Generation Dispatch in a Smart Grid Environment

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AREVA T&D Inc.

IEEE Innovative Smart Grid Technologies Conference
Jan 19-21, 2010
Washington, DC
Introduction
Smart Grid Challenges
Smart Dispatch Framework
Generation Control Applications (GCA)
Conclusions
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Smart Grid Challenges
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Conclusions
AREVA T&D Automation Activities

Market Management Systems (MMS)

Energy & Distribution Management Systems (EMS / DMS)

Dedicated telecommunication network

Substation
- Protection
- Measurement
- Substation Control

Substation Automation

Data Com

Substation Management Systems

Energy & Distribution Management Systems

Integrated refurbishment, system upgrade, system monitoring, system life-cycle management, system reliability, expert training
US electricity markets have been converging towards to a model of multi-settlement using locational marginal pricing for congestion management.
Optimization-based Integrated Approach

- Consistent dispatch signals and price signals
  - Security constrained economic dispatch (SCED)
  - Locational Marginal Pricing (LMP)
Outline

- Introduction
- Smart Grid Challenges
- Smart Dispatch Framework
- Generation Control Applications (GCA)
- Conclusions
Smart Grid Market Drivers

- Society’s growing dependency on electricity
  - Looming risks of major system disturbances
  - Focus on reliable demand-supply balance & grid security
- Global energy & environmental movement
  - Increasing presence of DER - Distributed Energy Resources (e.g. wind, DR, etc)
  - Operational challenges: DER performance uncertainties
- Experiences from deregulated system operations
  - Established foundation for integrating demand-supply balance with grid security constraints (e.g. LMP).
  - Identified emerging deficiencies in Dispatch Instructions

- Unrelenting complexity in business & technical decision process
  - Smart devices/resources with distributed intelligence
  - Coordinated decision making
Smart Grid from Vision to Product

**Smart Grid**

**Smart Dispatch**
- Generation Portfolio Management including renewable
- Full Integration of pricing and demand/supply principles to manage the grid
- Dynamic balancing with centralized and distributed resource

**Smart Transmission Grids**
- On-Line Stability Analysis & Defense Plans
- On-line Asset Management
- Smart Power Electronic Controls (HVDC, FACTS, SVC...)

**Smart Distribution Grids**
- Automatic Meter Management System
- Integrated Distributed Management Systems
- Renewable and load management integration

**Smart Substation**
- Substation Protection & Control Architectures
- Self-adaptive Defense Plans
- Secondary Distribution Smart Grid Box

Visualization, Situation Awareness and Decision Support Tools

System Architecture including Common Information Model

Secure, deterministic and reliable data communication
Evolution of Generation Dispatch

► Classical Dispatch
  ◆ Unit Commitment Scheduling, Economic Dispatch, AGC
  ◆ Grid security, scheduling, dispatch are Independent tasks

► Market-Based Dispatch
  ◆ UC/ED with explicit transmission security constraints
  ◆ Formal Day-Ahead and Real-time tasks
  ◆ Pricing - Dual of the MW signal
  ◆ Transparency & consistency
  ◆ Large-scale system dispatch

► Smart Dispatch
  ◆ Dispatch with explicit forward vision
  ◆ Dispatch with intelligence (e.g. parameter adaptation)
  ◆ Improve system resiliency against uncertainties (e.g. DER, RE, DR)
  ◆ Mitigate root-causes for dispatch deficiencies
  ◆ Process re-engineering for business/economic analysis
Smart Grid Challenges

- A lot of emphasis of renewables, distributed energy resources (DER) and demand response (DR), PHEVs etc.

- Increase amount of uncertainties:
  - Generations and Demand Response
  - Demand forecast
  - Transmission constraints
  - Resource characteristics

- Modeling of uncertainties
  - Confidence Interval
  - Scenario-based

- Volumes and distributiveness of DERs and DRs
  - Aggregation model

- Smart Dispatch
  - Holistic forward-looking view of system conditions
  - More robust solution
Expanded Dimensions in Smart Dispatch

- Classical Dispatch
- Smart Dispatch

- Time (Vision)
- Scenarios (Robustness)

(Forensic Analysis)
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Vision of a Smart Dispatch System

Comprehensive Operating Plan (COP)

 SKED 1
 t=30,60,90,120,180...720...

 SKED 2
 t=15,30,45,60...

 SKED 3
 t=5,10,15...

 Explicit Real-time Dispatch

 Implicit/Indirect Dispatch

 Demand Forecast

 Outages

 Adaptive Model Management

 After-the-Fact Forensic Analysis

 Perfect Dispatch

 Physical System Operation

 Archived System Operation History

 5 min to Hourly

 Quarter Hourly

 Hourly

 On Demand

 Asynchronous

 On Demand

 On Demand

 On Demand

 On Demand
Multi-stage resource scheduling Functions (SKED1, 2 & 3): security constrained unit commitment and economic dispatch sequences with different look-ahead periods (e.g. 6 hours, 2 hours and 20 minutes)

The results of each stage form progressively refined regions that guide the dispatching decision space of the subsequent stages.

Various SKED cycles are coordinated through the Comprehensive Operating Plan (COP).
After-the-Fact Analysis (AFA)

- Systematic analysis of past events and practices
- Quantitative assessments of how do specific events and practices affect system performance
- Use-case comparative approach

Perfect Dispatch

- A class of use cases of AFA that focus on “Day-After” analysis of the performance of actual system dispatch results, including the impacts of specific events.
Demand forecast takes DR, DER, and Wind generation into account.

Need to integrate various forecast engines to achieve performance.

Easy manipulation of forecast profile (similar day, transformation etc.)
Adaptive Constraint Modeling (ACM)
- ACM uses intelligent methods to preprocess transmission constraints based on historical and current network conditions, load forecasts, and other key parameters. It shall have ability to achieve smoother transmission constraint binding.

Adaptive Generator Modeling (AGM)
- AGM will provide other GCA components information related to specific generator operational characteristics and performances. The resource “profiles” may contain parameters such as ramp rate, operating bands, predicted response per MW of requested change, Max & Min limits, etc.
Comprehensive Operating Plan (COP)

- COP has the repository of all operating plans in a multi-stage decision process.

- Each stage in the decision process generates a set of schedules that are reflected in its corresponding COP (COPi).

- The aggregated results from the multi-stage decision process are captured in the total COP (COPt), which is the merged outcome of the individual COPi’s.

- A COP contains quantities (e.g. MW generation level) being scheduled over different Operating Intervals.

- Operator interaction is typically with COPt.
Benefits of COP

- Holistic forward-looking view of operating plan

- Modular SKED
  - Multiple SKEDI’s are coordinated using subordinate COPI’s which are synchronized into the overall COPt.
  - This removes the need for individual SKED applications to communicate with each other directly.

- Flexible design with high availability:
  - SKED’s may be added, removed and/or modified with minimal impact on the other SKEDs and COPs.
  - Ensures high availability for the mission critical real-time GCA SKED functions. Failure of any one or more SKED components will cause smooth degradation of, instead of abrupt service interruptions to, real-time dispatch instructions.
  - Intrinsic flexibility enables low-risk, cost-effective business process evolution.
Practical Applications of COP: An Example

- NCG (North China Grid) applies the concept of COP to build a unified scheduling framework.

- Scheduling processes range from annual planning to real-time dispatch.

- NCG generation scheduling processes:
  - Rolling forward scheduling monthly contract generation based on annual contracts.
  - Rolling forward scheduling daily contract generation based on monthly contracts.
  - Day-ahead quarter-hourly generation schedule
  - Rolling forward intra-day GCA SKEDs.

- COP streamlines the business processes.
North China Grid Generation Scheduling Coordination

Annual-To-Month Scheduling (e.g. year 2008)

12/15/2007::A

3/15/2008::A

Month-to-Day Scheduling (e.g. April 2008)

3/16/2008::M

4/10/2008::M

Day-Ahead Scheduling (e.g. April 11, 2008)

4/10/2008::D

Daily Contract Generation from latest Month-to-day scheduling results

Monthly Contract Generation – from latest Annual-to-Month Scheduling results

Annual Contract Generation

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Generation Control Applications (GCA)

- Optimization engine for security-constrained multi-period, time coupled commitment and dispatch.
  - Mixed Integer Programming (MIP) / Linear Programming (LP) based
- Support both price- and cost-based modeling and analysis, for energy, ancillary services, demand response, energy conservation, and emission reduction.
- Coordinate multiple scheduling time horizons (Intra-day, near real-time, real-time) with Comprehensive Operating Plan (COP).
- Scenario-based robust scheduling and dispatch
- Typical Configuration:
  - SKED-DA: day-ahead resource commitment (hourly interval for a look-ahead window of a day or two)
  - SKED 1: intra-day incremental resource commitment (15 min to hourly intervals for a look-ahead window of 6-8 hours)
  - SKED 2: Fast-start resource commitment (15 min intervals for a look-ahead of 2-4 hours)
  - SKED 3: Real-time dispatch of generating resources every 5 min
SKED3 sequential vs. dynamic dispatch

Value of pre-ramping

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Dynamic dispatch
Sundance ($95) can produce less

Dynamic dispatch
BRIGHTON ($10)
backs down to allow pre-ramping

Dynamic dispatch
Alta ($11) and Parkcity ($15) pre-ramp

Sequenti

Dynamic dispatch
Sundance ($95) can produce less

Dynamic dispatch
BRIGHTON ($10)
backs down to allow pre-ramping

Dynamic dispatch
Alta ($11) and Parkcity ($15) pre-ramp
Coupling between SKED2 and SKED3 to ensure that SKED3 solution gets into the envelope of SKED2.
COP – Resource Status Override
GCA
SKED Overview
Dimension Coverage in Smart Dispatch/GCA Applications

- **SKED 1**
  - Forensic Analysis
  - Vision

- **SKED 2**
  - Robustness

- **SKED 3**
  - Classical Dispatch

- GCA
  - Time

[Diagram showing different scenarios and their coverage in a grid]
Introduction

Smart Grid Challenges

Smart Dispatch Framework

Generation Control Applications (GCA)

Conclusions
Conclusions

- Discussed the vision and the challenges of Smart Dispatch in the context of control center’s operations for the evolving smart grid environment.

- Presented the framework of Smart Dispatch

- Proposed a new dispatch system (GCA)
  - Cope with the increasing amount of uncertainties
  - Provide a better holistic and forward-looking view of system conditions and generation patterns and help system operators to make better decisions.

- An example to apply COP is given.

- GCA is deemed critical for the success of efficient power system operations in the near future.
Q & A