Restructuring of Electrical Power systems

Dr M S R Murty
Vertically Integrated Structure

- Generation
- Transmission
- Distribution
Horizontal Structure

COORDINATOR

- GENERATION
- TRANSMISSION
- DISTRIBUTION
Unbundled Parts

• Generation Company GENCO: generation and ancillary services
• Transmission Company TRANSCO: transmission facilities
• Distribution Company DISTCO: to supply power to consumers
• The GENCO would try to minimize cost of production and maximize profits by reducing operating and maintaining costs.
• TRANSCO would reduce transmission losses and operate efficiently to justify delivery fees.
• DISTCO would also similarly reduce costs and negotiate with best possible GENCO.
Market Operations

Power Flow
- GENCO
- TRANSCO
- DISCO
- Customer

Money Flow
- Broker
- Marketer
- Retailer
- Aggregator

Customer
Automatic Generation Control

Control Area

Net Interchange from area
AGC

• Controls MW Generation to maintain (Regulate) Frequency and assist entire system irrespective of cause.
• Regulate Contractual Interchange
• Technical Criteria set by reliability Council
AGC in multiple areas

- Various aspects that are to be considered by AGC in multiple areas are:
  - Net Actual Interchange
  - Net Scheduled Interchange
  - Interchange Deviation
System Operator *(SO)*

• THE *SO* DOES NOT OWN ANY GENERATION BUT IS RESPONSIBLE FOR MAINTAINING THE QUALITY, RELIABILITY, AND SECURITY OF ELECTRIC SERVICE

• TO CARRY OUT ITS RESPONSIBILITY EFFECTIVELY AND EFFICIENTLY, THE *SO* SHOULD HAVE REAL-TIME CONTROL OF BOTH GENERATION & TRANSMISSION

• THIS REQUIRES SCADA LINKS BETWEEN POWER PLANT RTUs AND A CENTRAL MASTER

• POWER PLANT RTUs SHOULD BE A REQUIREMENT FOR OPEN ACCESS
RESTRUCTURED ELECTRICITY SECTOR

• A STATE-OWNED ELECTRICITY SECTOR IS RESTRUCTURED AS FOLLOWS:

• GENERATION IS PRIVATIZED INTO SEVERAL GENCOs; IPPs HAVE OPEN ACCESS

• TRANSMISSION IS PRIVATIZED INTO A SINGLE TRANSCO; DISTRIBUTION IS PRIVATIZED INTO SEVERAL DISCOs

• GENCOs and IPPs OWN GAS TURBINES, FOSSIL-FIRED UNITS, AND HYDRO UNITS

• MARKET INCLUDES BILATERAL CONTRACTS, LONG-TERM CONTRACTS, PURCHASED POWER AGREEMENTS, ANCILLARY SERVICES MARKET, AND A SPOT MARKET
• The Network Has Radial Ties to External Systems
• IT IS DECIDED THAT THERE WILL BE AN ISO
• The TRANSCo has an existing 10-year old SCADA/EMS control hierarchy consisting of a National Control Center (NCC) and several Regional Control Centers (RCCs)
• The ISO is a non-profit entity; the TRANSCo is a for-profit company
THE ISO CONTROL CENTER (ISOCC)

- Perform Power System Operation (PSO)
- Support Market Operations (MO)
- Perform Settlements (ST)
- Perform Operation Data Management (ODM)
• SUPERVISE, CONTROL, & DIRECT MAINTENANCE OF THE TRANSMISSION NETWORK

• EXECUTE NETWORK CONTROL COMMANDS ISSUED BY THE ISOCC

• (TRANSCO RESPONSIBLE FOR NETWORK EXPANSION)
• GENERATION SCHEDULING: Performed by Generators
• OBTAIN RESOURCES FOR SECURITY CONTROL
• REAL-TIME MONITORING & CONTROL
• SCADA
• EMS
• OPERATION RECORDING: Inputs to ODM Operation Reports
ENABLING TECHNOLOGIES FOR OPERATION AND REAL-TIME CONTROL IN A LIBERALIZED ENVIRONMENT

EPRI
THE WINDS OF CHANGE

PRIVATEIZATION
state-owned monopoly could become a
private monopoly or an oligopoly

GLOBALIZATION

RESTRUCTURING
divestiture

DEREGULATION

OPEN ACCESS

independent power
producers

more
competition
leads to
CONSOLIDATION
leads to

FREE MARKET

energy trading

independent
system
operator

less
competition

more
competition
leads to

technological
innovations

November 1999
DY-LIACCO
THE ENGINEERING CHALLENGE
DANCING TO CHANGE

• Adapt System Operation to the Liberalized, Restructured Environment
• Redesign Operation and Real-Time Control Functions
• Develop New Approaches to Control System Design Using Advanced Technologies
THE SYSTEM OPERATOR ( _SO ) IN A RESTRUCTURED UTILITY

› THE SO DOES NOT OWN ANY GENERATION BUT IS RESPONSIBLE FOR MAINTAINING THE QUALITY, RELIABILITY, AND SECURITY OF ELECTRIC SERVICE

› TO CARRY OUT ITS RESPONSIBILITY EFFECTIVELY AND EFFICIENTLY, THE SO SHOULD HAVE REAL-TIME CONTROL OF BOTH GENERATION & TRANSMISSION

  • THIS REQUIRES SCADA LINKS BETWEEN POWER PLANT RTUs AND A CENTRAL MASTER
  • POWER PLANT RTUs SHOULD BE A REQUIREMENT FOR OPEN ACCESS
AN EXAMPLE OF A RESTRUCTURED ELECTRICITY SECTOR

- A STATE-OWNED ELECTRICITY SECTOR IS RESTRUCTURED AS FOLLOWS:
  - GENERATION IS PRIVATIZED INTO SEVERAL GENCOs; IPPs HAVE OPEN ACCESS
  - TRANSMISSION IS PRIVATIZED INTO A SINGLE TRANSCO; DISTRIBUTION IS PRIVATIZED INTO SEVERAL DISCOs
  - GENCOs and IPPs OWN GAS TURBINES, FOSSIL-FIRED UNITS, AND HYDRO UNITS
  - MARKET INCLUDES BILATERAL CONTRACTS, LONG-TERM CONTRACTS, PURCHASED POWER AGREEMENTS, ANCILLARY SERVICES MARKET, AND A SPOT MARKET
OTHER CONDITIONS
FOR THE EXAMPLE

• The Network Has Radial Ties to External Systems
• IT IS DECIDED THAT THERE WILL BE AN ISO
• The TRANSCo has an existing 10-year old SCADA/EMS control hierarchy consisting of a National Control Center (NCC) and several Regional Control Centers (RCCs)
• The ISO is a non-profit entity; the TRANSCo is a for-profit company
DESIGN REQUIREMENTS
FOR THE EXAMPLE

• DESIGN AN ISO CONTROL CENTER (ISOCC) AND A TO CONTROL CENTER (TOCC)
• THE ISOCC WILL BE NEW & WILL HAVE SCADA LINKS TO RTUs AT GENCO & IPP POWER PLANTS
• THE TOCC WILL BE A MODERNIZATION OF THE EXISTING EMS HIERARCHY
• LINK THE ISOCC WITH THE TOCC
• PROVIDE A BACKUP ISOCC (B-ISOCC)
THE ISO CONTROL CENTER (ISOCC)

- Perform Power System Operation (PSO)
- Support Market Operations (MO)
- Perform Settlements (ST)
- Perform Operation Data Management (ODM)
THE TO CONTROL CENTER
(TOCC)

- SUPERVISE, CONTROL, & DIRECT MAINTENANCE OF THE TRANSMISSION NETWORK

- EXECUTE NETWORK CONTROL COMMANDS ISSUED BY THE ISOCC

- (TRANS CO RESPONSIBLE FOR NETWORK EXPANSION)
POWER SYSTEM OPERATION
FUNCTIONS

- GENERATION SCHEDULING
  - Performed by Generators
- OBTAIN RESOURCES FOR SECURITY CONTROL
- REAL-TIME MONITORING & CONTROL
  - SCADA
  - EMS
- OPERATION RECORDING
  - Inputs to ODM
  - Operation Reports
RESOURCES FOR SECURITY CONTROL
ANCILLARY SERVICES

› NORMAL & PREVENTIVE CONTROL
  • MUST-RUN UNITS
  • LOAD-FOLLOWING RESERVE
  • SPINNING & READY RESERVES
  • REACTIVE RESERVE

› EMERGENCY & RESTORATIVE CONTROL
  • CURTAILABLE GENERATION
  • DISPATCHABLE LOADS
  • BLACK-START CAPABILITY
EMS INNOVATIONS

• AUTOMATIC GENERATION CONTROL (AGC) -- THE LOAD-FOLLOWING CONTROL (The New LFC)
• SECURITY-CONSTRAINED OPTIMAL DISPATCH (SCOD)
• DYNAMIC SECURITY ANALYSIS (DSA)
  ‣ ON-LINE AUTOMATIC LEARNING DSA (ALDYSAS)
• DYNAMIC OPERATOR TRAINING SIMULATOR (DOTS)
AUTOMATIC GENERATION CONTROL (AGC)

• THE AGC FUNCTION WILL TAKE CARE OF:
  › LOAD-FOLLOWING CONTROL SETPOINTS FOR GENERATING UNITS
  › COMPLIANCE MONITOR

• THE UNIT SETPOINT VALUES WILL BE THE SUM OF THE UNIT REGULATION PARTICIPATION PLUS THE UNIT BASEPOINT

• UNIT BASEPOINTS GIVEN BY SCOD, BASE LOAD SCHEDULES, FIRM POWER CONTRACTS
SECURITY-CONSTRAINED OPTIMAL DISPATCH (SCOD)

SCOD REPLACES TRADITIONAL ECONOMIC DISPATCH

• Determines Optimal Basepoint of Each Generating Unit such that Total Generation Shall Meet Anticipated 10-minute Ahead System Base Load
• Uses Incremental Price Curves Provided by the GenCos and IPPs
• Uses the Optimal Power Flow (OPF)
DYNAMIC SECURITY ANALYSIS (DSA)

- NEEDED FOR PREVENTIVE AND EMERGENCY CONTROL AGAINST TRANSIENT OR VOLTAGE INSTABILITY
- CONSISTS OF TRANSIENT STABILITY ANALYSIS (TSA) & VOLTAGE STABILITY ANALYSIS (VSA)
- FOR TSA THE HYBRID METHOD USING SINGLE-MACHINE EQUIVALENT IS PREFERRED
REAL-TIME AUTOMATIC LEARNING DSA (ALDYSA)

• Automatic Learning in Real-Time Using Pattern Classification Approaches
  ‣ Artificial Neural Networks
  ‣ Decision Trees
  ‣ Hybrid Methods

• Training Set Derived Continuously in Real-Time
DYNAMIC OTS (DOTS)

- DYNAMIC POWER SYSTEM MODELLING USING EMBEDDED STABILITY PROGRAM
  - Power Swings and Out-of-Step Tripping Simulated
  - Distance Relay Protection, Automatic High-Speed Reclosing, Synchrocheck Reclosing, Out-of-Step Blocking, Loss-of-Excitation Protection
  - DOTS May be Performed in Real-Time & Linked with ALDYSA
    - Off-line DOTS Trains the Human Operator
    - Real-Time DOTS Trains the Computer to be an Operator
OPERATION DATA MANAGEMENT

• CENTRAL REPOSITORY (Data Warehouse) FOR MARKET OPERATIONS, SETTLEMENTS, AND POWER SYSTEM OPERATION DATA

• PUBLIC INFORMATION PUBLISHING VIA WEB SERVER ON AN EXTRANET

• DATA WAREHOUSE AVAILABLE FOR DATA MINING
CONCEPTUAL DESIGN
THE TCP/IP ENTERPRISE/CONTROL
NETWORK
ENTERPRISE (Business & Financial Processing) &
SYSTEM CONTROL FUNCTIONS INTEGRATED
IN ONE INTERNET-BASED NETWORK
CONSISTING OF:
› SCADA INTRANET
› ISOCC TCP/IP LAN
› TOCC WAN INTRANET
› PUBLIC INFORMATION EXTRANET
MULTI-VENDOR INTEROPERABILITY
DFS & OBJECT/COMPONENT TECHNOLOGIES

• A SO-CALLED STANDARD IS A STANDARD ONLY IF IT IS OR BECOMES A DE FACTO STANDARD (DFS)
  ▶ EPRI UCA/MMS/ICCP
  ▶ Internet Protocol Suite: HTTP; FTP; HTML; XML
  ▶ Java & Java-Enabled Web Browsers
  ▶ Interoperability Middleware for Distributed Components
    • Common Object Request Broker Architecture (CORBA) with Internet InterORB Protocol (IIOP)
    • Enterprise JavaBeans (EJB)
    • Distributed Component Object Model (DCOM)

• EMERGING DFS
  ▶ EPRI Common Information Model (CIM) for EMS, IEC TC57 WG13
MULTI-VENDOR INTEROPERABILITY
DISTRIBUTED MANAGEMENT

• WEB-BASED ENTERPRISE MANAGEMENT (WBEM)
  ‣ Distributed Management Task Force (DMTF)
  ‣ The Path to Interoperability
    • Data Model: -- Common Information Model (CIM)*
    • Data Representation: -- Extensible Markup Language (XML)
    • Data Transport: -- HTTP

*(not to be confused with EPRI CIM)
THE SCADA INTRANET

- MASTER-RTU PROTOCOL: -- TCP/IP WITH EPRI UCA-MMS/ICCP
- THE NETWORK INTERFACE UNIT (NIU)
  - A Java-Powered Single-Board Unit with Web Server

THE REMOTE INTERNET UNIT (RIU) CONCEPT
ISOCC ETHERNET TCP/IP LAN

- Redundant: Switching Hubs, Fiber Optic Links, Servers, & Interfaces
- Mix of RISC Workstations and PCs
- Links to Metering System
- Firewall and Web Server for ODM
TOCC INTRANET WAN

- REDUNDANT HIGH-SPEED BACKBONE LINKING THE NCC AND THE RCCs
- RCCs MAY BE PC-BASED SYSTEMS
- DATA CONCENTRATORS MAY BE CONNECTED TO THE WAN
- WAN LINKED TO ISOCC LAN
DAC = Data Acquisition & Control
MO = Market Operations
ST = Settlements
PSO = Power System Operation
ODM = Operation Data Management
SW DEV = Software Development

WS 1 = Trading Coordinator
WS 2 = Settlements Operator
WS 3 = Power System Operator
WS 4 = Software Developer

TCP/IP

DY-LIACCO
9/1/99
THE BACKUP ISOCC (B-ISOCC)

• INSTALL THE REDUNDANT SET OF ISO-CC SERVERS & INTERFACES IN A SEPARATE, DISTANT LOCATION
• USE THE B-ISOCC AS A TRAINING & SOFTWARE DEVELOPMENT CENTER
• ISO WORKLOAD MAY BE SHARED BETWEEN THE ISOCC AND THE B-ISOCC
SUMMARY
ENABLING TECHNOLOGIES FOR OPERATION & CONTROL

› Load-Following Control via SCADA
› Security-Constrained Optimal Dispatch
› Dynamic Security Analysis
› Automatic Learning DSA (ALDYSA)
› Off-Line and Real-Time Dynamic Operator Training Simulator (DOTS)
› TCP/IP Enterprise/Control Network
› Web Technologies
› Remote Internet Units & Web-Based SCADA
› DFSs & Object/Component Technologies for Multi-Vendor Interoperability
CLOSING REMARKS
ONE CAN ONLY OPERATE WHAT ONE HAS

• A CONTROL SYSTEM NO MATTER HOW TECHNICALLY ADVANCED CAN DO LITTLE FOR SERVICE RELIABILITY & SECURITY IF GENERATION IS INADEQUATE OR TRANSMISSION IS WEAK OR CONTROLLABILITY IS LIMITED

• THE MAJOR NEGATIVE IMPACT OF RESTRUCTURING ON RELIABILITY IS THE LOSS OF RESPONSIBILITY FOR GENERATION-TRANSMISSION SYSTEM PLANNING & THE LACK OF INCENTIVES FOR SYSTEM EXPANSION