Chapter 4: The Scheduling and Dispatch Process

Foreword

- Our scheduling and dispatch process incorporates a range of activities associated with managing the close to real-time planning and operation of the power system.

- This process is designed to implement European and jurisdictional policy objectives based on a range of market and technical inputs. This is achieved through: the production of Indicative Operations Schedules; the issuing of dispatch instructions; the provision of data to pricing and settlement systems and information to support various reporting mechanisms and

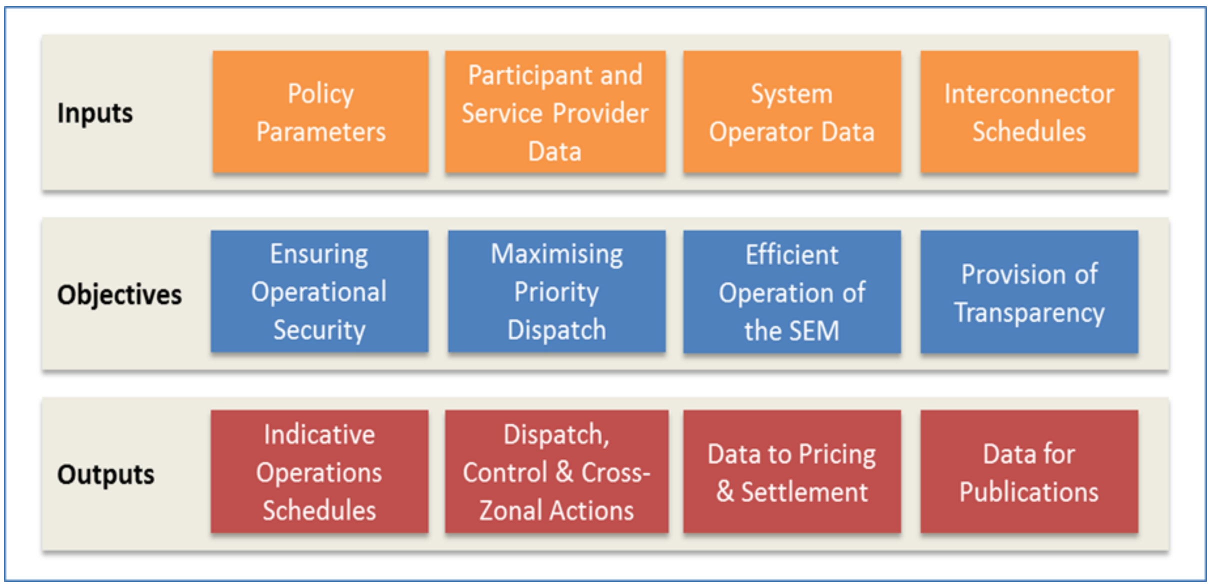

Figure 6 Overview of the Scheduling & Dispatch Process

Process Overview – (1/2)

- The scheduling and dispatch process is built around the Balancing Market which is the sole mechanism by which we dispatch units to manage constraints, provide System Services and dispatch balancing energy.

- The Balancing Market requires Participants to submit PNs with COD, representing their incremental and decremental costs to move from this position, by Gate Closure of the Trading Day (13:30 day-ahead). Participants can update their PNs and COD after this time and up to Gate Closure of the Imbalance Settlement Period to reflect their intraday trading activity or any update to their balancing offers and bids. These offers and bids form the basis of our ability to efficiently position units to provide System Services, manage system constraints and dispatch energy balancing actions.

- Conditions on the power system can change from what was forecast (demand and wind variations), and transmission circuit and unit availability can change in an unplanned manner. We operate a continuous scheduling process to ensure the latest market and system information feeds into the actual dispatch. The continuous nature of the process means that whenever a dispatch instruction is issued, it will be on the basis of the latest market positions, the latest notification of unit capabilities and the latest actual and forecast system conditions.

Process Overview – (2/2)

- Our scheduling and dispatch process operates from real-time through to the next Trading Day. Given the volume of inputs to the process and the complex nature of the process itself, it is split into a number of timeframes that allow for short term analysis to be performed quickly and regularly while longer term analysis, which takes more time to process, is performed less frequently. The aim is to achieve a rolling, integrated and current plan of actions.

- The scheduling and dispatch run types are summarised on the next slide. Each of these run types operate over a different timeframe and uses different inputs as a result. Each run type uses either Security Constrained Unit Commitment (SCUC) or Security Constrained Economic Dispatch (SCED) algorithms. The output of each of these runs is an Indicative Operations Schedule (IOS) of unit production and consumption (of storage units and demand side units rather than supplier units) levels (MW levels per scheduling time interval) that meet the objectives of the scheduling and dispatch process.

Scheduling & Dispatch Run Types

LTS – Long-Term Schedule

- Provides medium to long-term Security Constrained Unit Commitment (SCUC) schedules.
- Runs every 4 hours. Produces a schedule from initiation time +4 hours for a duration of up to 30 hours (horizon depends on purpose and timing of the run).
- The scheduling interval is 30 mins (i.e. a MW value for each unit is determined for each hour and half hour over the horizon).
- Output is an IOS (Indicative Operations Schedule) that is used to inform unit commitment instructions, of the form ‘sync and go to minimum load’ or ‘desync’, which are issued in line with unit notification times.

RTC - Real-Time Commitment

- Provides short term Security Constrained Unit Commitment (SCUC) schedules.
- Runs every 15 minutes. Produces a schedule from initiation time +30 mins for a duration of 3½ hours.
- The scheduling interval is 15 mins (i.e. a MW value for each unit is determined every 15 mins over the horizon).
- Output is an IOS that is used to inform unit commitment instructions, of the form ‘sync and go to minimum load’ or ‘desync’ which are issued in line with unit notification times.

RTD - Real-Time Dispatch

- Provides Security Constrained Economic Dispatch (SCED) schedules close to real time consisting of incremental and decremental MW schedules.
- Does not make unit commitment / de-commitment decisions but accounts for these decisions which come from RTC and LTS.
- Runs every 5 minutes. Produces a schedule from initiation time +10 mins for a duration of 60 mins.
- The scheduling interval is 5 mins (i.e. a MW value for each unit is determined every 5 mins over the horizon).
- Output is an IOS that is used to inform dispatch instructions of the form ‘go to x MW’ which are issued in line with unit ramping capability.

Illustrative Scheduling and Dispatch Run Sequence

- These schedules are run automatically and continuously as illustrated in Figure 7 below. Manually initiated LTS runs can also be performed to consider significant changes to inputs (such as a forced outage of a large unit) so that we can, if necessary, update our plans to ensure that, for example, system security requirements are met.

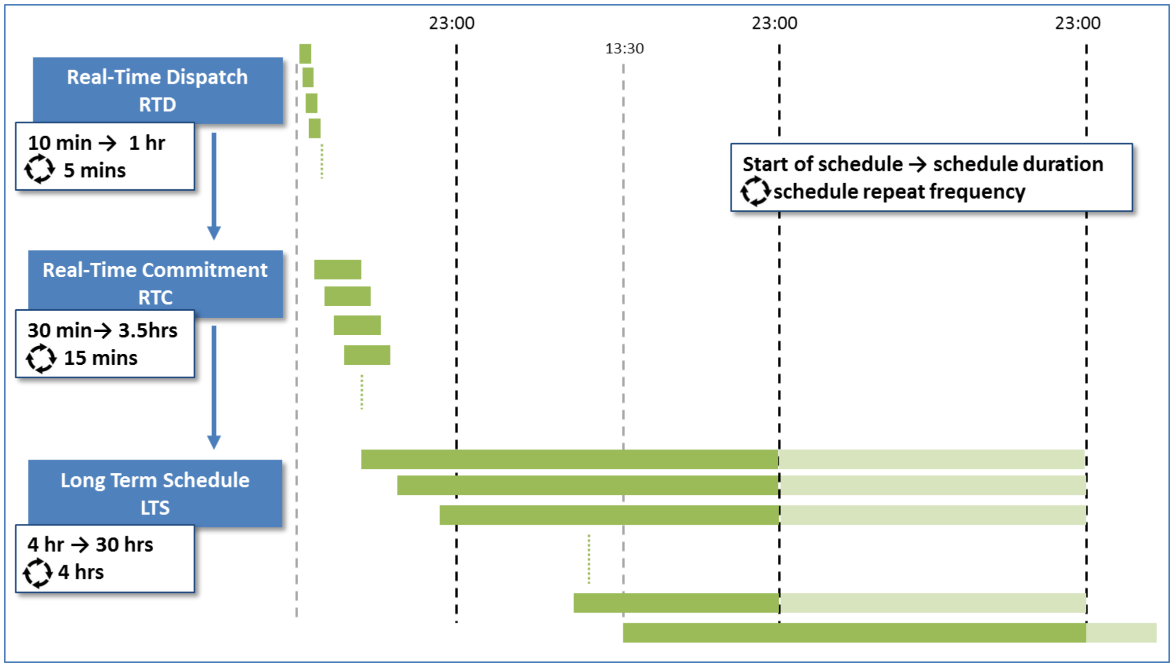

Figure 7 Illustrative Scheduling & Dispatch Run Sequence

- In addition to the production of IOSs, the process produces merit orders of available actions that we can take to increment / start-up units or decrement / shut-down units in response to changing system conditions that may not have been factored into the IOS (e.g. a deviation from forecast wind levels or a unit trip that requires fast start units to be started up).

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SCUC & SCED

- Scheduling is an highly complex task, taking many diverse inputs in terms of data and objectives to produce IOSs. Complex mathematical programs are used for these purposes. These programs employ optimisation techniques to simplify the scheduling problem so that it can be determined within the time restrictions of real-time operations. This is because, with the scale of the problems to be solved, "brute force enumeration", where every possible outcome is tested is not feasible.

- The optimisation programs used to produce IOSs are known as Security Constrained Unit Commitment (SCUC) and Security Constrained Economic Dispatch (SCED).

- The purpose of SCUC is to determine the commitment status of units, i.e. whether or not a unit is on (synchronised) or off (de-synchronised) and the schedules of units, i.e. their indicative MW output level at instances in time, at least cost while respecting technical constraints and other policy objectives.

- SCED does not make unit commitment decisions (it takes these from SCUC) but optimises the MW schedules of units already committed or scheduled to be committed. Like SCUC, its objective is to schedule at least cost while respecting technical constraints.

Data Preparation

- Some of the data items described in the inputs section are processed / selected to facilitate the scheduling process as described in the following sections.

Availability Data Selection

- Both forecast availability and real-time availability of units form inputs to the process (as described in the Inputs section). For the same unit, real-time availability can differ from the forecast availability (say due to a unit trip) so the scheduling run types use the following sources of unit availability data.

Scheduling Run Type	Source of Unit Availability	
	Dispatchable Unit	Wind
LTS – Long-Term Schedule	Forecast availability as submitted via the BMI	Per TSO wind forecast
RTC – Real-Time Commitment	Forecast availability as submitted via the BMI or real-time availability as declared in EDIL	Per TSO wind forecast blended with real-time availability from EMS
RTD – Real-Time Dispatch	Real-time availability as declared in EDIL	Per TSO wind forecast blended with real-time availability from EMS

Commercial Offer Data Selection

- Participant commercial offer data submissions can be in complex and simple formats as described in the Inputs section. This data is applied in each of the scheduling run types as described in the table below.

Scheduling Run Type	Source of Commercial Data		
	Primary	Back-Up 1	Back-Up 2
LTS – Long-Term Schedule	Complex	Default	N/A
RTC – Real-Time Commitment	Complex	Default	N/A
RTD – Real-Time Dispatch	Simple	Complex*	Default*

*Note: only inc/dec component of complex or default commercial offer data is used
The Back-up sources are utilised if the primary source of commercial data is not available.
Arrangements for the submission of default commercial offer data are set out in the TSC Part B section D.

Composite Cost Curve – (1/2)

- The complex and simple commercial offer data submitted by Participants contains two separate Price/Quantity (PQ) curves based on absolute MW; one containing a range of break points and incremental prices, the other containing a range of break points (not necessarily the same) and decremental prices. Within the scheduling process, for each Imbalance Settlement Period, for each unit, a composite PQ curve is created by using the PN value to combine the two curves as described below:

- All segments from the decremental curve where the MW range is below or equal to the PN; and

- All segments from the incremental curve where the MW range is above or equal to the PN.

Composite Cost Curve – (2/2)

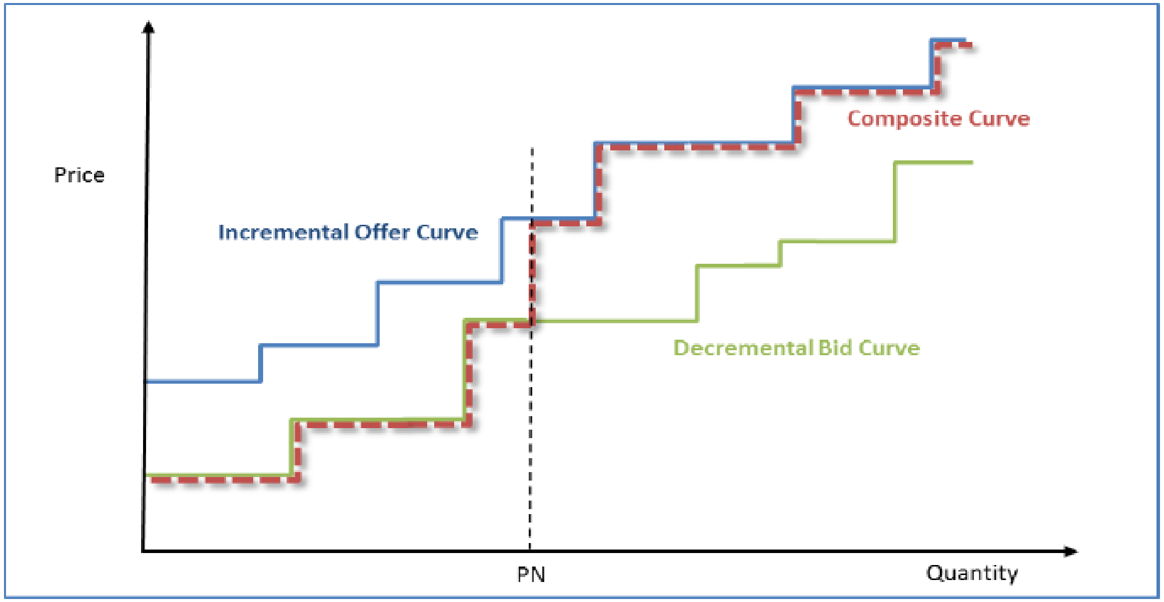

Figure 8 Illustration of Composite Cost Curve

- This composite curve (the red dashed line in the Figure above) for each unit, for each Imbalance Settlement Period is used within the scheduling tool as the cost curve used to make incremental and decremental adjustments within the optimisation.

Conversion of Interconnector Schedules to Reference Programmes

- The Moyle and EWIC interconnector schedules that are provided to us are block schedules – hourly for the day-ahead market, half-hourly for intraday updates. While the interconnectors are physically capable of achieving rapid changes between trading periods, a ramping rate is applied to ensure that changes to the physical interconnector flows respect the relatively slower ramping capability of units on the system and the slower rate of change in demand and wind production levels. Rapid changes to interconnector schedules could otherwise result in disturbances on the power system.

- We convert the block schedule for each interconnector to a physical Interconnector Reference Programme (ICRP) that describes the point in time flow on the interconnector and which respects the operational ramp rates applied to each interconnector. The conversion of the block market schedule to an ICRP is illustrated in Figure 12 below. This conversion process seeks to minimise the energy volume difference between the ICRP and the block market interconnector schedule so as to minimise any energy imbalance that arises over the Trading Day. In the Figure below this imbalance is represented as the net area within each imbalance settlement period between the ex-ante market interconnector schedule and the ramp limited ICRP.

Conversion of Interconnector Schedules to Reference Programme Illustration – (1/2)

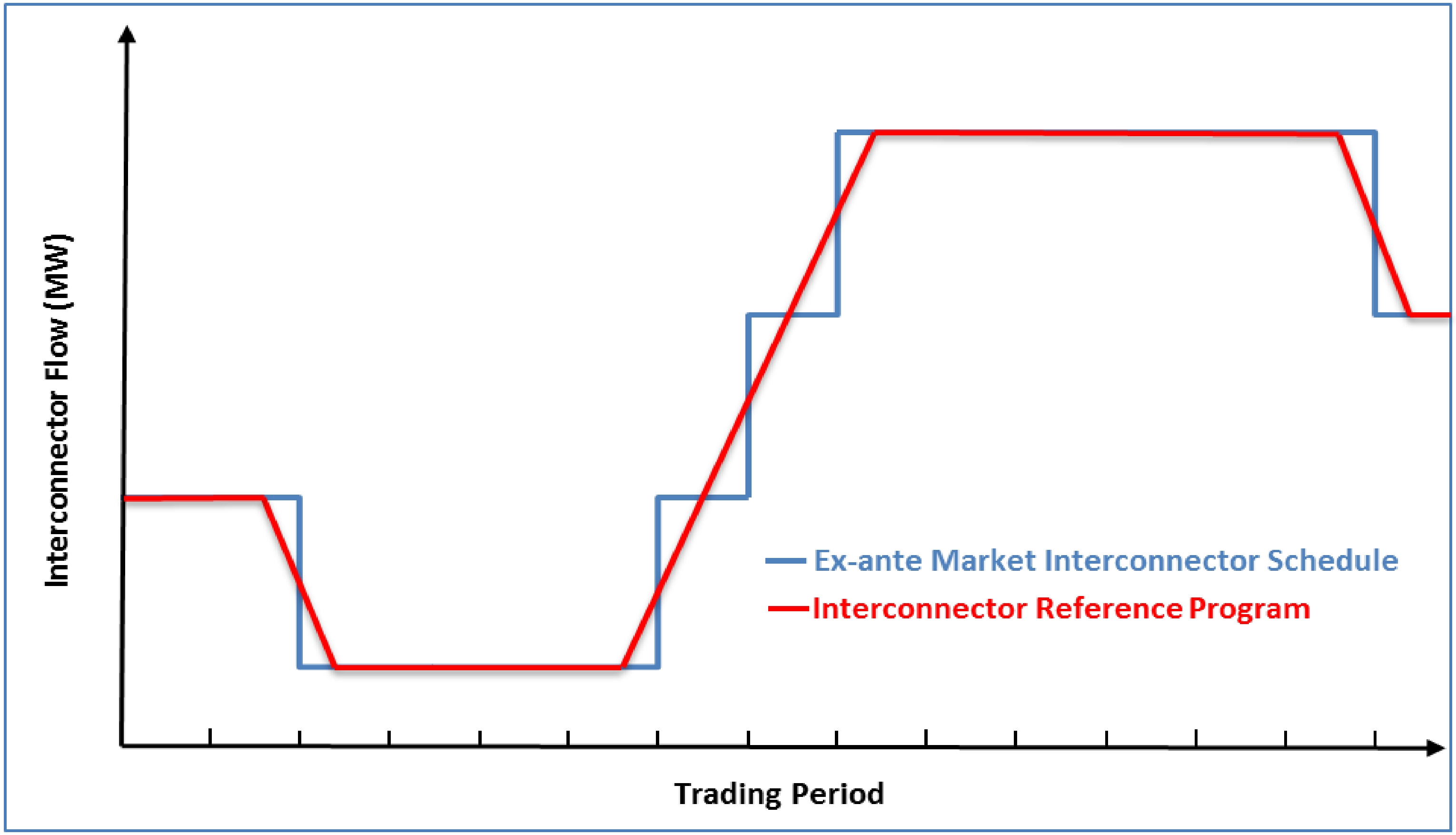

Figure 9 Conversion of Block Market Schedule to ICRP

Units Under Test

- Units that we approve to be under test (having provided the required notice as set out in the Grid Codes) will be scheduled and dispatched according to their submitted test PNs as far as secure operation of the power system allows.

- Participants may also submit offers and bids with their Test PN although these will not normally be utilised in the scheduling and dispatch tools during the test period (as the units is fixed to its PN). However, in the event of an operational security issue arising, we may override the scheduling process and manually dispatch a unit away from its test profile. In such an event, the applicable commercial offer data will apply to the settlement of our action (acceptance of a bid or offer) as any other bid-offer acceptance.

Cross-Zonal Actions

- The scheduling tool can be configured to either leave the ICRP unadjusted from the position determined from the ex-ante market schedule (i.e. no consideration of Cross-Zonal Actions) or to allow adjustment of the ICRP to facilitate priority dispatch for example.

Note: These arrangements remain under review and are subject to change.

The Optimisation – (1/2)

- The underlying optimisation objective is to minimise the cost of diverging from PNs. This objective is bound by the need to respect security constraints, maximise priority dispatch generation and to weight the schedule towards shorter notice dispatch actions. By assigning constraint violation costs and substituting commercial offer data within the optimisation, a schedule can be developed which minimises the cost of diverging from PNs (as seen by the optimiser rather than 'real' costs) but still satisfies these constraints and policy objectives. The mechanisms by which these requirements are reflected in the optimisation and their hierarchy is illustrated in the Figure on the next slide.

- Note that this optimisation objective is different to the objective in the current SEM market. In the current SEM, the objective is to minimise the cost of production based on the commercial offer data provided by Participants. The optimisation does not take into account the market position of Participants. Under the revised SEM arrangements, the schedule seeks to minimise the cost of moving away from Participants' intended running position as reflected in their PN.

The Optimisation – (2/2)

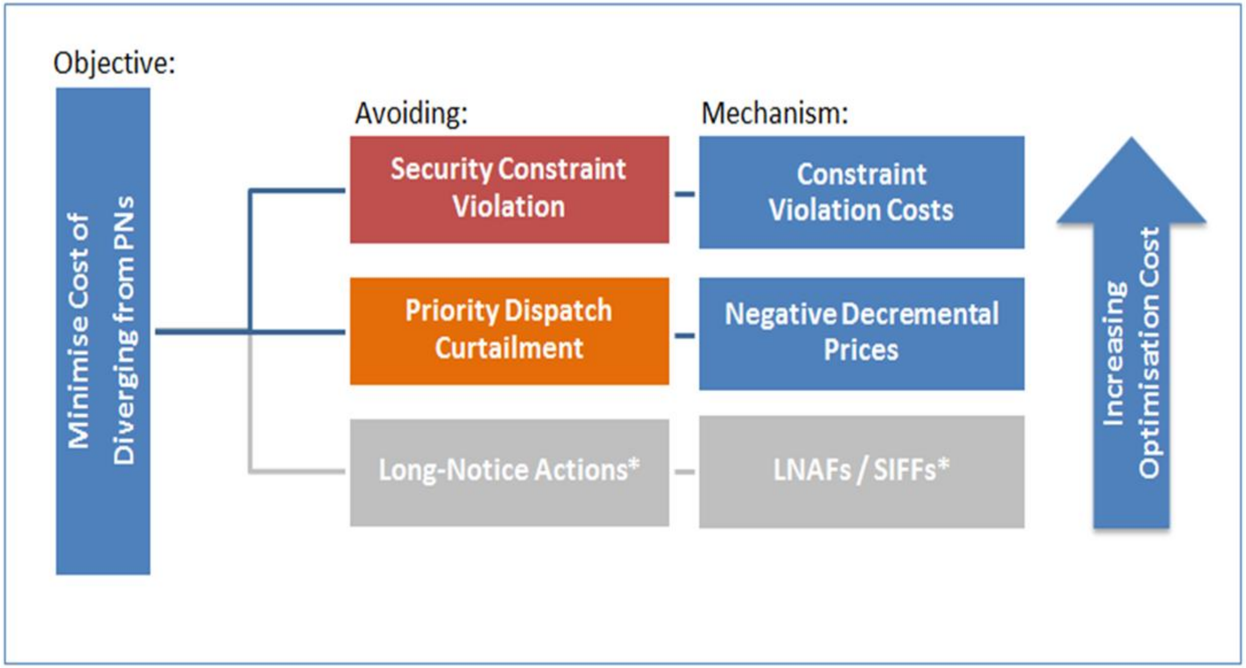

Figure 10 Illustration of Optimisation Objectives

(*not being implemented at go-live of the revised SEM arrangements)

Security Constraints

- Each constraint type is assigned a constraint violation cost which is incurred if the constraint is breached within the optimisation cycle. This cost deters the optimisation from breaching a constraint as to do so would result in a higher apparent cost within the optimisation. These constraint violation costs are parameters within the optimisation that we can tune to give effect to each constraint. In principle all constraints are absolute requirements which must be respected.

Priority Dispatch – (1/2)

- We assign priority dispatch status in the scheduling and dispatch process by allocating a range of pre-determined negative decremental prices to the units defined as priority dispatch (see Inputs section). These prices reflect their relative position in the priority dispatch hierarchy – the higher the priority the more negative the decremental price. Any submitted decremental price is substituted by this predefined priority dispatch price for the purpose of the optimisation however this replacement price does not feed into pricing or settlement. These negative decremental prices can be tuned to account for potential conflicts with other constraints or the prices of other units.

- The intent of these negative decremental prices is to have the optimisation engine avoid these actions as they would result in a high cost (the optimiser is trying to minimise cost). However these units can still be decremented in order to avoid violation of any operational security constraints (which have a higher violation cost).

Priority Dispatch – (2/2)

- Priority Dispatch generation is comprised of dispatchable units (e.g. peat, hydro, CHP) and non-dispatchable (but generally controllable) units (wind and solar). Dispatchable units must submit PNs and their priority dispatch status will apply to their PN'd quantities. Any availability above the PN'd quantity will not be treated as priority dispatch but in normal economic order. Non-dispatchable units may submit PNs however we will use our own forecast of availability to schedule these units to their full actual availability subject only to operational security constraints.

- We develop the schedule to ensure that sufficient 'room' is made available to accommodate priority dispatch generation (i.e. non priority dispatch units will have their output reduced or they may even be de-committed) and that sufficient System Services are scheduled to support system operation (such as the scheduling of sufficient inertia on the system to support the operation of the system during high wind conditions). Our objective is to minimise any operational security related constraint or curtailment of priority dispatch sources.

Outputs

The following sections describe the outputs of the scheduling and dispatch process:

- Indicative Operations Schedules (IOSs)
- Dispatch Instructions (DIs), Control Actions and Cross-Zonal Actions
- Data to Pricing and Settlement Systems

Indicative Operations Schedules (IOSs)

- The output of each scheduling run (LTS, RTC and RTD) is an IOS representing a plan of commitment / de-commitment decisions and MW levels for each unit given the inputs at the point when the schedule is initiated.

- Relevant IOSs will also indicate any proposed implementation of a Cross-Zonal Action (subject to an agreed approach to taking/facilitating such actions).

- The continuous nature of the scheduling process in accounting for the latest inputs means that the IOSs will be a good indication of expected commitment and running levels however they are always indicative until a dispatch instruction is issued or a control action taken by the TSOs.

- The TSOs publish IOSs.

Dispatch Instructions, Control Actions and Cross-Zonal Actions Overview Part – (1/4)

- Based on the IOS, and taking real-time system conditions into account (such as system frequency, voltage and thermal circuit loadings), dispatch instructions and other control actions are determined and issued by us to individual dispatchable and controllable units. Any required deviation from the IOS will be taken in line with a merit order of available actions (to increment/start-up units or decrement/shut-down units) taking into account real-time unit operating levels, unit response characteristics and operational security requirements.

- Each IOS is a MW schedule of unit production/consumption levels from which the following dispatch instructions / control actions are determined:
  - Synchronise – connect to the power system;
  - De-synchronise – disconnect from the power system;
  - MW Level – the active power MW level to which the unit should operate. All MW instructions are 'open' meaning that once achieved; the MW level should be maintained until a subsequent instruction is issued. Within this instruction type the TSO has the ability to define a time until which the instruction applies, known as the effective until time, however this is only relevant to settlement and not physical operation;
  - Wind farm / solar unit Active Power Control – MW active power control set-points;
  - Cross-Zonal Action – implementation of a change to an ICRP to implement a Cross-Zonal Action.

Dispatch Instructions, Control Actions and Cross-Zonal Actions Overview Part – (2/4)

- In addition to these instructions based on the IOS, other control actions on units and interconnectors can be taken:
- Instructions to provide System Services which can be explicit or implicit:
  - Explicit: an instruction to provide reactive power or operate in a specific mode (see 'Operating Mode' below) or
  - Implicit: an instruction implied from the MW dispatch instruction such as a unit being instructed to operate below its maximum output to provide operating reserve;
- Operating Mode – Pumped Storage and some CCGT units can operate in different modes. The scheduling process will be based on the mode of operation determined by the Participant via their TOD set selection however we may also instruct a mode change;
- Instructions to change fuel – some units are capable of operating on different fuels and may be instructed to switch fuel based on their own requirements, for the purposes of a test or in a fuel emergency situation;
- Maximisation instruction – an instruction to operate at a level in excess of declared availability;
- Emergency Instruction – an instruction that could require operation outside of normal declared capability.

Dispatch Instructions, Control Actions and Cross-Zonal Actions Overview Part – (3/4)

- We issue dispatch instructions and control actions over a range of timescales reflecting the technical characteristics of units. These instructions can be categorised as long notice (prior to Balancing Market Gate Closure) and short notice (after Balancing Market Gate Closure)

  i. Long notice actions: Instructions to synchronise can take a number of hours to implement and are issued in line with the notification time required by the unit to start-up which, for many thermal units, is ahead of Balancing Market Gate Closure. These longer notice instructions relate to managing operational security constraints such as deployment of sufficient capability to provide operating reserves and constraining on units to provide voltage support. They can also be taken to ensure sufficient headroom is made available, and System Services provided, to facilitate priority dispatch generation. On some units, the de-synchronisation process may take longer than one hour, i.e. the time from a unit being told to shut-down until it actually disconnects from the power system.

  ii. Short notice actions: Instructions associated with real-time balancing of supply and demand, optimisation of security constraints and priority dispatch levels (‘MW’ dispatch instructions and wind farm / solar unit active power control). These instructions are issued after Balancing Market gate closure in real-time taking into account the ramp rates of units that are already on. Units with short notification times can also be instructed to synchronise/de-synchronise in this timeframe. Delivery of System Services such as reactive power are also instructed in real-time taking into account the unit’s control system response characteristics.

Dispatch Instructions, Control Actions and Cross-Zonal Actions Overview Part – (4/4)

- We may issue dispatch instructions at any time point in time and for any quantity so long as it respects the technical characteristics of units (other than for the maximisation and emergency type instructions listed above). So while dispatch instructions should align with the latest IOS, they do not have to exactly coincide with the IOS's scheduling interval or scheduled quantity. For example, an IOS with the following schedule for a unit 14:00 100 MW, 14:05 110 MW, 14:10 120 MW, could result in an actual dispatch instruction issued at 14:02 of 130 MW.
- The timing and magnitude of actual instructions that we issue will take into account the real-time conditions of the power system. For example we will delay or bring forward a dispatch decision for a unit to change output based on actual system frequency. If system frequency is low, indicating a negative imbalance, we may advance an instruction to increment a unit or delay the decrement of a unit.
- In the event of wind curtailment being required, we issue curtailment instructions to wind farms on a pro-rata basis in order of wind farm dispatch category.
- All units must follow the dispatch instructions that we issue. All controllable wind farms are controlled directly by us. No unit should synchronise, intentionally desynchronise or change output (other than for automatic frequency response) without a dispatch instruction from us.
- It is intended that solar units will be treated like wind units with respect to curtailment.

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Data to Pricing and Settlement Systems – (1/2)

- The dispatch instructions issued and actions that we take result in the delivery of balancing energy and System Services. Data from the scheduling and dispatch process feeds the respective settlement systems so that Participants and System Service providers are settled appropriately. There are also charges related to the performance of units such as Other System Charges and Generator Performance Incentives (GPIs) and outputs of the process that relate to Capacity Market settlement.

- The table below illustrates the range of scheduling and dispatch process outputs used in pricing and settlement systems. Note that there are additional data inputs to each system such as COD, TOD and market metering that are not included in this illustration.

Data to Pricing and Settlement Systems – (2/2)

Scheduling and Dispatch Process Data Item	Imbalance Pricing	Balancing / Capacity Market Settlement	System Services Settlement	Other System Charges & GPIs
Dispatch instructions	Y	Y	Y	Y
Cross-Zonal Actions	Y	Y	Y	
Real-Time Availabilities	Y	Y	Y	Y
System Operator Flags	Y			
Non-Marginal Flags	Y			
Short Term Reserve Quantity	Y			
Short Term Reserve Requirement	Y			
Quantity of Demand Control	Y			
System Services Flag		Y		
Operational metering (SCADA)			Y	Y

The Imbalance Price for each Imbalance Pricing Period (each 5 min period) is set by the marginal, unconstrained unit in that period. Whether or not a unit is constrained in each 5 minute period is identified within each RTD schedule. This identification process is an automated, rule based, process which is captured in our ‘Methodology for System Operator and Non-Marginal Flagging’.