Energy Management Systems (EMS)

Dr M S R Murty
SCADA System

• **Supervisory Control and Data Acquisition (SCADA)**
  Supervisory Control => Remote Control of Field Devices
  Data Acquisition => Monitoring of Field Conditions
• **SCADA System Components**
  Master Station => System “Nerve Center” Located in Electric Utility Energy Control Center (ECC);
  Dispatchers Use to Monitor and Control Power System
• Field Devices => Needed Wherever There is Data to be Sent to Master Station (Substations, Lines or Feeders)
• Communications => Links Master Station with Field Devices; Continuous 24 by 7 Operation
SCADA SYSTEM CONFIGURATION

SCADA Workstation/Servers
- Dispatcher Consoles
  - 300 MHz RISC Processor
  - 256MB RAM, (2) 9GB HDD, CD-ROM, (2) 21" CRTs

Historical Data Server
- 300 MHz RISC Processor
- 512MB RAM, (2) 5GB HDD CD-ROM

ICCP Node
- 700 MHz Pentium III PC
- 128MB RAM, 6.4GB HDD CD-ROM, 17" CRT

Dispatcher Console
- 300 MHz RISC Processor
- 256MB RAM, 9GB HDD CD-ROM, (2) 21" CRTs

Dispatcher Consoles
- 700 MHz Pentium III PC
- 128MB RAM, 9.1GB HDD CD-ROM, (2) 21" CRTs

Remote Access Router
- Laser Printer
- PSTN

Port Servers
- RTU Communication Ports
- Front-End Processors

10/100 Ethernet Hubs
- LAN Router
- To Corporate LAN

Remote User Stations
- 600 MHz Pentium II PC
- 64MB RAM, 6GB HDD CD-ROM, 56k Modem, 13.3" Active Color LCD

Diagnostic Modem
Energy Control Center
Energy Management System (EMS) Primary Functions

- Network Configuration / Topology Processor
- State Estimation
- Contingency Analysis
- Three Phase Balanced Operator Power Flow
- Optimal Power Flow
- Dispatcher Training Simulator
Distribution Automation System (DAS) Primary Functions

• Voltage Reduction
• Load Management
• Power Factor Control
• Two-Way Distribution Communications
• Short-Term Load Forecasting
• Fault Identification / Fault Isolation / Service Restoration
• Interface to Intelligent Electronic Devices (IEDs)
Energy Management System: Applications
SCADA Functions

- Data acquisition.
- Supervisory Control.
- Tagging: Identifying a device that should not be operated.
- Alarms: Analysis, Chronology.
- Logging.
- Load Shedding
- Trending.
SCADA Computer

- Downloading RTV files.
- Conversion of engineering units.
- Management of communication circuit configuration.
- Detection & citation of alarms.
- Sequence of events recording.
- Respond to operator requests for information display, execution of control action, etc.
Automatic Generation Control (AGC)

- **Major functions:**
  
a) Load Frequency Control (LFC).
  
b) Economic Dispatch (ED).

- **Objectives of Load Frequency Control:**
  
i) To maintain frequency at scheduled value.
  
ii) To maintain net power inter-changes with neighboring control areas at scheduled values.
  
iii) To maintain power allocation among generated units at economic values.
Economic Dispatch

- Minimum cost dispatch: Equal incremental cost criteria

- ED Algorithm
  (Thermal) considers:
  - Generator incremental costs
  - Penalty factors
  - Transmission loss factors

- For Hydro
  - ‘Water worth’ concept is used.
LFC and ED functions in real time:

- LFC : Every few seconds
- ED : Every few minutes
- Conflict : Unit control Errors (UCE) in different directions by LFC & ED
- Logic : Permissive Control : Follow load
  Mandatory control : Follow Economics
Energy Management Functions

- System load forecast: Every hour for a period of 1-7 days.
- Unit Commitment: Start up & shut down times for most economic operation of thermal units for each hour.
- Fuel Scheduling: Economic choice, fuel purchase contracts.
- Transaction evaluation: Purchase & sale of energy with neighboring companies.
- Transmission loss minimization: Controller actions for minimization of loss.
- Security constrained dispatch: Ensuring eco dispatch without violating network security.
- Production cost calculation: Actual & economical for each generated unit on hourly basis.
Real-time Network Analysis Sequence

Study Network Analysis: Based on postulated state
Security Control

- Starts with ‘current state’ and executes programs sequentially.
- **Contingency:**
  Event that causes important component to be removed from service (eg: tr-line, generator, transformer).
- A list of contingencies are processed as applicable to current state.
• **Topology Processing:**
  Building a network model based on real-time measurements.

• **State Estimator:**
  Determining “best” estimate from real-time measurements.

• **Power Flow:**
  Load flow analysis (Voltages, Phase angles).

• **Contingency Analysis:**
  Impact of a set of contingencies to identify harmful ones.
• **Optimal Power Flow:**
  Optimization of a specified objective function (with constraints).

• **Preventive Action:**
  To prevent contingency.

• **Short Circuit Analysis:**
  Determines the fault currents for 1-ø & 3-ø faults for fault locations across the power system network.
SCADA/EMS/DMS Architecture

<table>
<thead>
<tr>
<th>Approximate sizes</th>
<th>High load events per second</th>
<th>Updated analogs per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data points</td>
<td>Sub stations</td>
<td></td>
</tr>
<tr>
<td>SCADA</td>
<td>100 – 1 000 000</td>
<td>1000 – 10 000</td>
</tr>
<tr>
<td>EMS</td>
<td>10 000 – 100 000</td>
<td>10 – 10 000</td>
</tr>
<tr>
<td>DMS</td>
<td>10 000 – 1 000 000</td>
<td>1000 – 100 000</td>
</tr>
</tbody>
</table>
DMS Functions

• Three Phase Unbalanced Operator Power Flow
• Map Series Graphics
• Interface to Automated Mapping / Facilities Management (AM/FM) or Geographic Information System (GIS)
• Interface To Customer Information System (CIS)
• Interface to Outage Management
Intelligent Electronic Device (IED)

- IED – Building Block of Substation Integration and Automation
- Any device incorporating one or more processors with the capability to receive or send data/control from or to an external source (e.g., electronic multifunction meters, digital relays, controllers)
Power System Action Time Frames

transient stability
- generator/excitation dynamics
- mech.
- switched cap’s
- under-voltage load shedding
- SVC, DC
- relaying, incl. under-frequency load shedding

long-term stability
- LTCs & dist. voltage reg.
- excitation limiting
- line/transformer overload
- system operator

Time - Seconds

0.1 1 10 100 1000 10000
Some time scales in grid management

• There are four levels in grid management.
  – Unit commitment – which works on a scale of days
  – Scheduling needed on a day upon day basis
  – Load following which has a time scale of minutes to hours
  – Regulation which happen over seconds to minutes

• We need to understand that it is a complex issue and needs detailed analysis either to accept or reject an idea.
Evacuation – The big picture – Northern & Southern Grids

- 5 Regional Networks in the Country
- Currently 4 Regional Networks merged

INDIA CURRENTLY OPERATING AT
“TWO” FREQUENCIES – NORTH & SOUTH
INTER-REGIONAL EXISTING CAPACITIES

Inter-regional capacity - 16,500MW

<table>
<thead>
<tr>
<th>Name of the Link</th>
<th>Capacity (MW)</th>
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</thead>
<tbody>
<tr>
<td><strong>East-North</strong></td>
<td></td>
</tr>
<tr>
<td>Dehri-Sahupuri 220kV S/c</td>
<td>150</td>
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<tr>
<td>Sasaram HVDC back-to-back</td>
<td>500</td>
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<tr>
<td>Muzaffarpur-Gorakhpur 400kV D/c (Quad)</td>
<td>2000</td>
</tr>
<tr>
<td>Bihar Sharif-Balia 400kV D/c (Quad)</td>
<td>2000</td>
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<tr>
<td>Patna-Balia 400kV D/c (Quad)</td>
<td>2000</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>6650</strong></td>
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<tr>
<td><strong>East-West</strong></td>
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<tr>
<td>Budhipadar-Korba 220kV T/c</td>
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<tr>
<td>Rourkela-Raipur 400kV D/c</td>
<td>1200</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>1650</strong></td>
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<tr>
<td><strong>West-North</strong></td>
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</tr>
<tr>
<td>Vindhyachal HVDC back-to-back</td>
<td>500</td>
</tr>
<tr>
<td>Existing 220kV AC Lines</td>
<td>200</td>
</tr>
<tr>
<td>Gwalior-Agra 765kV S/Io</td>
<td>1500</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>2200</strong></td>
</tr>
<tr>
<td><strong>East-South</strong></td>
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<tr>
<td>Gazuwaka HVDC back-to-back</td>
<td>1000</td>
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<tr>
<td>Existing 220kV AC Lines</td>
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<tr>
<td>Talcher-Kolar HVDC bipole (Enhanced)</td>
<td>2500</td>
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<td><strong>Sub-Total</strong></td>
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<tr>
<td><strong>West-South</strong></td>
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<tr>
<td>Chandrapur HVDC back-to-back</td>
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<tr>
<td>Existing 220kV AC Lines</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>1300</strong></td>
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<tr>
<td><strong>East-North East</strong></td>
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<tr>
<td>Bongaigaon-Siliguri 400kV D/c</td>
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<tr>
<td>Birpara-Salakati 220kV D/c</td>
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</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>1000</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16500</strong></td>
</tr>
</tbody>
</table>
INTER-REGIONAL PROPOSED CAPACITIES BY 2011-12

30,000 MW OF INTER-REGIONAL POWER BY 2011-12

“NO Augmentation” proposed between “Southern & Northern” Grids

SOURCE: CEA
Control centers (CC) in the market environment.
EMS and BMS interactions.

Market Participants
- Energy Offers
- Prices
- Bills

Business Management System (Market Operations System)
- Long-term Contracts
- Day Ahead Schedules
- Hour Ahead Adjustments
- Real-time Dispatches
- Billing and Settlement

Energy Management System
- Schedules and contracts
- Operating constraints
- SCADA
- State Estimation
- Contingency Analysis
- SCUC
- AGC
- Load Management
- Generation
- Transmission Substation
- Load
CC functions.
Conventional CC architecture.
Integration needs of control centers.
Middleware-based distributed system.
Distributed data acquisition.
IP-based distributed SCADA.
Control center application services.
EMS real time