

Tier 2
Primary distribution substations

Tier 3
Secondary distribution substations and Line Voltage Regulators

Control

Communication

Voltage Control
Centralized concept

Integrated Volt-VAr control

Utilizing network management software to optimize the power factor downstream to customers, upstream to feeders / substations and across the network

Additional advantages to coordinated VVC:
- Increases reliability through better systemic load flow management
- Can reduce line losses by up to 10%
- Can deliver power factor improvements up to .98
Centralized concept

SCADA/DMS

How does the VVO really work?

The optimization problem assumes the following basic form:

Minimize weighted sum of ((MW loss and/or MW load) + Voltage violation + Current violation)

Subject to:
- Nodal power flow equations
- Consumer voltage range constraints
- Equipment limit constraints

There are three different execution modes:
- Automatic Run of VVO in Real-Time
- Manual Run of VVO in Real-Time
- And Manual Run of VVO in Simulation
Centralized concept
From VVO to VOC

VVO
- Model-based
- Full phase based network model
- As switched real-time model
- Phase based non-linear model of network
- Based on optimal power flow solution

VOC
- Model predictive control
- Next generation Voltage and VAR Optimization (VVO) based on feedback control
- Minimize demand (CVR)
- Controls power factor
- Maintains voltage within regulatory limits
- Controls generation, regulating transformers and capacitors
- Accounts for high penetration solar PV with autonomously regulating solar PV
Volt-Var management

References
## Reference

**Integrating renewable energy with ease**

### Challenge

- A new solar plant with 134 kW was installed
- Result was violation of voltage limits in LV grid
- Distribution transformer did not have regulation function

### Solution

- ABB's remote terminal unit as control unit within LV-LVR
- Monitoring and control function adjust line voltage

### Benefit

- Improved power quality
- Avoided to spend high costs for a new transformer
- Operational savings
- Cyber-secure communication
### Reference

**Predictive Load Flow based on forecasts of DER’s**

**EnBW ODR and REG, Germany (Riesling)**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
<th>Benefit</th>
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<tbody>
<tr>
<td>- New challenges caused by high share of distributed energy resources (DER)</td>
<td>- Equipment for monitoring, voltage control and fault detection</td>
<td>- Modular, scalable solutions</td>
</tr>
<tr>
<td>- Voltage control and optimization</td>
<td>- Predictive Load Flow based on forecasts of DER's</td>
<td>- Detection of bottlenecks and voltage problems in advance</td>
</tr>
<tr>
<td>- Implementation of automation equipment in secondary substations</td>
<td>- Topology change by remote controllable RMU via MicroSCADA Pro DMS600</td>
<td></td>
</tr>
<tr>
<td>Challenges</td>
<td>Solution</td>
<td>Benefit</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1. Improve power quality and reliability</td>
<td>Network Manager ADMS with SCADA, DMS (VVO, FLISR), OMS, Service Suite and Focalpoint business analytics</td>
<td>1. Restoring power to nearly 1.2 million customers without a phone call</td>
</tr>
<tr>
<td>2. Develop a self-healing grid</td>
<td></td>
<td>2. Avoiding over 102 customer outage minutes</td>
</tr>
<tr>
<td>3. Reduce operation costs</td>
<td></td>
<td>3. Improving power reliability by over 28%</td>
</tr>
<tr>
<td>4. Extend life of electrical assets</td>
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Summary

Enabling you to see inside your grid

- There is a solid business case to dealing with Energy Efficiency by implementing some of the Advanced Distribution Management application we've just discussed.

- The technology is available and more and more affordable to digitize the Distribution Network, enabling to drive the Grid in a Smarter way.

- Dealing with Network Losses isn’t a new problem. Advanced distribution management application supported by field device information will optimize the Utilisation of the Distribution Network.

- The acceleration of DER Penetration brings more focus on these challenges.

- Leverage on the Grid Modernisation trends, that bring more granularity to our view of the Grid and allow these application to perform best.