Automation in Large Urban Power Distribution System

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• Need for Automation and Current trends

• Automation Systems and Functionality

• REL Experience

• Best Practices
• Bottleneck is here
• Last mile reliability
• Huge no. of elements
• Theft
• Revenue collection
Load Demand in Mega cities

2006 Peak Load (MW)

- Mumbai: 2500
- London: 4200
- Chicago: 6560
- HK: 10380
- NY: 13141
- Shanghai: 16680
- Osaka: 33600
- Tokyo: 64300
What is Distribution Automation?

- “A set of technologies that enable an electric utility to remotely monitor, coordinate and operate distribution components in a real-time mode from remote locations” - (IEEE definition)

- DA is an umbrella concept that embraces all the other real-time and operational functions for the distribution network
<table>
<thead>
<tr>
<th>With...</th>
<th>...you receive</th>
<th>..which results to</th>
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<tbody>
<tr>
<td>Remote Control</td>
<td>Fast outage / fault management</td>
<td>Shorter outage times</td>
</tr>
<tr>
<td>Fault indication</td>
<td>Faster fault management</td>
<td>Shorter outage times</td>
</tr>
<tr>
<td>Protection</td>
<td>Actual current seen by relay</td>
<td>PM analysis</td>
</tr>
<tr>
<td>Measurements</td>
<td>More information from network</td>
<td>Accurate network analysis</td>
</tr>
<tr>
<td>Quality monitoring</td>
<td>Information on problem areas</td>
<td>Improved quality of power</td>
</tr>
<tr>
<td>Condition monitoring</td>
<td>Service information of switches</td>
<td>Reduced maintenance intervals</td>
</tr>
</tbody>
</table>
Automation Roadmap

**PAST**
- Monitoring: Manual & Decentralised
- Decision: Centralised
- Control: Decentralised (Manual RMU)

**PRESENT SCADA**
- Monitoring: Centralised
- Decision: Centralised
- Control: Decentralised (Manual RMU)

**FUTURE SCADA & DMS**
- Monitoring: Centralised
- Decision: Centralised
- Control: Centralised (Automated RMU)
Automation Systems and Functionality
Automation Systems – Distribution Utilities

• SCADA
• Distribution Management System (DMS)
• Geographical Information System (GIS)
• Automatic Meter Reading System (AMR)
• Outage Management System (OMS)
• Communication Systems
• Billing and Business Process Automation
• Enterprise Resource Planning (ERP) Systems
Automation Systems – Description

• **Supervisory Control & Data Acquisition Systems (SCADA)**
  — Develop and integrate Real-time SCADA systems

• **Distribution Management Systems (DMS)**
  — Solutions for DMS systems for distribution utilities for faster Fault Location, Isolation and Supply Restoration (FLISR) and reduction in downtime

• **Geographical Information Systems (GIS)**
  — GIS systems for asset management
Automation Systems – Description

• **Automatic Meter Reading System**
  - Solutions for AMR systems for energy auditing
  - High end consumer load profile monitoring
  - Integrated with billing and other processes to reduce cycle time

• **Communication System**
  - Fibre Optic *(SCADA / partly DMS on Fibre)*
  - Mobile – CDMA / GSM / GPRS *(partly DMS on CDMA)*
  - VSAT / Low Power Radio
  - Wimax *(Pilot under progress)*
SCADA/DMS Functionalities

• Monitoring and Control of EHV and HV network

• Fault Location, Isolation and Service Restoration (FLISR)
  — To determine the location of feeder faults
  — Recommend actions to isolate the faulty sections & restore supply to the healthy sections of feeders

• Voltage and VAR Control
  — For optimal switching of Capacitor banks and OLTC control
Typical Integrated Solution – Distribution Utility

- **CIS** (Customer Information System)
- **GIS** (Geographic Information System)
- **SCADA/DMS** (Supervisory Control and Data Acquisition/Distribution Management System)
- **AMR** (Automatic Meter Reading System)
- **ERP system** (SAP R/3)

Data Flows:
- Trouble tickets to **CIS**
- Outage Data to **CIS**
- Customer Data to **SCADA/DMS**
- Equipment Data to **GIS**
- System & Equipment faults, Switching counts to **SCADA/DMS**
- Equipment Data to **ERP system**
- Billing & Settlement to **ERP system**
- Status data, Maps, Equipment Data from **GIS**

Other Data Points:
- Load Profiles
- Outage Data
- Customer Data
- System & Equipment faults, Switching counts
- Equipment Data
- Billing & Settlement
- Status data
Present Operations

- CB Trips on fault
- Additional network restored manually, total time 40 mins
- Faulty Section

Circuit Breaker
RMU / DT
Normally open point
Automation Philosophy

- **Automated RMU / DT with FPI**
  - Normally open point

- **Remote Operation of RMU Switch & Partial Restoration of supply – typically 1-2 mins**
  - Normally open point

- **Remote operation to close switch**
  - Additional network restored, total time 11-18 mins

- **FPI indicates passage of fault current**

- **CB Trips**
Post RMU, FPI & Automation Scenario

Total Fault Restoration time reduced from 65 to 35 minutes
REL Experience
REL MUMBAI DISCOM

- Total load served – 1400 MW
- Number of consumers – 25 lacs
- Area of supply - 384 sq. km
- No of Receiving stations – 61 (22kV or 33kV / 11 kV)
- No of substations – 4900 (11 kV / 415 V)
- Average availability (ASAI) – 99.92%
- Distribution loss (T & D) – 12%
- 33kV Cable Network – 400km
- 11kV Cable Network – 2400km.
Approach

Centralised data acquisition and Control / intelligent load shedding / energy balance/Alarm & event handling/Historian/ Trending/Reporting

Network power flow
Switching procedure management
Fault isolation & service restoration
Volt /VAR control
Capacitor bank control

Integration with other systems (ERP / GIS / AMR)

Priority

SCADA

DMS Applications

Integration with other business processes
- System integration and data engineering
  - DIAS/OPC DMS/GIS Interface
DMS Implementation in REL

• Automate 20% of RMU (1000 out of 5000 substations)

• Installation of FRTU

• Integration of RMU with FRTU

• Selection of Communication Technology
  150 Substations – CDMA; 20 Substations – Fibre

• System integration and data engineering

• Installation of Fault Passage Indicator
Fault Passage Indicator (FPI)

- Earth Fault Indicator for underground cables.

- Detects earth faults only and helps in locating faulty cable section.

- Phase to phase faults will not be detected.
  Majority (>70%) – Earth faults

- Composed of:
  - Sensor
  - Split core CBCT
  - Indicator
Logic for Identification of faulty section with FPI

Conclusion: Fault is in the section between a glowing FPI and a Non glowing FPI
REL Mumbai Distribution System - Experience

- Integrated view of Generation, Transmission and Distribution
- Centralized remote monitoring of network elements
- Centralized remote control of switches and transformers
- Reliable Islanding after grid collapse and Optimal load shedding after islanding
- Network reconfiguration and load transfer switching performed remotely for most situations.
- Centralized storage of event logs, fault analysis and report generation.
REL Mumbai Distribution System - Experience

- Real-time alarm on a network fault or abnormality
- Better assistance to field staff in pin-pointing faulty section by utilizing FPIs at all DT stations → Reduction in time for fault identification
- Interruption time reduced from 40 mins to 5-20 mins on an average.
- Reduction in customer hour loss by 50%
- Improved power supply quality due to reduced test charges.
- Equipment subjected to less stress → better equipment condition
Effect of DMS is reflected in Customer Average Interruption Duration Index (CAIDI) apportioned to HT tripping

<table>
<thead>
<tr>
<th>Central Zone (Jul-Sep)</th>
<th>No. of HT Trippings</th>
<th>No. of consumers</th>
<th>CAIDI in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre DMS (Y-2006)</td>
<td>102</td>
<td>577,010</td>
<td>95.16</td>
</tr>
<tr>
<td>Post DMS (Y-2007)</td>
<td>103</td>
<td>599,376</td>
<td>50.24</td>
</tr>
</tbody>
</table>

Reduction in CAIDI by 50%
Daily Operations at REL, Aarey BCC

- Tap changing operations from SCADA: 350 per day
- No. of breaker (switching) operations: 290 per day
  - 8700 operations per month – one of the highest in the WORLD
- No. of Isolator operations through DMS: 1000 per month
  - (During floods 120 operations per day!)
- Cable fault isolation
- Load transfer operation
- Capacitor switching in / off for power factor improvement
Best Practices
Best Practice...General

• Phased Implementation
  — SCADA with Some Applications
  — Selected DMS Applications
  — Enterprise Integration

• Follow International Standards

• Flexible and Open Architecture

• Minimize Customization

• Disaster Recovery Capability

• No Single Point of Failure

• Selective Feeder Automation

• Establish Quality Indices Goals and Track Them
Best Practice...Operation Criteria for SCADA

• All Grid Substations Unmanned with Central Decision Making Processes

• Decision Making based on Real-Time Accurate and Consistent Information

• Remote Control of all Key Field Equipment Devices

• Selected Distribution Substations (11kV/415V) control

• Monitoring of All Data Required to Support contingencies

• Monitoring of Power System Equipment (condition monitoring)

• Remote Monitoring of protective relay data
Best Practice... Communication Criteria

- No Loss of Information due to Single Point Communication Failure
- Automatic Routing of Field Data to Active System in case of Communication Failure
- Transparent routing of users to active control system
- All communications on TCP/IP using standard protocols (i.e. IEC 104)
- Maximum use of available bandwidth for other uses such as video and voice transmission
What can go wrong?

- Overly ambitious goals – too many features
- Inadequate specification
- Unclear objectives
- Not ready with data to kick start the project
- Lack of know-how within organization
- Poor implementation (SCADA/DMS adaptation)
- Lack of training
- Primary equipment compatibility
DMS STATION MODEL
Thank You
GIS asset information integrated by other business processes
Metering Solutions – AMR Systems

Information Portals

Telephone

Main Control Centre

Master Data Concentrators

Sub – Data Concentrators

Meter Interface Units

Last Mile Telephone / PLC

AMR systems for energy audit / billing / consumer profile monitoring
Typical System Architecture: SCADA/DMS

- **MCC-BCC-RTU links**
  - MCC
  - Modem
  - Front End
  - Serial link 9600 Baud
  - 2 Mbit
  - 2 Mbit

- **WAN (SDH)**
  - 9600 Baud Serial links
  - 2 Mbit

- **IEC 104**
  - RTU
  - FRTU
  - CDMA Modem

- **IEC 101**
  - RTU
  - (45)

- **IEC 104**
  - RTU
  - (15)

- **IEC 104**
  - (200)
DMS Architecture

CDMA Network

- FRTU
- FRTU
- CDMA Modem
- RMU

2 Mbps Link

- RMU
- MIDC SDH
- BCC SDH
- DMS FEP

DAKC

- CDMA Architecture

RELIANCE Energy
Anil Dhirubhai Ambani Group
SCADA System

DAHANU TPS

Transmission SCADA
( 4 EHV Stations )

Distribution SCADA
( 61 Rec. Stations )

220kV

33 kV

11 kV OUTGOING
- Load Shedding & Islanding Logic from Centralized Location
- Redundant LAN
- Enhanced Communication System – Fault tolerant, Faster, scalable
- Centralized Control Concept for all Divisions
- IED Integration – Numerical Relays of all makes, Digital RTCC
- Inbuilt DMS Application extended to 11 kV Sub Transmission Network
- Data mining of SCADA database to unearth valuable information
- Interface with other tools – GIS, SAP, CIS System
### Santacruz

**Busbar - 1 Feeders Relay Events/Trip Indications**

<table>
<thead>
<tr>
<th>Elements</th>
<th>Feeders</th>
<th>11567</th>
<th>136</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>5</th>
<th>10</th>
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<tr>
<td><strong>Aj SPAJ 140C</strong></td>
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<tr>
<td>1) SP@J 4D 28 (3 O/C + E/F)</td>
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<td></td>
<td></td>
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<tr>
<td>IL1/Current on phase 1 (Recd)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>IL2/Current on phase 2 (Recd)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>IL3/Current on phase 3 (Recd)</td>
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<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>IO/Neutral Current (Recd)</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
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<tr>
<td>Phase L1 Trip</td>
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<tr>
<td>Phase L2 Trip</td>
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<tr>
<td>Phase L3 Trip</td>
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<tr>
<td>Phase IO Trip</td>
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<td>Operation of Stage I&gt;</td>
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**Recorded Fault Current**: 13

**Trip Indication**: Red circles indicate trip indication.
Conventional RTCC panel
600mm (W) x 600mm (D) x 2000mm (H)

Digital RTCC
250mm (W) x 100mm (D) x 300mm (H)
Wi Max Technology

- **BTS** – Base Station
- **BA Ring** – Building Aggregation Ring
- **MA Ring** – Main Aggregation Ring
- **MCN** – Media Convergence Node
- **FRTU**
- **BCC**
- **BCC SDH**
- **BTS**
- **Antenna**
- **2 Mbps Link**
- **MIDC HUB**
- **MIDC SDH**
- **DMS FEP**

**Wireless LAN Switch**

**SUBSTATION**

**BA Ring** - Building Aggregation Ring

**MA Ring** - Main Aggregation Ring

**MCN** - Media Convergence Node

Antenna

**Wi Max Technology**
<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated RMU supply and Installation</td>
<td>Rs. 12 lacs</td>
</tr>
<tr>
<td>(US$ 30,000)</td>
<td></td>
</tr>
<tr>
<td>Automation including FRTU, Modem,</td>
<td>Rs. 2 lacs</td>
</tr>
<tr>
<td>Hardware and software at Control centre</td>
<td>(US$ 5,000)</td>
</tr>
</tbody>
</table>

COST OF AUTOMATION APPROXIMATELY 20% OF PRIMARY EQUIPMENT COST!
REL 220kV Network

- **GT#1**: 16.5/220kV, 250MW
- **GT#2**: 16.5/220kV, 250MW

Connections:
- **MSEB - BOISAR (GRID)**
- **TATA - BORIVALI (GRID)**
- **DAHANU**
- **GHODBUNDER**
- **VERSVOA**
- **AAREY**
REL’s ISLANDING & LOAD SHEDDING SCHEME

• REL islands from grid under following conditions:
  - Reverse power with under frequency (47.9Hz)
  - Steep fall in frequency ie. 49Hz + 0.5Hz/sec.

• Post islanding, load shedding is done to match load with available generation.

• Different load shedding schemes are implemented depending on GT and tie line breaker status.

• Load shedding is done based on the set priority table.

• Real time tie line power flows, generator output and load are considered for load shedding.
REL 220kV Network

REL ISLANDED!

GEN#1 250MW
GT#1 16.5/220kV

GEN#2 250MW
GT#2 16.5/220kV

DAHANU
GHODBUNDER
VERSOVA
AAREY

TATA - BORIVALI (GRID)

MSEB - BOISAR (GRID)