Disclaimer

• This training presentation is provided as a reference for preparing for the PJM Certification Exam.
• Note that the following information may not reflect current PJM rules and operating procedures.
• For current training material, please visit: http://pjm.com/training/training-material.aspx
Security Constrained Economic Dispatch System (SCED)

Interconnection Training Program Module LS 8

Winter, 2011
• **Upon completion-What you should know:**
  – explain the purpose of the Security Constrained Economic Dispatch System (SCED)
  – identify the data sources
  – identify where the output gets sent
  – understand how to use the SCED
Purpose

What should my dispatch rate be?

Which generator should I use to control this constraint?

How much generation will I need an hour from now?

What should my dispatch rate be?

How do I communicate with 1600+ generators?

SCED will help answer all of these questions!
PJM

Security Constrained Economic Dispatch
• Economic dispatch was previously performed via transmission of zonal dispatch rates

• Simple during unconstrained conditions

• Inefficient when transmission constraints occur, requiring significant manual intervention
What Individual Unit Dispatch Is ...

• Transition from zonal dispatch rates with manual exceptions to individual unit MW signals as primary dispatch mechanism
• Continuation of communications with the same locations via existing links
• Typical Configurations

PJM → T.O./G.O. → Units

PJM → M.O.C. → Units

PJM → Units
## A Word About Communications

<table>
<thead>
<tr>
<th>TOTAL CAPACITY</th>
<th>CONNECTING ASSET</th>
<th>PROTOCOL</th>
<th>COM DEVICE</th>
<th>NETWORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 500 MW</td>
<td>Gen</td>
<td>ICCP</td>
<td>SCADA System</td>
<td>PJMnet (dual router)</td>
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<td>SCADA System</td>
<td>PJMnet (single router)</td>
</tr>
<tr>
<td>0-100 MW</td>
<td>Gen</td>
<td>DNP3</td>
<td>Any DNP3-Capable Device</td>
<td>Internet</td>
</tr>
</tbody>
</table>

Methods 1 to 6 refer to different methods of communication based on the total capacity.
A Word About Communications

Method 1
- Large control centers, such as used by Transmission Owners, often connect their EMS to PJM with ICCP over a dual-router PJMnet network.

Method 2
- Large generating stations may have a dedicated SCADA connection to PJM similar in scope to a large control center.

Method 3
- Mid-sized control centers, which have aggregated more than one generating station or demand response asset, may use ICCP over a single-router PJMnet network.

Method 4
- A mid-sized generating station may use the DNP3 protocol over PJMnet. Many providers and devices available to members will support DNP3 over TCP/IP (Ethernet) communications. A DNP3 over TCP/IP enabled device can connect directly to the PJMnet router. The communicating device may be as complex as the station DCS or as simple as a stand-alone protocol gateway.

Method 5
- A generating station with less than one-hundred megawatts of capacity can connect directly to PJM. PJM supports links over the public-domain Internet using DNP3 as the data protocol specially encrypted. This encryption method is not a published open-standard like DNP3 or ICCP. However PJM will provide details, guidance and resources for establishing this link.

Method 6
- Demand response assets that are not aggregated to a control center may receive a digital signal for spin events, regulation, or other market data through a dedicated encrypted DNP3 link.
Technical Definitions:

Demand Response refers to load response assets and operations within PJM.

DNP3 is a common data-level protocol to tie utility devices together. Less sophisticated.

DNP3 (Distributed Network Protocol)

EMS is an Energy Management System that can monitor and control generation or T&D.

ICCP is a common network-level protocol to tie control centers together. More sophisticated.

Inter-Control Center Communications Protocol,

Internet is the worldwide public network. Not inherently secure and lower cost.

PJMnet is PJM’s private wide area network. Inherently very secure. Higher regular cost.

SCADA is a Supervisory Control and Data Acquisition system.

TCP/IP is a set of ubiquitous protocols that form the basis for almost all modern network communications.

Transmission Control Protocol (TCP)

Internet Protocol (IP)
• **Former Economic Dispatch Tools**
  
  – **RT UDS** *(Real-time Unit Dispatch System)*
    - Projecting out 15 minutes to dispatch online units
    - No CT commitment, only de-commitment
  
  – **LA UDS** *(Look-ahead Unit Dispatch System)*
    - Projecting out 15, 30, 45, & 75 minutes to commit CTs
    - No coupling of LA solutions or coupling of RT UDS and LA UDS results

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**On Wednesday, June 9 at 9:30 am** PJM switched to RT SCED permanently. After this time, RT SCED will be the source for all real-time economic dispatch data.
**RT SCED** and **IT SCED** design

- **RT SCED** = Real-time Security Constrained Economic Dispatch
- **IT SCED** = Intermediate Term Security Constrained Economic Dispatch
  - Introduce multi interval/multi horizon solution with flexible individual objectives
  - Employ a “time-coupled” optimization engine

**Dispatcher-focused user interface**
  - Information displayed in a more relevant format
  - Many dispatcher actions can occur directly from the user interface
The **Generation Control Application** consists of the four high-level functions:

<table>
<thead>
<tr>
<th>Function</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Automatic Generation Control (AGC)</td>
<td></td>
</tr>
<tr>
<td><strong>Multi-interval Security Constrained Economic Dispatch (SCED)</strong></td>
<td></td>
</tr>
<tr>
<td>Adaptive Constraint Model (ACM) – In evaluation phase</td>
<td></td>
</tr>
<tr>
<td>Adaptive Generator Model (AGM) – In evaluation phase</td>
<td></td>
</tr>
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</table>

Some entirely new components, some re-designed components as part of the AC$^2$ program
How It All Fits Together

Generation Control Application (GCA)

**AGM**
realistic generator response profiles

**ACM**
intelligent constraint control

**IT-SCED**
demand trajectory, generator loading strategy, CT commitment

**RT-SCED**
final dispatch contour, pricing

**AGC**
regulation signals

Current Operating Plan (COP)
generator dispatch range & sequence solution
Purpose of SCED

• **Security C**onstrained **Economic D**ispatch (SCED)

• Calculate the desired MW output level for all units on the PJM System.

• Consider transmission constraints when calculating the Economic Dispatch Signal (LAMBDA).
Components of SCED

- Real Time (RT) SCED
  - 10-20 minutes

- Intermediate Term (IT) SCED
  - 15-120 minutes
UDS vs. SCED

UDS and LA UDS today

RT & IT SCED
• IT SCED “looks ahead” to guide RT SCED solutions.

• Unlike Look Ahead UDS, The IT SCED intervals are time-coupled.
  – This replaces the on/off CT commitment of LA UDS

• IT SCED intervals are synchronized with the clock ¼ hours, 00, 15, 30 and 45.
• Intervals are slices of time.
• Inputs:
  – Load
  – Unit parameters
  – Day ahead schedules
  – Hydro schedules
  – Interchange
  – Constraints
  – Committed CT’s (logged)
• Why are there two SCEDs?
  – Processing Speed
  – Each has its own objective
  – IT SCED
    – CT commitment
    – Guide RT SCED
  – RT SCED
    – On-line unit dispatch
    – Pricing Calculation
  – 2 Independent engines
    – But IT SCED creates a path for RT SCED to follow
• RT SCED solutions are guided by SCED IT solutions
• This path is referred to as an Envelope
• Limit Priorities
  – Regulation or Spinning Limits
  – Economic Limits
  – Envelope Limits
  – Ramp Limits
• Load Forecast
• Current generator outputs and actual interchange values from the State Estimator.
• Scheduled interchange from EES.
• Generator offer information from eMKT. (Includes incremental curves, rate of response, normal and emergency limits).
• Constraint information from the Dispatcher Management Tool (DMT).
A solution that contains:
- Recommendation changes of Dispatch Rate.
- A list of all active constraints on the system.
- A list of all units that will be used for constraint control.
- Individual Generation setpoints and dispatch rates for all units
- The ability for the Generation Dispatcher to produce alternative solutions.
Process Overview

PJM eMKT
- Generation Offer Data
- Demand Schedules & Bids
- Unit Availability
- Schedule Availability

Markets Database

PJM EMS
- ACE
- Regulation Signal
- Load Forecast

State Estimator
- Unit Output
- Constraint Sensitivities
- Constraint Flows

EES
- Energy Transactions
- Net Tie Schedules

Security Constrained Economic Dispatch

Dispatch Solution
Individual Unit Dispatch Points
• Companies will receive a specific MW output level for each unit
  – This value will take into consideration any MW the unit may be providing for regulation or tier 2 spinning reserve
  – Output level will be for either economic dispatch or for transmission constraint control
• Output level will change as system conditions change
• PJM will notify company(ies) if unit(s) is(are) cost capped
Combustion Turbines and SCED

• CT dispatch
  – Operator sets max start-up time and min-run time parameters based on expected constraint and/or peak load duration
  – CTs called based on operating rates (price schedule for economic dispatch, cost schedule for transmission constraint control, unless unit not subject to cost-capping)
  – PJM operator is prompted to phone CTs that are committed by SCED
Steam Units

- Constrained by ramp rates (SCED will only dispatch a unit to a level it can reach in the given look-ahead interval)
- Block Loading (SCED will override with ramp rate limitations, however, this is for solution purpose only)
- Must Run, Min=Max (SCED treats as fixed generation injection)
- Must Run, Min≠Max (SCED will dispatch between Min and Max)
- SCED will send a dispatch signal which mirrors the unit’s actual until it reaches its’ economic minimum
• Hydro Units
  – Modeled as fixed generation (positive or negative)
  – Changes in hydro status are entered by the operator
Transmission Constraint Control

- Operator monitors transmission elements using EMS Security Analysis tool
- When a trend toward a constraint begins, the operator will bridge the constraint to SCED so that SCED can monitor the contingent element
- Units with a 5% or greater effect on constraints are passed to SCED from State Estimator
- SCED will calculate a solution to a user-determined percentage of the constrained element limit
- SCED solves for all “active” constraints simultaneously, returning the most economic solution possible
• Solutions must be approved by operator before being sent to generators
  – PJM goal is to approve a new solution at least every 15 minutes

• Three solutions are presented to the operator
  – One of the three can be approved, or wait for the next set of solutions
  – The three solutions will vary by an operator entered delta factor
• Adjustments that can be made by the Generation Dispatcher
  – Look ahead interval.
  – CT Startup and minimum run times.
  – The constraint controls that will be used in the solution.
  – % of rating for constraint control.
    • Adjust dispatch levels for two additional solutions.
- Bias the solution up or down
The Generation Dispatcher will:

- Validate system constraints
- Review Constraint Controls
- Review recommended solution
- Review alternate solutions
- Select a solution or adjust inputs and execute a new solution.
- Approve solution

The PJM Generation Dispatcher must “accept” at least one SCED solution every 15 minutes.
Control Area Configuration

Generation Instructions

Individual Generators

Inputs
Constraints
Outages
SE Solution
Load Curves
Generator Performance Monitor (GPM) Overview
• SCED dispatch signals are based on units’ bid-in ramp rate
• Under-performing generators cause over-/under-estimating outputs for system control
• **GPM: Generator Performance Monitor**
  – Objective: Keep track of how close the generators are responding to the SCED dispatch signals
  – Keep monitoring and evaluating unit’s actual performance
  – Near real-time predicting unit’s performance
• Inputs: Generator status, run-time limitations, regulation status, historic and latest generator outputs, historic and latest generator dispatch MW
• Outputs: Degree of generator performance (DGP)
  – Interval DGP (IDGP):
    • **Measure** the responsiveness of a generator to dispatch instructions in terms of its actual generation MW output
    • Formula:
      \[
      IDGP_t = \frac{(AU_{gen_t} - AU_{gen_{t-1}})}{(U_{gen_t} - AU_{gen_{t-1}})}
      \]
    – **AU_{gent}:** Actual unit output for interval \(t\)
    – **U_{gent}:** SCED dispatch signal for interval \(t\)
    • 0 ≤ IDGP ≤ 1
      – IDGP = 0 : the unit is not following SCED dispatch
      – IDGP = 1 : the unit is following SCED dispatch perfectly
    • Calculated every 5 minutes for on-line units
Example 1 – Good performing unit

- Unit X is following PJM Dispatch Rates
  - Current actual MW output = 98 MW
  - Current SCED solution asking for output = 100 MW
  - At the last SCED solution, actual MW output = 90 MW
- Interval Degree of Generator Performance (IDGP) is:
  \[
  \text{IDGP} = \frac{98 - 90}{100 - 90} = .8
  \]
  - This indicates for the most recent SCED interval, the unit is following the dispatch rate fairly closely (IDGP close to 1)

Example 2 – Poor performing unit

- Unit Y is following PJM Dispatch Rates
  - Current actual MW output = 200 MW
  - Current SCED solution asking for output = 120 MW
  - At the last SCED solution, actual MW output = 202 MW
- Interval Degree of Generator Performance (IDGP) is:
  \[
  \text{IDGP} = \frac{200 - 202}{120 - 202} = .024
  \]
  - This indicates for the most recent SCED interval, the unit is not following the dispatch rate very well (IDGP close to 0)
• Achievable DGP (ADGP):
  • Used to **project** the responsiveness of a generator to dispatch instructions for the next SCED look-ahead interval
  • Based on the historical IDGPs: \{ IDGP_t \}
  • Algorithm uses generator’s response in the last 10 SCED intervals to predict the expected future performance of the generator
    – Weights most recent performance higher
      » See next slide
    – Upon generator startup, ADGP will be set to 1
    – Unit operated below Economic Minimum will have ADGP set to 1 until unit is above Economic Minimum
      » I.e. SCED does not dispatch unit if it is below Economic Minimum
• Achievable DGP (ADGP):
  – Formula:
  \[ ADGP_t = \frac{\sum_{i=0}^{N-1} EWF_{t-i} \times IDGP_{t-i}}{\sum_{i=0}^{N-1} EWF_{t-i}} \]
  – \( 0 \leq ADGP \leq 1 \)
    • \( ADGP = 0 \) : SCED does not expect the unit to move
    • \( ADGP = 1 \) : SCED expects the unit to move according to its bid-in ramp rate
  – Calculated every 5 minutes for on-line units

• Achievable ramp rate:
  – \( \text{Achievable}_\text{Ramp}_\text{Rate} = ADGP \times \text{Bid-in}_\text{Ramp}_\text{Rate} \)
  – ADGP-limited ramp rate limit is used by SCED for dispatch solution
GPM Analysis
10/15/03 6:00AM - 10/16/03 6:00AM

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1. Unit drops about 50 MW

2. SCED tries to dispatch up- GPM notices the actual drop and restricts its prediction.

3. As poor performance continues, GPM expects fewer MW, non-GPM does not

4. GPM prediction recovers as actual output improves

5. Similar situation-similar results
Evolution

Economic Dispatch

Generator Performance Monitor

Adaptive Generator Model