

# Introduction to Reserve Constrained Unit Commitment

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## **Purpose of Scheduling**

## **Production of Schedules – Day Ahead & In-Day**

## **Sources of Data required for Scheduling**

## **Reserve Constrained Unit Commitment**

- Ø Requirement for RCUC
- Ø How RCUC fits in with the Central Market Systems
- Ø Differences between System Operator Schedules and Market Schedules
- Ø RCUC inputs and outputs

### **Purpose of Scheduling**

- ∅ To ensure there are sufficient generation resources committed to meet the forecasted system demand at all times
- ∅ To ensure that the output of the generation resources is such that all transmission plant is operated within acceptable limits
- ∅ To plan for credible contingencies on the generation and transmission system
- ∅ To provide information to Generators who have daily fuel purchasing commitments
- ∅ To feed into the real time dispatch process

### **The Schedule should:**

- ∅ Minimise total production cost on the island whilst meeting all of the above requirements
- ∅ Be technically feasible
- ∅ Be produced and communicated in a timely fashion
- ∅ Be sufficiently flexible to allow for real time management of deviations from forecasted demand, wind generation and availabilities

## Scheduling Process

**A single schedule is jointly produced by EirGrid and SONI for the Island**

**Scheduling occurs in two separate time frames**

- Ø Day-ahead
- Ø In-day

**Day-Ahead Schedules**

- Ø Jointly produced by the 'Day Staff' in EirGrid and SONI
- Ø Cover the time period from 06:00 on D up to 11:30 on D + 1
- Ø Completed and published by 16:00 on D-1
- Ø Updated as required and republished at 01:00

## Scheduling Process (In day)

### In-Day Schedules

- Ø Jointly produced in real time by Control Centres in EirGrid and SONI
  
- Ø Day Ahead is updated with latest information and becomes the In-Day schedule at 6am
  
- Ø New In-Day schedules are produced if changes in the following items means that either SO cannot meet their demand and maintain the tie line and reserve schedules without deviating from the existing plan
  - § System Demand
  - § Wind Generation
  - § Availability of Plant
  - § Transmission Plant operation
  
- Ø End time of the In-Day schedule is always 11:30, starting time varies
  
- Ø In-Day schedule published every 4 hours starting at 8am

## Sources of Data required for Scheduling

### Data required for producing a schedule

- ∅ Wind and Demand Forecasts
  - § EMS Load Forecasting Tool, Weather Forecasting information
  - § Anemos / More Care / WeProg wind forecast tools
  
- ∅ Real Time Availability of generation resources (In-Day)
  - § EDIL
  
- ∅ Results of Transmission Power Flow Studies
  - § PSSE / Energy Management System in real time
  
- ∅ Generator Commercial & Technical Data
  - § RCUC
  
- ∅ Generator 'Starting' Position
  - § RCUC

## Why RCUC?

- ∅ Before SEM
  - § Both SOs scheduled and dispatched units under their control
  - § Two separate markets in operation
  - § Tie line flow set by market on D-1
  - § Reserve apportioned on a fixed basis
  
- ∅ During AIP the SOs identified the requirement for a joint scheduling tool
  - § Harmonisation of markets required a harmonisation of scheduling process
  - § Minimise overall system constraint costs
  - § Optimise reserve scheduling
  - § Optimise use of tie-line
  
- ∅ ABB as supplier of SEM Unconstrained Unit Commitment System were the chosen to supply RCUC

## Reserve Constrained Unit Commitment

- Ø Software tool which utilises a Mixed Integer Program (MIP) to perform Unit Commitment and Linear Programming to perform Economic Dispatch
- Ø What is MIP? *A mixed-integer program is the minimization or maximization of a linear function subject to linear constraints*
- Ø What is Linear Programming *“Put simply Linear Programming problems determine the way to achieve the best outcome (such as maximum profit or lowest cost) given some list of requirements represented as linear equations. “  
(courtesy of wikipedia!)*
- Ø Has been in use since the Single Electricity Market went live on November 1<sup>st</sup> 2007
- Ø Has now produced over 180 ‘Day Ahead’ Schedules and over 400 ‘In-Day’ Schedules

## RCUC and the Central Market Systems

### RCUC and the Central Market Systems

- Ø RCUC is an ABB product and was delivered as part of the All Island Project
- Ø RCUC is only used by the System Operators and all costs associated with RCUC are SO costs and not SEM-O costs.

### Components of RCUC

- Ø Database
  - § Reads all data from the Central Market System Database
- Ø Application
  - § RCUC is a stand alone application which runs on its own servers
- Ø Webserver
  - § RCUC has its own Webservers
- Ø Publication
  - § RCUC utilises the Market Participant Interface (MPI) for publishing schedules

## RCUC and the Central Market Systems

### Change Control

- Ø RCUC is a System Operator Tool
- Ø The RCUC application runs on its own server and does not impact on, or interact with, the Market Unconstrained Unit Commitment (UUC) applications or any participant interfaces
- Ø RCUC down time is minimised by scheduling deployments to coincide with Market Application deployments
- Ø RCUC Reports are published via the (MPI) and therefore any changes in these reports that could impact on Participant Interfaces are notified to Participants as per AP11

## RCUC versus UUC

- ∅ Ex- Ante UUC calculates MSQ (Market Scheduled Quantity) for each unit and takes account of the following
  - § Price Quantity Pairs
  - § No Load Costs and Start-Up costs
  - § Technical Characteristics
  - § Forecast System Demand
  - § Forecast wind output
  - § Energy Limits for energy limited plant such as Hydro Targets & Pumped Storage
  
- ∅ RCUC takes account of each of the above and the following when calculating the DSQ for each unit
  - § Reserve Requirements
  - § Reserve Capability Curves
  - § North-South Tie Line restrictions
  - § Specified Transmission Constraints Groups
  - § Forbidden Zones
  
- ∅ Furthermore RCUC accurately models
  - § Loading up and down rates from zero to Min Load (ignored in UUC)
  - § Actual Ramp Rates (averaged in UUC)

## Two Main Categories of Data

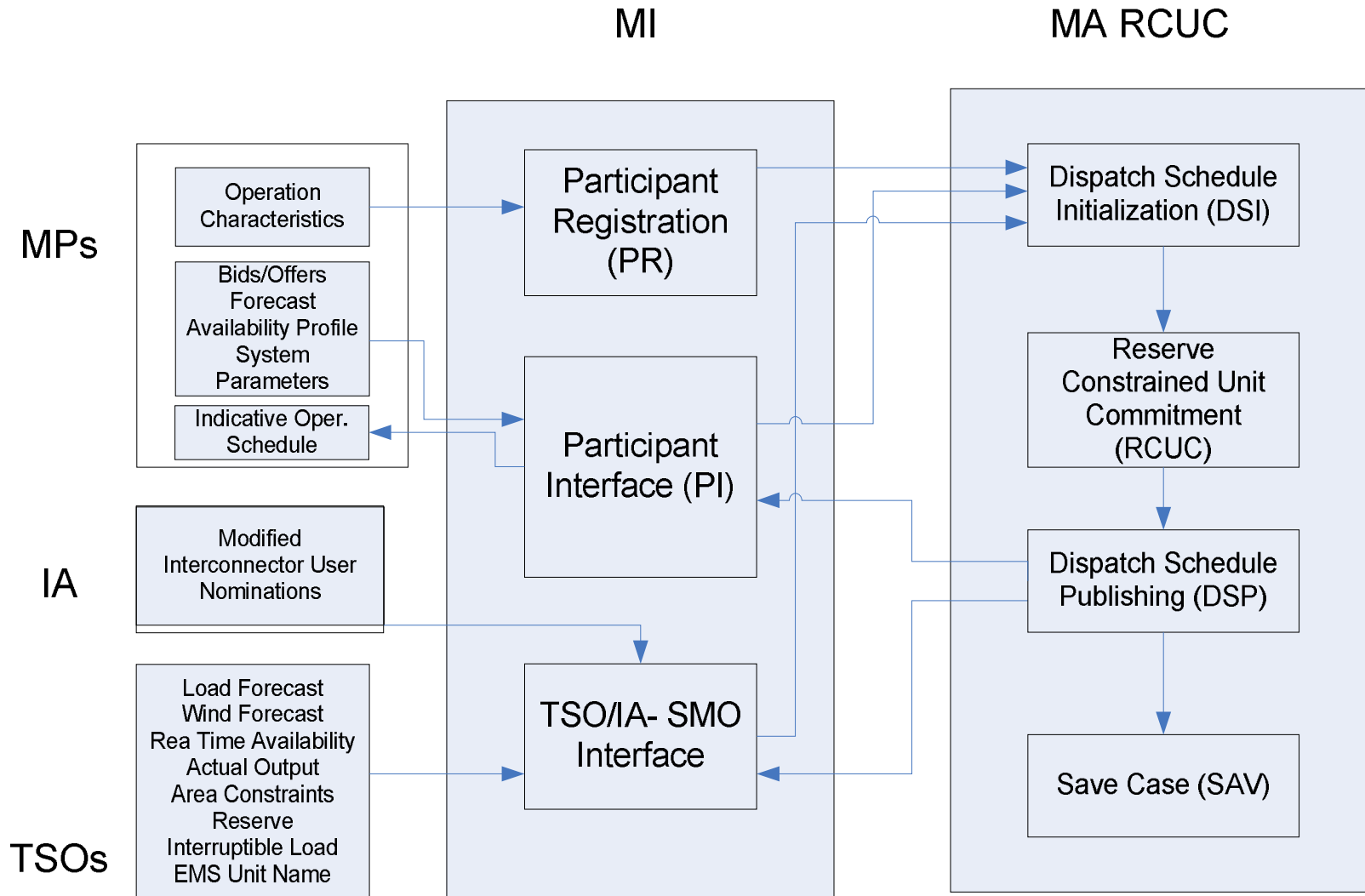
### Generator Data – Submitted by Participants

- ∅ Generator Bids and Offers
- ∅ MSG & Availability
- ∅ Generator Parameters
- ∅ Interconnector Parameters

### System Operator Data – Submitted by SOs

- ∅ Reserve Requirements and capabilities
- ∅ Transmission Constraint Groups
- ∅ Wind and Load Forecasts
- ∅ Real Time Availability
- ∅ Remaining Energy Limit (hydro)
- ∅ Real Time Output (MW)

Overview of data flow in RCUC





Browse:



Tree Locate

- SEM-MA
  - Market Applications
    - Application Messages
    - Day-Ahead RCUC
      - Workflow
        - Day-Ahead RCUC Sequence
        - Day-Ahead RCUC Sequence Messages
        - RCUC Events
      - Dispatch Schedule Initialization (DSI)
      - Reserve Constrained Unit Commitment (RCUC)
        - RCUC Input
          - RCUC Commitment Execution Parameters
          - System Load
          - Company Load and Interruptible Load
          - Generator Operating Limits
          - Generator Ramp Up Rates
          - Generator Ramp Down Rates
          - Generating Cost Curves
          - Generator Start-Up Cost
          - Generator Status
          - Generator Operating Data
          - Pump Storage Unit Data
          - Energy Limited Unit Data
          - Shared Energy Limit for Trading Site
          - Unit List for Trading Site
          - Energy Group Limit
          - Unit List for Energy Group
          - Pump Storage Plant Limit
          - Pump Storage Min and Max Reservoir Limit
          - Unit List for Pump Storage Plant
          - Reserve Generation Capability Curve
          - System Reserve Requirement Data
          - TCG Data
          - TCG Load, Limit and Reserve Constraints
          - Operator Participation
          - Interconnector Ramp Limit
          - Penalty Function Cost Parameters
          - North-South Tie-Line Flow Ramp Limit
        - RCUC Output
      - Dispatch Schedule Publish (DSP)
      - In-Day RCUC
      - System Administration

## Day-Ahead RCUC

### Sequence Optimization Time

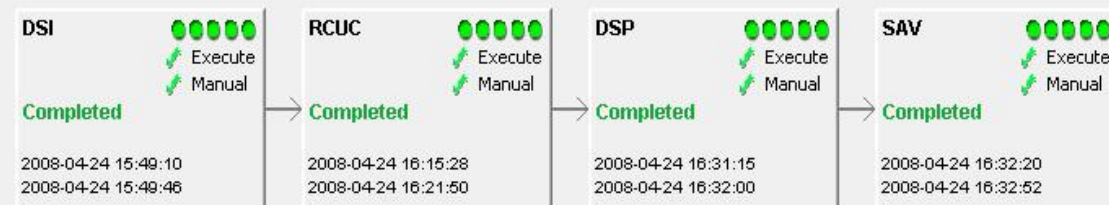
Start Time: 25/04/2008 06:00:00 IST  
 End Time: 26/04/2008 11:30:00 IST  
 Trading Period (min): 30  
 Number of Trading Periods: 60  
 Post Time: 24/04/2008 16:00:00 IST  
 Effective:  Yes

### Sequence Parameters

Operator Override Trading Date: 25  
 Approval of Indicative Operation Schedule:   
 Initialize From: Lat

### Control

### Workflow



### Run

## RCUC Outputs

- RCUC Output
  - Generation Schedule
  - Gross Generation Schedule
  - Generation Schedule - INC/DEC
  - Generation Schedule - SPD
  - Generation Commitment Status
  - Generation Production Cost
  - Reserve Contribution
  - Reserve Contribution - Gross
  - Reserve Contribution - INC/DEC
  - Reserve Contribution - SPD
  - Energy for Individual Energy Limited Units
  - Energy for Shared Energy Trading Sites
  - Energy for Energy Group
  - Energy in Reservoir for Pump Storage Plants
  - Generator Excess Capacity
  - Generator Excess Energy
  - Schedule by Generator
  - Schedule by Date
  - System Summary
  - EirGrid Company Summary
  - SONI Company Summary
  - System Daily Summary
  - System Reserve Summary 1
  - System Reserve Summary 2
  - TCG Load and Generation Summary
  - TCG Reserve Summary 1
  - TCG Reserve Summary 2
  - Individual Output Summary
  - RCUC Output Summary for EirGrid
  - RCUC Output Summary for SONI



Company Summary

## RCUC Output Summary for EirGrid

Name	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00
Load	2,406	2,543	2,799	3,179	3,439	3,637	3,650	3,683	3,716
Wind Gen	124	124	131	131	129	129	124	124	124
POR Actual	304	289	263	192	189	190	191	191	191
SOR Actual	303	332	262	330	271	283	279	279	279
TOR1 Actual	323	352	367	346	281	286	282	282	282
TOR2 Actual	550	579	529	346	296	286	282	307	307
CONT Actual	2,789	2,644	2,386	1,946	1,651	1,471	1,454	1,399	1,399
Inter-Area Flow	-124	-116	-62	-2	41	80	98	120	120
AA1	0	0	0	0	4	21	21	21	21
AA2	0	0	0	0	0	4	22	22	22
AA3	0	0	0	0	4	19	19	19	19
AA4	0	0	0	0	4	24	24	24	24
ER1	0	0	0	0	0	10	10	10	10
ER2	0	0	0	0	0	10	10	10	10
ER3	0	0	0	0	0	22	22	22	22
ER4	0	0	0	0	0	22	20	22	22
LE1	0	0	0	1	15	15	15	15	15
LE2	0	0	0	0	0	0	0	0	0

## RCUC Output Schedules

### Key Features

- Ø Shows the output for each unit for each trading period
- Ø Cannot be modified 'on screen'
- Ø Day Ahead Schedules cover 60 trading periods
- Ø In-Day cover the remainder of the trading day and the first 6 hours of the next day
- Ø Calculates the reserve schedule for each unit
- Ø Produces a tie-line flow schedule for every trading period
- Ø Reports any breaches of constraints

2008-04-24 12:45:19.970095000	Unit TB4 violates the ramp time constraint by 9.67492 MW at 11:00 of 2008-04-26
2008-04-24 12:45:19.617773000	Reserve for transmission group NI violates NEG. reserve constraint by 36.94251 MW at 05:30 of 2008-04-26.
2008-04-24 12:45:19.546392000	Reserve for transmission group NI violates NEG. reserve constraint by 15.89350 MW at 05:00 of 2008-04-26.

## Conclusions

- Ø Scheduling Process performed daily on a Day Ahead basis and an In-Day Basis
- Ø System Operators work together to produce the least cost schedule for the island
- Ø RCUC is one of many tools used by the System Operators in preparing generation schedules
- Ø RCUC uses data submitted by the participants and updated by the SOs where appropriate
- Ø RCUC uses the most up to date load forecast and real time information
- Ø RCUC outputs are on an all-island basis and on a jurisdiction basis
- Ø RCUC outputs used by the Control Center operators as an input into the Dispatch process