Overview of SDP Solution for Synchronous Condenser Units

Scheduling and Dispatch Programme

04/08/2026

Glossary

Table 1: Key Acronyms

COD	Commercial Offer Data
DESY	Dispatch Instruction to Desynchronise / Turn Off
DI	Dispatch Instruction
DS3	Delivering a Secure, Sustainable Electricity System
DS3 System Services	The contractual agreement between System Operator and DS3 Service Providers for system security services and compensation
EDIL	Electronic Dispatch Instruction Logger
EMS	Energy Management System
LTS	Long-Term Scheduling
MMS	Market Management System
MNMW	Minimum Generation Available
MWOF	Dispatch Instruction to Adjust the Generator Unit Output to the specified Target Instruction Level at the specified Instruction Effective Time
PN	Physical Notification
PQ Pairs	Price / Quantity Pairs
QBOA	Bid Offer Acceptance Quantities
QD	Dispatch Quantity
RA	Regulatory Authority
RTC	Real-Time Commitment
RTD	Real-Time Dispatch
SDP	Scheduling and Dispatch Programme
SDP_06	Scheduling and Dispatch Programme Initiative 6
SEMO	Single Electricity Market Operator
SEM	Single Electricity Market
SO Flag	System Operator Flag
SNSP	System Non-Synchronous Penetration
SSPF	System Services Provider Flag
SSRP	Steady-State Reactive Power
SYNC	Dispatch Instruction to Synchronise
TCG	Transmission Constraint Group
TOD	Technical Offer Data
TSC	Trading and Settlement Code

TSO	Transmission System Operator

Table: 2 Key Terms

Imbalance Pricing	The process by which the Market Operator determines the price applied to energy imbalances in each Imbalance Pricing Period.
Optimisation Time Horizon	The forward-looking period over which the scheduling optimisation determines the optimal commitment of generation units.
Production Cost	The total cost of generating electricity, including energy costs, variable operations, start-up/shut-down, used in energy market optimisation to minimise system costs.
System Services Providing Units	An apparatus or group of apparatus connected to the transmission or distribution system that is contracted to deliver specific system services to the System Operator.

Executive Summary

The Scheduling & Dispatch Programme (SDP) is a series of initiatives aimed at improving the scheduling and dispatch systems and processes on the island of Ireland. Initiative 6 of the Scheduling and Dispatch Programme (SDP_06) focuses on Synchronous Condensers and aims to effectively schedule and dispatch Synchronous Condensers alongside other grid resources. Synchronous Condensers are an important part of the asset mix for system operations and security of supply. They are operated by the TSOs to deliver essential non-energy system services, including inertia and reactive power. These services are increasingly vital for maintaining grid stability, particularly during periods of high renewable energy generation. SDP_06 also allows the Control Rooms to define and apply jurisdictional/regional inertial constraints, in addition to the current system-wide inertial requirements.

This document has been prepared with the following points in mind:

1) This document outlines the supporting information used to inform the Trading and Settlement Code Synchronous Condenser Modification (Mod_01_25).
2) This document outlines how the current treatment of Synchronous Condensers is inappropriate in the TSOs' operational scheduling tools providing sub-optimal decision support to Control Rooms.
3) SDP_06 comprises two principal changes:
    (a) more appropriate treatment of Synchronous Condensers in scheduling processes, enabling greater decision support from existing tools
    (b) ability for Control Rooms to define and apply jurisdictional/regional inertial constraints, in addition to the current system-wide inertial requirements

The structure of this document is as follows:

Section 1: provides an introduction to SDP_06.

Section 2: outlines Synchronous Condensers in System Operations.

Section 3: gives a detailed breakdown of the SDP Solution for Synchronous Condensers.

Section 4: gives a 'Day in the Life' overview highlighting the key stages of the SDP_06 approach.

Contents

1. Introduction

In support of Irish and Northern Irish Government renewable electricity targets, EirGrid, SONI and SEMO are progressing a series of initiatives to enable secure system operation at up to 80% renewable electricity and 95%+ instantaneous System Non-Synchronous Penetration (SNSP). A number of these initiatives relate to the evolution of scheduling and dispatch arrangements and, together with changes required to support compliance with the EU Clean Energy Package, are being delivered under the Scheduling & Dispatch Programme (SDP).

Initiative 6 (SDP_06) focuses on the integration of Synchronous Condenser Units into market and operational processes. The objective is to ensure that these units are more effectively represented within scheduling and dispatch systems, reflecting their technical characteristics and enabling their efficient use in supporting system stability. As renewable penetration increases, the system requires alternative sources of inertia and voltage support, reducing reliance on conventional synchronous generation. Synchronous Condensers play a key role in this transition by providing:

- Inertia to support frequency stability; and
- Reactive power (both generation and absorption) to support voltage control.

However, current market frameworks and systems do not fully reflect the operational characteristics of Synchronous Condensers. As a result, multiple workarounds are in place. For example:

- Units are modelled as multi-fuel generators in the Market Management System (MMS);
- They cannot be dispatched to negative levels or recognised as being ON while not exporting active power; and
- They are assigned a nominal 1 MW dispatch instruction, which does not reflect their true operation.

In addition, Synchronous Condensers can submit Commercial Offer Data (COD) in the Balancing Market despite not providing balancing energy, which can lead to distortions in scheduling and dispatch outcomes. These limitations mean that current systems do not provide optimal decision support to Control Centre Engineers and can lead to inefficient utilisation of Synchronous Condensers, including unnecessary operation and increased system costs.

Purpose of SDP_06

SDP_06 addresses these challenges by aligning the representation of Synchronous Condenser Units across market frameworks, systems, and operational tools with their actual technical and operational characteristics.

The solution spans:

- Registration
- Data submissions - including Physical Notifications, Commercial Offer Data and Technical Offer Data;
- Scheduling and dispatch - including more appropriate treatment of Synchronous Condenser Units in scheduling processes; and
- Imbalance Pricing, QBOA and Instruction Profiling (Synchronous Condensers will be excluded from these processes).

The design builds on the principles established under TSC Modification MOD_13_19, which recognised that energy costs should be covered where units are operating for non-energy purposes.

Design Principles

The SDP_06 solution is underpinned by the following principles:

- Synchronous Condensers do not provide energy and therefore should not be participating directly in the balancing energy market (albeit that the consequential energy effects of their operation on generation from other units are rightly included as balancing actions).
- Scheduling, as decision support to dispatch activities, should seek to avoid unnecessary costs of meeting inertial needs (i.e. should not unnecessarily over-procure). As a result, Synchronous Condensers will only be scheduled when required to meet regional, jurisdictional, or all-island inertia requirements, or to satisfy other relevant constraints (e.g., voltage support in a region).
- Commitment of Synchronous Condensers should always result in an increase to the Production Cost, ensuring cost efficiency in optimisation and enabling avoidance of unnecessary over-scheduling of inertia.
- The scheduling process should account for the cost of additional generation required to meet the increased demand when the Synchronous Condenser is ON (i.e., to meet the load needed to operate Synchronous Condensers).
- Synchronous Condensers should not be scheduled to artificially increase demand (e.g., to maximise priority dispatch generation).
- Scheduling should incorporate applicable technical, locational, and operational characteristics of Synchronous Condensers, such as inertia contribution, consumption levels, location, availability, and ramp rates.

These principles ensure that the SDP_06 solution delivers an efficient, transparent, and optimised approach to scheduling Synchronous Condensers, aligning with system stability and cost-effectiveness goals.

2. Synchronous Condensers and System Operations

2.1 How Synchronous Condensers are Used in System Operations

Synchronous Condensers are operated by the TSOs to provide non-energy system services such as inertia and reactive power, which are increasingly critical for maintaining system stability during periods of high renewable energy generation.

Unlike conventional generators, Synchronous Condensers do not produce active power. When synchronised, they consume a small amount of active power while delivering inertia and reactive power for voltage control. Their use is targeted at times of high renewable energy generation, when conventional generators are not committed to meet demand, and system-supporting services (inertia, reactive power) would be insufficient from operating generators. In such cases, utilising the decision support provided by the operational scheduling optimisation, a Synchronous Condenser may be committed instead of a conventional generator to maintain system security.

The scheduling and dispatch of Synchronous Condensers is supported via the TSO's operational scheduling tools, which optimise energy costs while ensuring system services and other system requirements (including minimum inertia) are met. These units should only be committed when their contribution is necessary to meet a defined system need. While their energy consumption incurs a cost, this is typically lower than the cost of committing a conventional generator solely for system services. In line with SDP_06, Synchronous Condensers should only be scheduled when required to meet the specified minimum inertia floor or any other TCG requirements (i.e. voltage support), ensuring cost-effective delivery of system services.

Synchronous Condensers are dispatched via SYNC (synchronise) and DESY (de-synchronise) dispatch instructions, reflecting their binary ON/OFF operation. They are not considered in the balancing market for energy actions (just energy cost settlement as per MOD_13_19). However, their operation is included in Control Centre decision support tools, such as schedules and merit orders (in MMS), along with the real-time status (in the EMS), allowing for accurate assessment of their availability and contribution towards meeting inertial/reactive power needs.

2.2 What Requirements are Necessary to Optimise the Use of Synchronous Condensers

Data submitted for Synchronous Condenser Units (along with data for all other scheduled generator units) are made available to the Operational Scheduling process within MMS. The principal data considerations for data submission (or not) under the Trading and Settlement Code and/or Grid Code, in the context of Synchronous Condensers, is outlined below:

- Physical Notifications as described in Section 3.2.1
- Technical Offer Data as described in Section 3.2.2
- Commercial Offer Data as described in Section 3.2.3
- Inertia contribution and reactive power provision as described in Section 3.2.4
- Real-time availability declarations as described in Section 3.4.3

3. SDP_06 Approach

3.1 Registration

Synchronous Condenser Units will be defined in the Trading and Settlement Code and will be registered in the systems as Generator Units with the fuel type "SYNCHRONOUS_CONDENSER". Each Synchronous Condenser Unit must be registered as part of a single Trading Site, which includes the Synchronous Condenser Unit, a single Supplier Unit that is Trading Site Supplier Unit.

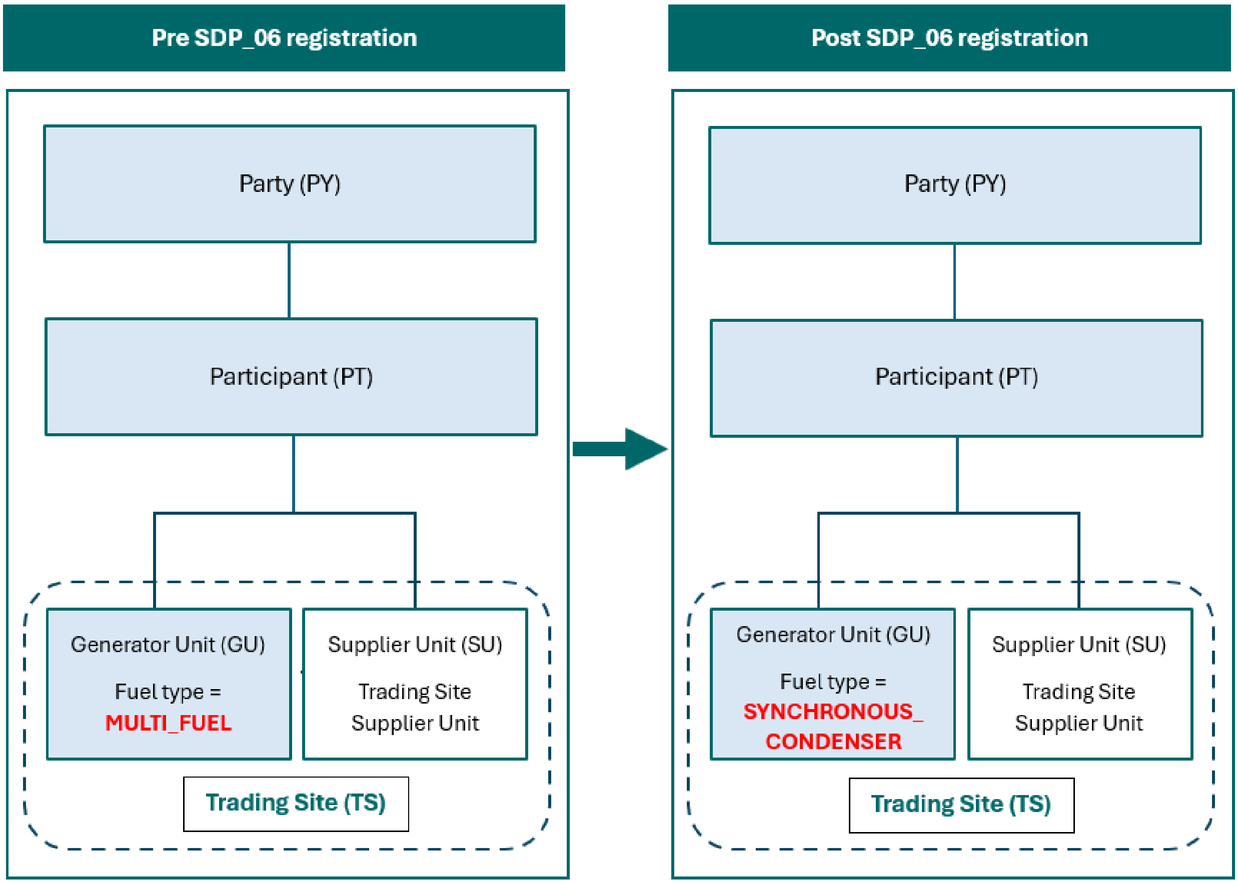

Figure 1: Registration for Synchronous Condensers Pre and Post SDP_06

3.2 Synchronous Condenser Data Submission

3.2.1 Physical Notification (PNs)

Physical Notifications (as the ex-ante market inputs for TSO balancing) shall be zero for Synchronous Condenser Units. This may be given effect by the Participant not submitting Physical Notifications, resulting in defaulting to zero within the market systems.

3.2.2 Technical Offer Data (TOD)

Synchronous Condenser Units will be required to submit only a limited subset of Technical Offer Data (TOD), as many of the parameters have been confirmed to not be applicable to this technology type. The TOD parameters that are relevant to Synchronous Condenser Units are as set out in the remaining content in this sub-section. Together, these TOD parameters are sufficient to enable Synchronous Condenser Units to be scheduled and dispatched effectively, fulfilling their role in maintaining grid stability and overall system reliability.

Table 3: TOD parameters: "Unit Limits"

Parameter(s)	Justification
Registered Minimum Stable Generation (MW)	For Synchronous Condensers, will be zero (as this data is not applicable to this technology)
Registered Minimum Output (MW)	For Synchronous Condensers, this value will reflect the consumption level of the unit when operating (i.e. providing inertial support)
Maximum Generation (MW)	For Synchronous Condensers, will be zero.

Table 4: TOD parameters: "Starting Up"

Parameter(s)	Justification
Synchronous Start Up Time Hot (hours), Synchronous Start Up Time Warm (hours), Synchronous Start Up Time Cold (hours)	Representing the time for a Generator Unit to start up (values for Hot, Warm and Cold must be equal for Synchronous Condenser)
Block Load Flag (True or False)	Must be false for Synchronous Condensers, reflecting that they have no block loading characteristics

Table 5: TOD parameters: "Ramping up and down"

Parameter(s)	Justification
Ramp Down Rate 1 (MW / minute)	A single ramp rate, which for Synchronous Condensers will reflect the rate at which the Unit moves from OFF to operating at its consumption load
Ramp Up Rate 1 (MW / minute)	A single ramp rate, which for Synchronous Condensers will reflect the rate at which the Unit moves from operating at its consumption load to OFF
Start of Restricted Range 1 (MW) End of Restricted Range 1 (MW)	Defining a MW range within which the Generator Unit cannot operate (or be scheduled). For Synchronous Condensers, this will be a range between zero MW and its consumption level (Minimum Output) when operating

Note: Loading and De-loading parameters are not relevant for Synchronous Condensers, as such parameters apply from zero to Minimum Stable Generation and vice versa. As Minimum Stable Generation for Synchronous Condensers is equal to zero, no such parameters apply.

Table 6: TOD parameters: Unit status change limitations

Parameter(s)	Justification
Minimum On Time (hours)	Reflects the minimum time that a Unit must remain ON once starting to operate (e.g., in response to a Dispatch Instruction to transition from OFF to ON). Relevant to Synchronous Condensers
Minimum Off Time (hours)	Reflects the minimum time that a Unit must remain OFF once decommitted (e.g., in response to a Dispatch Instruction to transition from ON to OFF). Relevant to Synchronous Condensers
Maximum On Time (hours)	Reflects the maximum time that a Unit can remain ON once operating (e.g., once responding to a Dispatch Instruction to transition from OFF to ON). Relevant to Synchronous Condensers

3.2.3 Commercial Offer Data (COD)

Market Participants operating Synchronous Condenser Units will be required to submit Commercial Offer Data as per the TSC. The Commercial Offer Data parameters for Synchronous Condensers are as set out in the remaining content in this sub-section.

3.2.3.1 Fixed Costs and Price Quantity Pairs

As previously described, Synchronous Condensers are not participating directly in the balancing market. As such, they should not be submitting costs to the balancing market via their Commercial Offer Data, and the following elements of Commercial Offer Data will be zero.

Table 7: COD element: Fixed Costs and Price Quantity Pairs

Data Element	Detail
Fixed Costs	• No Load Costs = 0 • Start Up Costs = 0 This may be enabled by the submission and application of Standing COD so does not need to be submitted every day
Price Quantity Pairs (PQ Pairs)	• Simple Incremental Price = 0 • Simple Decremental Price = 0 • Complex Incremental Price = 0 • Complex Decremental Price = 0 This may be enabled by the submission and application of Standing COD so does not need to be submitted every day

3.2.3.2 *Forecast Availability*

The following Forecast Availability elements of Commercial Offer Data are required for Synchronous Condenser Units. Participants may utilise Standing Complex Commercial Offer Data, however Forecast Availability elements should be updated on a daily basis where availability differs from the standing submission.

Table 8: COD element: Forecast Availability

Data Element	Detail
Forecast Availability Profile	For Synchronous Condensers, will be zero.
Forecast Minimum Output Profile	For Synchronous Condensers, will be ≤0. • 0 if unavailable • Otherwise <0 (representing the consumption load when operating)
Forecast Minimum Stable Generation Profile	For Synchronous Condensers, will be zero.

Figure 2 provides a visual display of these elements for Synchronous Condensers, alongside other unit types for context.

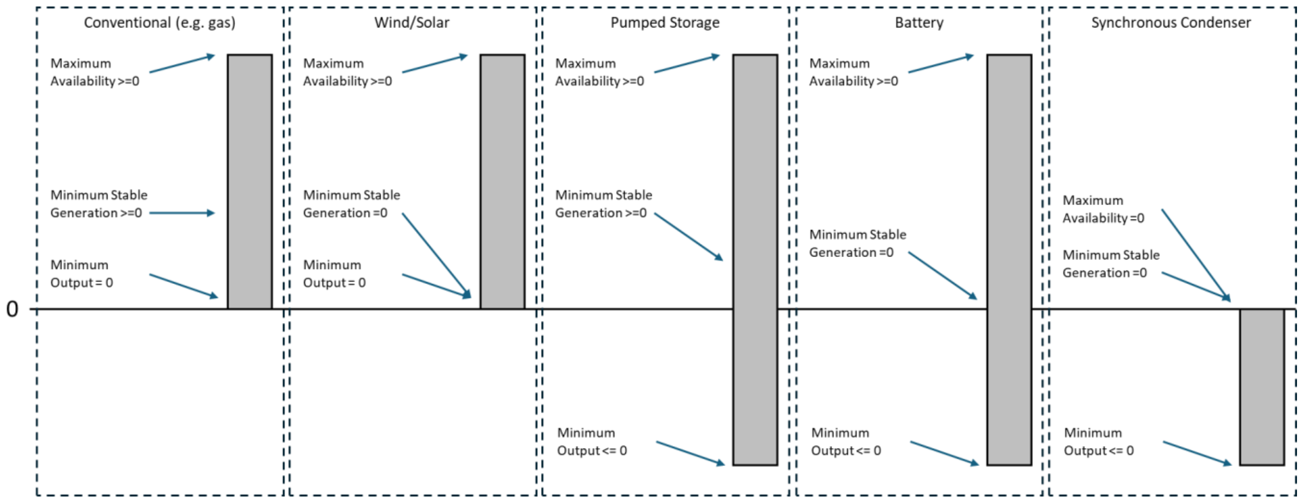

Figure 2: Applicable Availability values for different unit types

3.2.4 Inertia Contribution and Reactive Power Provision

In accordance with the Grid Code, Synchronous Condenser Units are required to submit parameters on their inertia contribution and reactive power capability during the commissioning process. These parameters are critical for system planning and operational decision-making.

Once submitted, these values are manually entered into the Scheduling and Dispatch systems. As they reflect inherent design characteristics of the units, they are considered static and do not vary on a day-to-day basis. This ensures consistency in system modelling and facilitates accurate assessment of system stability and voltage support capabilities.

3.3 Operational Scheduling

The TSO Licences (Condition 10A of EirGrid's TSO Licence and Condition 22A of SONI's TSO Licence) require the TSOs to consider the following objectives:

- minimising the cost of diverging from Physical Notifications; and
- as far as practical, enabling the Ex-Ante Market to resolve energy imbalances; and
- as far as practical, minimising the cost of non-energy actions.

3.3.1 Objectives of Operational Scheduling

The TSOs' Operational Scheduling process provides decision support to the TSO Control Centres, providing the following primary inputs:

- Merit Orders (for online and offline units)
- Advisory Operational Schedules (primarily used for commitment and decommitment decisions)

The Operational Schedule is determined via a mathematical optimisation which is summarised at a high-level as follows in Figure 3:

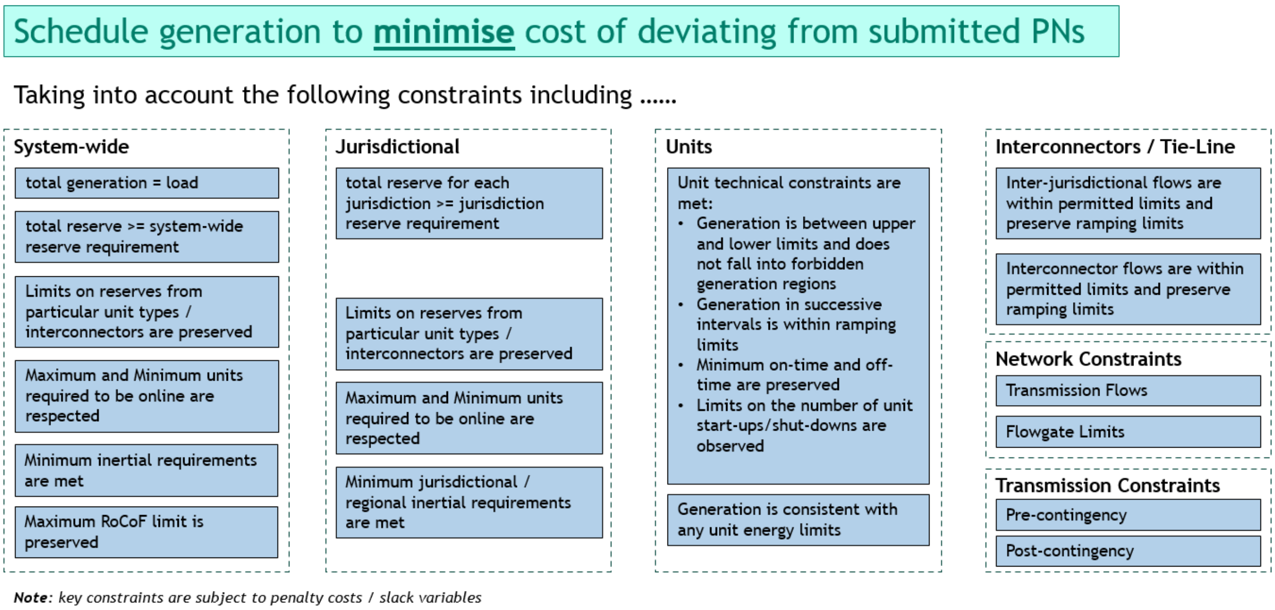

Figure 3: Overview of Operational Scheduling Optimisation

Important Note: minimising the costs of deviation from PNs is implemented in the Operational Scheduling tools as a minimisation of production costs, utilising composite cost curves which are the combination of the portion of the Inc PQ curve above PN and the portion of the Dec PQ curve below PN. As shown in Figure 4.

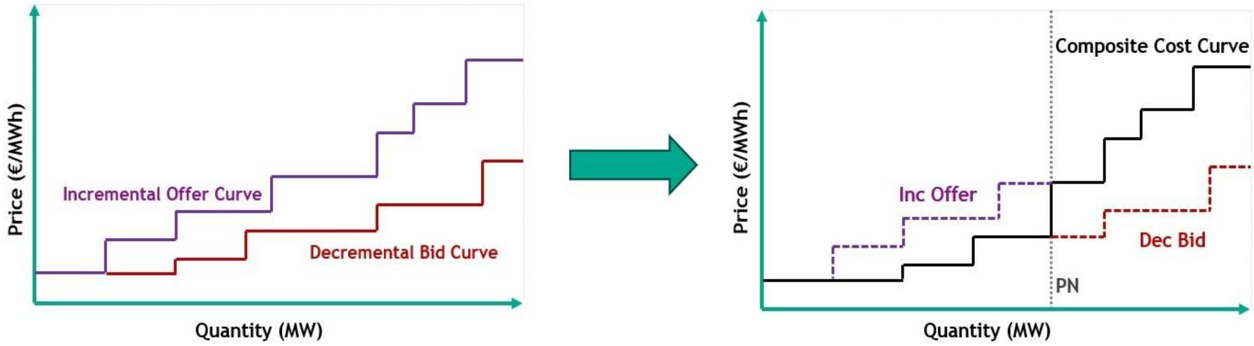

Figure 4: Production of Composite Cost Curves

Operational Scheduling produces an indicative generation schedule for each interval within the respective Operational Scheduling Run, by considering the initial conditions of each unit and optimising costs across the Optimisation Time Horizon. It produces an Indicative Operating Schedule for all units generating or consuming power within the scheduling time frame.

3.3.2 Reflecting Jurisdictional and Regional Inertia Requirements

In the scheduling optimisation, inertia requirements may be defined on an all-island, jurisdictional and regional basis, as shown in Figure 5, with conventional synchronous generators and Synchronous Condensers capable of contributing to requirements depending on availability. Regional inertia group definitions and requirements may evolve over time as network reinforcements are built.

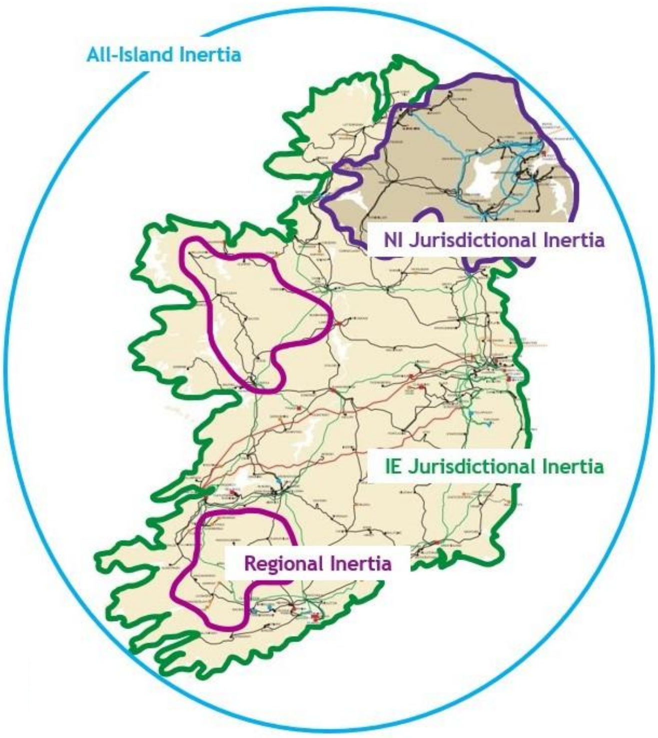

Figure 5: Jurisdictional and Regional Inertia Demarcation[1]

[1] *The regional inertia demarcation shown is for illustrative purposes only and is subject to change. Actual regional demarcation will be determined based on system studies and future network buildout.*

3.3.3 Integration of Synchronous Condensers into the production cost optimisation

The objective of the operational scheduling optimisation is to minimise the cost of deviation from units' Physical Notifications (PNs), while respecting technical constraints and broader system policies. However, it is important to note that within the SEM, only the cost of energy is explicitly optimised. The costs of non-energy services, such as reserves, inertia and reactive power, are not optimised in the scheduling algorithm. Instead, their provision is optimised implicitly through operational constraints and system requirements.

Synchronous Condensers are included in this optimisation framework. Although they do not produce active power, their operation results in an energy demand that must be met by other scheduled generation. The cost of meeting this demand is incorporated into the overall energy optimisation.

To support the effective scheduling and dispatch of Synchronous Condensers, a new Transmission Constraint Group (TCG) type is being introduced. This TCG enables the specification of minimum inertia requirements at the system, jurisdictional and regional level. Both Synchronous Condensers and other synchronous units can contribute toward meeting these requirements, providing a transparent and flexible mechanism for ensuring system stability.

3.3.4 Production Cost Optimisation

SDP_06 does not change the production cost optimisation that is inherent in the operational scheduling process. This means that post-SDP_06, the optimisation will continue to minimise the cost of meeting the constraints (including meeting energy demand, reserve requirements, inertial needs, minimum unit constraints etc). Synchronous Condensers will appear in the energy balance constraint as a source of demand rather than how they are currently represented as a source of 1 MW of generation. A set of representative numerical examples are detailed in section 3.3.6. The impact of Synchronous Condensers on the production cost will <u>only</u> be as a result of the additional generation required when a Synchronous Condenser is committed.

3.3.5 Effect of Synchronous Condensers on Scheduling Outcomes

Synchronous Condensers can contribute towards meeting the constraints within the Operational Scheduling process, primarily with respect to inertial requirements and to ensure that voltage support TCG needs are met. Under the TSOs' proposals for SDP_06:

- Synchronous Condensers CAN contribute to
  - Inertial requirements
  - Voltage-based TCGs
- Synchronous Condensers CANNOT contribute to
  - Meeting demand needs if not needed for inertia or to satisfy a voltage TCG
  - Meeting operating reserve requirements

Any contribution of Synchronous Condensers to meeting the Operational Scheduling constraints (e.g., inertia) is only possible when the unit is considered ON and available if the Forecast Minimum Output for the Unit is less than zero.

The Operational Scheduling process is an optimisation seeking to identify the minimum total production cost of energy schedules across a defined Optimisation Time Horizon, which meets all of the applied constraints. Synchronous Condensers will be scheduled based on consumption level, inertia contribution and the cost of production will be the incremental cost of generation required to meet Synchronous Condenser demand.

3.3.6 Commitment and Tie-Breaking

Commitment of Synchronous Condensers will always be based on the cost of energy required to meet the consumption of that Synchronous Condenser. The commitment of Synchronous Condensers in a scheduling run will, in the majority of instances, result in an increase in production cost for the optimisation. The commitment of a Synchronous Condenser should have a lower contribution to overall production costs than a conventional generator so in cases where only the inertia is required, they will be committed first.

There will be no consideration of the System Services cost as there is no co-optimisation of energy and System Services costs within the MMS.

Tie-breaking is a common and necessary feature of optimisation problems that is utilised within the TSOs' Operational Scheduling processes. For determination of Operational Schedules, tie-breaking is relevant when the generation output and cost of production from two units is equal.

In order to avoid such tie-breaks, the Operational Scheduling tools add an infinitesimally small random amount to the costs (Start Up Costs, No Load Costs and each Price as part of a Price-Quantity Pair). Such random application is repeatable by the TSOs in the event that an Operational Scheduling run is re-executed, which is particularly relevant for testing purposes.

The application of tie-breaking is non-discriminatory, as the random "adders" are independently applied per Operational Scheduling interval. The "adders" are only utilised in the Operational Scheduling processes and do not feed to downstream processes.

A simplified set of scenarios have been developed to help explain how the cost minimisation with respect to the commitment decision works and how parallel requirements are met.

Scenario 1: Commitment of Synchronous Condenser with tie-breaking logic not required

System Requirements:
Demand = 800 MW
Inertia >= 1000 MWs

Units Available to meet requirements:

Unit	PN (MW)	Availability (MW)	Consumption Level (MW)	Inertia (MWs)	Inc/Dec Price (€/MWh)
Conventional Gen 1	400	420	n/a	400	50
Conventional Gen 2	400	420	n/a	400	70
Sync Con 1	0	-5	-5	300	0
Sync Con 2	0	-3	-3	300	0

To meet the system demand both conventional generators will be required. However, to meet the inertia requirement there are two possible combinations either Sync Con 1 or 2 can be used alongside the conventional generators with the cheaper Gen 1 meeting the additional generation needs to power whichever Synchronous Condenser is preferable.
How to meet requirements:

Option 1: Gen 1 + Gen 2 + Sync Con 1
System Demand = 405 MW + 400 MW - 5 MW = 800 MW: Requirement Met
Inertia = 400 MWs + 400 MWs + 300 MWs = 1100 MWs: Requirement Met

Production Cost[2] = 5 * 50 €/MWh -5 * 0€/MWh = € 250

Option 2: Gen 1 + Gen 2 + Sync Con 2
System Demand = 403 MW + 400 MW - 3 MW = 800 MW: Requirement Met
Inertia = 400 MWs + 400 MWs + 300 MWs = 1100 MWs: Requirement Met
Production Cost = 3 * 50 €/MWh –3 * 0€/MWh = € 150

Option 2 has the lower contribution to overall production costs so Synchronous Condenser 2 is committed and Convention Gen 1 increased to meet its demand.

Scenario 2: Commitment of Synchronous Condenser with tie-breaking logic required

System Requirements:
System demand = 800 MW
System Inertia Requirement = 1000 MWs

Units Available to meet requirements:

Unit	**PN (MW)**	**Availability (MW)**	**Consumption Level (MW)**	**Inertia (MWs)**	**Inc/Dec Price (€/MWh)**
Conventional Gen 1	400	420	n/a	400	50
Conventional Gen 2	400	420	n/a	400	70
Sync Con 1	0	-3	-3	300	0
Sync Con 2	0	-3	-3	300	0

How to meet requirements:

Option 1: Gen 1 + Gen 2 + Sync Con 1
System Demand = 403 MW + 400 MW - 3 MW = 800 MW: Requirement Met
Inertia = 400 MWs + 400 MWs + 300 MWs = 1100 MWs: Requirement Met
Production Cost Increase = 3 * 50 €/MWh -3 * 0€/MWh = € 150

Option 2: Gen 1 + Gen 2 + Sync Con 2
System Demand = 403 MW + 400 MW - 3 MW = 800 MW: Requirement Met
Inertia = 400 MWs + 400 MWs + 300 MWs = 1100 MWs: Requirement Met
Production Cost Increase = 3 * 50 €/MWh -3 * 0€/MWh = € 150

As both Options 1 and 2 result in the same production cost increase, a tie-break is applied where a very small number is added at random for both options to determine which unit to commit.

Option 1: Gen 1 + Gen 2 + Sync Con 1
Production Cost Increase = 3 * 50 €/MWh -3 * 0€/MWh = € 150
After Tie Break
Production Cost Increase = 3 * (50+0.000018) €/MWh -3 * (0+0.000023) €/MWh = € 149.999985

[2] *Production cost = Start Cost + Energy Costs + No Load Costs, where "Energy Cost" is the cost of volume of energy between schedule and PN. In the examples Start Costs & No-Load costs for all are 0 since they are mandated as 0 for Synchronous Condensers and the conventional generators have PNs.*

Option 2: Gen 1 + Gen 2 + Sync Con 2
Production Cost Increase = 3 * 50 €/MWh -3 * 0€/MWh = € 150
After Tie Break
Production Cost Increase = 3 * (50+0.000018) €/MWh -3 * (0+0.000031) €/MWh = € 149.999961

Option 2 has the lower contribution to overall production costs so Synchronous Condenser 2 is committed and Convention Gen 1 increased to meet its demand.

3.3.7 When will Synchronous Condensers be used?

As the levels of non-synchronous generation increases, there is a need to utilise other sources of grid-supporting services. Synchronous Condensers are a non-fossil fuel-based solution to assist with inertia, reactive power and voltage control, which TSOs (including EirGrid/SONI) are procuring to provide such services when required.
As an illustration, Figure 6, Figure 7, Figure 8 and Figure 9 provide an explanation of when Synchronous Condensers would typically be used by the TSOs to meet system demand.

Scenario 1: Low Wind

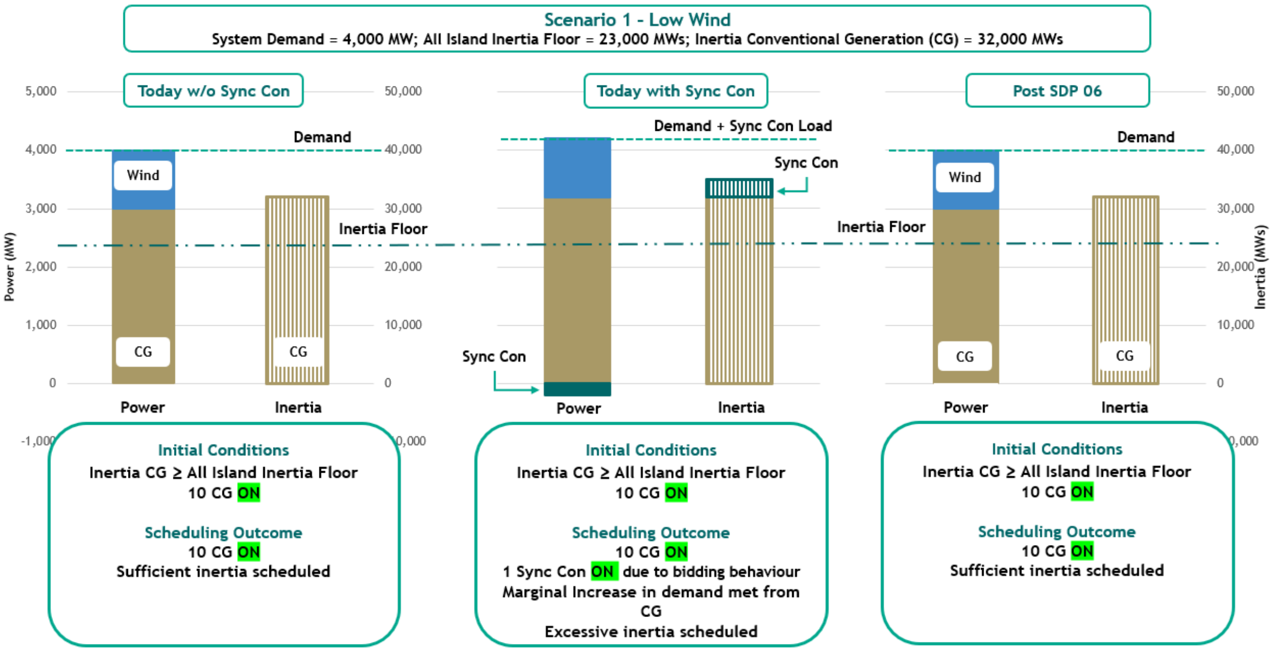

Figure 6: Scenario 1 - Low Wind

In the scenario depicted above, 10 large conventional generation units are operational to meet most of the system demand on a low wind day. These generators fulfil the Minimum Conventional Units Online (MUON[3]) constraint, which requires at least 7 large conventional units to be online at all times. Collectively, they provide more than the required minimum system inertia. Therefore, the commitment of a Synchronous Condenser is not necessary to meet the minimum system inertia requirement.

[3] *The Minimum Conventional Units Online (MUON) is a constraint on the market unit commitment schedule to ensure there is a minimum number of large synchronous generator units required to be online, on the Ireland and Northern Ireland system. The constraint is to ensure safe and secure operation of the system.*

- Today with Synchronous Condenser

In the current operational context, a Synchronous Condenser is committed online because it is modelled as a generator producing 1 MW of power, and due to its bidding behaviour, the optimisation algorithm perceives that committing a Synchronous Condenser will reduce the overall system cost. Consequently, even though the system inertia requirement is already met by the conventional generators, the Synchronous Condenser is still brought online to optimise costs. The marginal increase in demand from committing the Synchronous Condenser is met by increasing the output from conventional generation units.

- Post SDP 06

The optimisation algorithm will not commit a Synchronous Condenser if the minimum system inertia requirement is already optimally met.

Scenario 2: High Wind with Minimum Conventional Units Online (MUON[4]) constraint not-binding

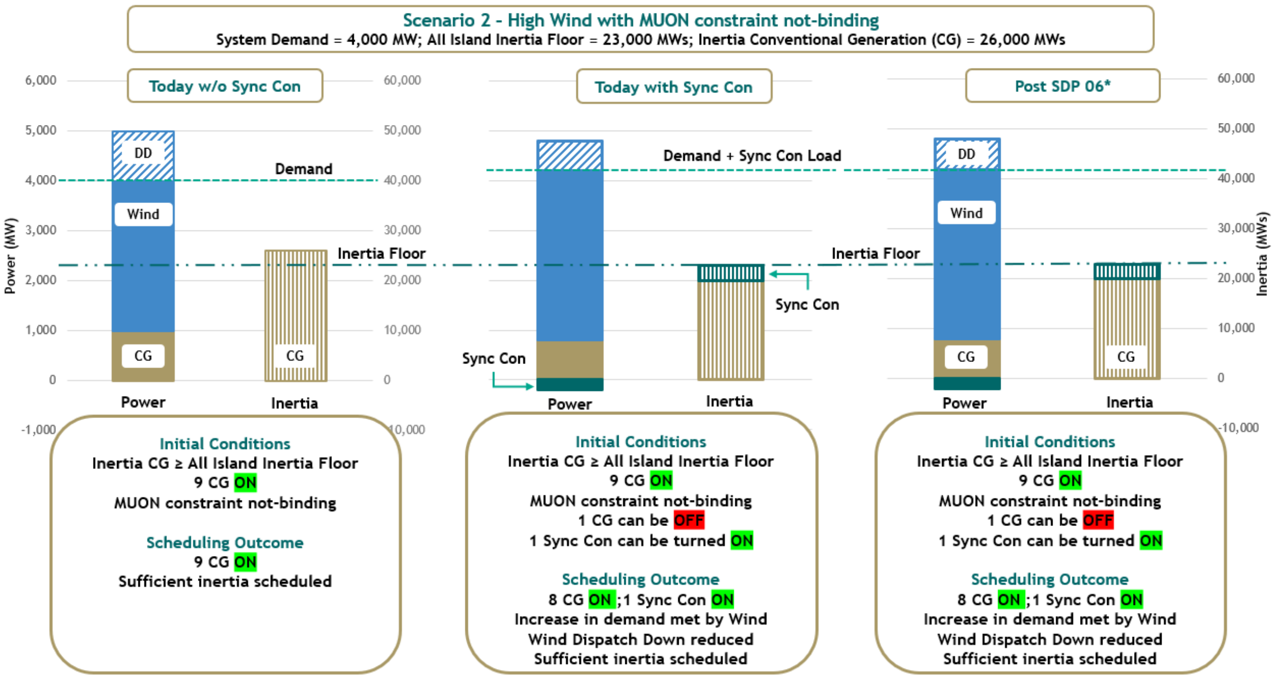

Figure 7: Scenario 2 - High Wind with MUON constraint not-binding

In the scenario depicted above, 9 large conventional generation units are operational to meet part of the system demand and satisfy the dynamic stability needs of the system on a high wind day. These generators fulfil the Minimum Conventional Units Online (MUON) constraint, which requires at least 7 large conventional units to be online at all times. Collectively, they provide sufficient inertia to meet the required minimum system inertia. The MUON constraint is not-binding, meaning that if a Synchronous Condenser is available to provide inertia in place of a conventional generation unit, the Synchronous Condenser should be committed and the conventional generation unit de-committed.

[4] *The Minimum Conventional Units Online (MUON) is a constraint on the market unit commitment schedule to ensure there is a minimum number of large synchronous generator units required to be online, on the Ireland and Northern Ireland system. The constraint is to ensure safe and secure operation of the system.*

- Today with Synchronous Condenser

In the current operational context, a conventional generation unit is de-committed, and a Synchronous Condenser is committed online. The output of the de-committed conventional generation unit and the Synchronous Condenser load will be met by wind generation, resulting in a reduction in wind dispatch down.

- Post SDP 06

No change to scheduling outcome post SDP 06. The optimisation algorithm will de-commit a conventional generation unit and commit a Synchronous Condenser to ensure the minimum system inertia requirement is met. The output of the de-committed conventional generation unit and the Synchronous Condenser load will be met by wind generation, resulting in a reduction in wind dispatch down.

Scenario 3: High Wind with Minimum Conventional Units Online (MUON) constraint binding

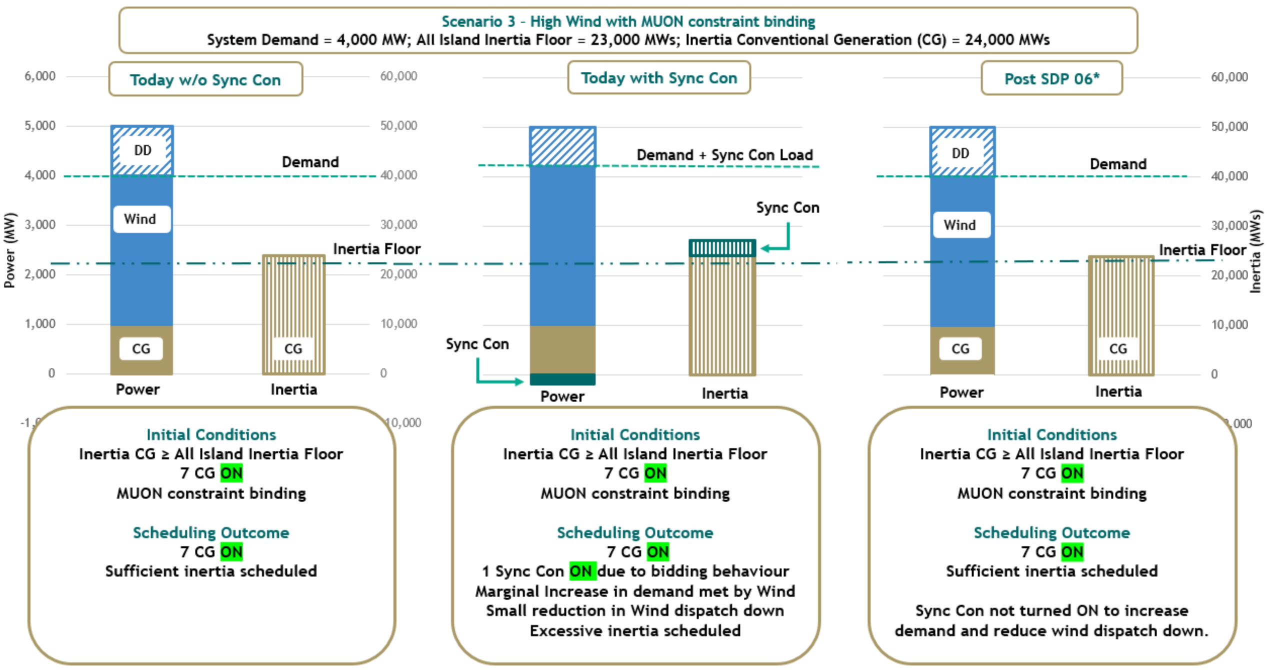

Figure 8: Scenario 3 - High Wind with MUON constraint binding

In the scenario depicted above, 7 large conventional generators are operational to meet part of the system demand and satisfy the dynamic stability needs of the system on a high wind day. These generators fulfil the Minimum Conventional Units Online (MUON) constraint, which requires at least 7 large conventional units to be online at all times. Collectively, they provide sufficient inertia to meet the required minimum system inertia. The MUON constraint of at least 7 conventional units online is binding, meaning that a conventional generation unit cannot be de-committed.

- Today with Synchronous Condenser

In the current operational context, the 7 conventional generation units remain online, and a Synchronous Condenser is also unnecessarily committed because it is modelled as a generator producing 1MW. The marginal increase in demand from committing the Synchronous Condenser is met by wind generation, resulting in a small reduction in wind dispatch down.

- Post SDP 06

The optimisation algorithm will not commit a Synchronous Condenser when the minimum system inertia requirement is already met. Additionally, post SDP 06, the optimisation algorithm will be tuned to ensure that a Synchronous Condenser is not committed solely to increase demand and reduce wind dispatch down. If some Synchronous Condenser Units are committed online by the optimisation algorithm, removing the inertia contribution of any one of these units will violate the system's inertia requirement. Therefore, only the minimum number of Synchronous Condenser Units needed to optimally meet the system's minimum inertia requirement will be committed.

Scenario 4: High Wind with Regional Inertia Requirement

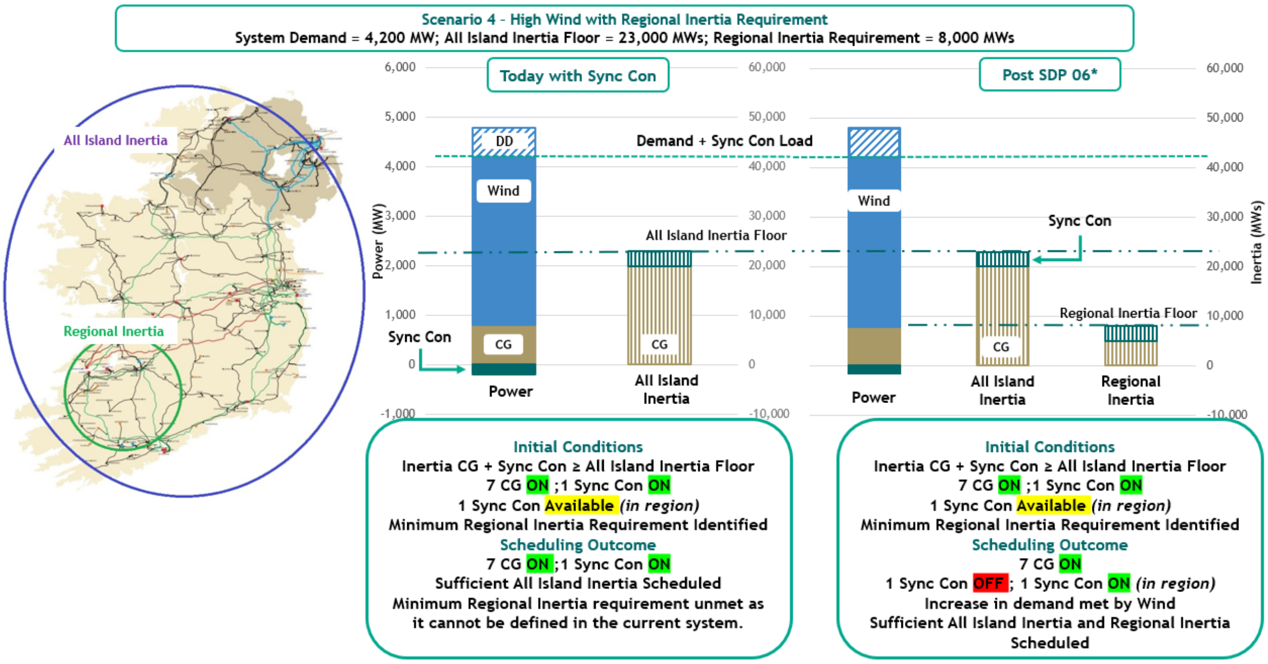

Figure 9: Scenario 4 - High Wind with Regional Inertia Requirement

In the scenario depicted above, seven large conventional generators and one Synchronous Condenser are operational to meet the all-island inertia requirement on a high wind day. A region has been identified with weak local system stability due to the high penetration of wind generation. To strengthen the system, a minimum regional inertia requirement has been established. A Synchronous Condenser is available in this region to meet the inertia requirement.

- Today with Synchronous Condenser

In the current operational context, the seven MUON units and one Synchronous Condenser remain committed to meet the all-island minimum inertia requirement. However, the second Synchronous Condenser is not committed because the current Market Management System (MMS) lacks the functionality to define regional inertia requirements and the units that can contribute towards meeting this.

- Post SDP 06

The MMS will be upgraded to include the functionality to define regional inertia requirements, and the regional inertia TCGs will be included to schedule available units if a regional inertia need is defined. In the above scenario, the optimisation algorithm will commit the second Synchronous Condenser to meet the regional inertia requirement and the all-island inertia requirement, and de-commit the first Synchronous Condenser as its commitment is no longer necessary to meet the all-island inertia requirement.

3.3.8 Meeting Systems Services Requirements (Inertia and Reactive Power)

Synchronous Condensers are scheduled to meet the minimum system, jurisdictional, regional inertia requirements, as well as to fulfil TCG requirements (i.e. voltage control). Their reactive power capabilities are utilised in accordance with the provisions set out in the Grid Code, ensuring compliance with voltage control and system stability obligations.

3.4 Dispatch and Merit Order Lists

3.4.1 Energy Management System (EMS)

The Energy Management System (EMS) is the primary tool for close to real-time situational awareness and control of the transmission system by the TSOs. The EMS comprises various components, primarily utilised by the TSOs' control rooms, including real-time data acquisition (Supervisory Control and Data Acquisition, SCADA), real-time state estimator, real-time contingency analysis, real-time reserve monitoring and the Wind Dispatch Tool (utilised to dispatch wind and solar generator units).

For Synchronous Condensers, SCADA will provide real-time information relating to the status and output of the units. Voltage regulation set-points and/or reactive power set-points will be issued directly via the EMS to the Synchronous Condenser Units, which will respond automatically in accordance with Grid Code requirements. This data, along with information from other units, is used within the EMS to monitor real-time levels of inertia and reactive power.

3.4.2 Merit Order Lists / Commitment Decision Support

As described in Section 3.3.1, the TSOs' Operational Scheduling tools provide decision support to Control Centre Engineers for dispatch decisions. Additionally, the TSOs utilise a set of "merit orders", to determine dispatch decisions. These merit orders incorporate various inputs, including PNs, Commercial Offer Data, availabilities, real-time unit status, and current dispatch positions.

Synchronous Condensers will not appear in the offline or online merit orders as they are not available for energy dispatch. However, they will appear in a display which indicates to Control Centres, which units should be committed or de-committed at what point in time based on the indicative operations schedules.

3.4.3 Electronic Dispatch Instruction Logger (EDIL)

EDIL is a tool utilised by the TSOs, which primarily facilitates dispatch and declarations for generator units that are dispatchable. EDIL supports issuance of the following primary instruction types:

- SYNC = instruction for a Unit to synchronise to its Minimum Stable Generation
- MWOF [x] = instruction to go to a level of [x] MW and to stay there until a further instruction is issued (note that in MMS, an instruction to MWOF[x] without a previous SYNC instruction will be treated as though a SYNC instruction was issued)
- DESY = instruction to desynchronise / turn off

Under the TSOs' proposals for SDP_06, Synchronous Condensers will be issued with SYNC and DESY instructions as follows:

- SYNC when the TSO requires the unit to synchronise to the grid.
- DESY when the TSO requires the unit to desynchronise from the grid.

As a result, Synchronous Condensers will provide the appropriate System Services only when determined by the TSOs to be required for system security.

Real-time declarations for availability are also provided by Participants via EDIL, in accordance with the provisions of the Grid Code. A declaration reflecting energy consumption level should be made using the declaration code MNMW when available to synchronise.

3.5 Effect of Synchronous Condenser on Flagging and Imbalance Pricing

SO Flagging is a post-process to the determination of the Indicative Operational Schedule (RTD). This process uses information from the latest Indicative Operational Schedule to determine whether an operational constraint is binding, and whether the unit's scheduled output is bound by that constraint. A unit bound by such a constraint will have an SO Flag of zero in Imbalance Pricing, determining that action has been taken for system reasons.

Synchronous Condensers will be included within the existing system-wide minimum inertia operational constraint; and also included within the regional inertia constraints that will be introduced as part of SDP_06. Active operational constraints are included in the TSO's weekly constraints update, published on the SEMO Website. Further information on operational constraints and SO Flagging can be found in the "Methodology For Determining System Operator and Non-Marginal Flags" document available on the SEMO website[5].

The approved TSC modification for SDP_06 removes Synchronous Condensers from Imbalance Pricing and Instruction Profiling processes (as explained in Section 3.6 below), as Synchronous Condensers do not provide balancing energy (albeit that when operating they affect the total energy requirement). As a result, SO Flags relating to inertia constraints will have no impact on Synchronous Condenser Units.

3.6 Balancing Market Settlement for Synchronous Condensers

3.6.1 Instruction Profiling

In addition to the Instruction Profiling process for Imbalance Pricing as described in the previous section, there is also an Instruction Profiling process for settlement. This process converts Dispatch Instructions into Dispatch Quantities (QD).

Synchronous Condensers are excluded from the settlement Instruction Profiling process. As no QBOAs or QD will be calculated for Synchronous Condensers, settlement payments and charges based on these quantities will not apply.

3.6.2 Modification Mod_13_19

Modification Mod_13_19 was approved by the Regulatory Authorities in July 2022 and was implemented in the Central Market Systems from November 2022.

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[5] General Publications | SEMO

The key principle of Mod_13_19 is that whilst payment for System Services is handled through the DS3 System Services Arrangements, there are occasions when the TSOs will need to dispatch on a generator (or other unit) to provide non-energy services. This includes a generator with the capability of operating in synchronous compensation mode or a wind farm capable of providing reactive power, both of which consume energy when operating in those modes.

Mod_13_19 ensures that System Services Providing Units are not charged for their energy consumption while providing System Services. This is delivered via the following:

- A System Services Provider Flag (SSPF) is set to 1 where a unit is a System Services Providing Unit and is dispatched to provide System Services.
- Where this flag is set to 1 for an Imbalance Settlement Period, the Trading Site Supplier Unit associated with the System Services Providing Unit is not charged for the energy consumed.

Modification Mod_01_25 proposes no change to the arrangements implemented in Mod_13_19.

3.7 Reporting and Data Publication

Data reporting and publication processes within the Balancing Market provide participants and the general public with essential data reports. These reports are categorised based on accessibility:

- **Member Private**: Accessible via Balancing Market Interface (BMI), showing information about participants' own units.
- **Member Public**: Accessible via BMI, showing information for all units.
- **General Public**: Accessible via EirGrid, SONI or SEMO websites.

There will be no new reports resulting from SDP_06. This is as data for Synchronous Condenser Units will be incorporated into existing reports, with the key reports outlined in Appendix D: Reporting and Data Publication Key Reports.

3.8 Dataflows Necessary to Support the Operation of Synchronous Condensers

Figure 10 displays the principal data flows relevant for all units including Synchronous Condensers, from data submission, to scheduling and dispatch and reporting systems.

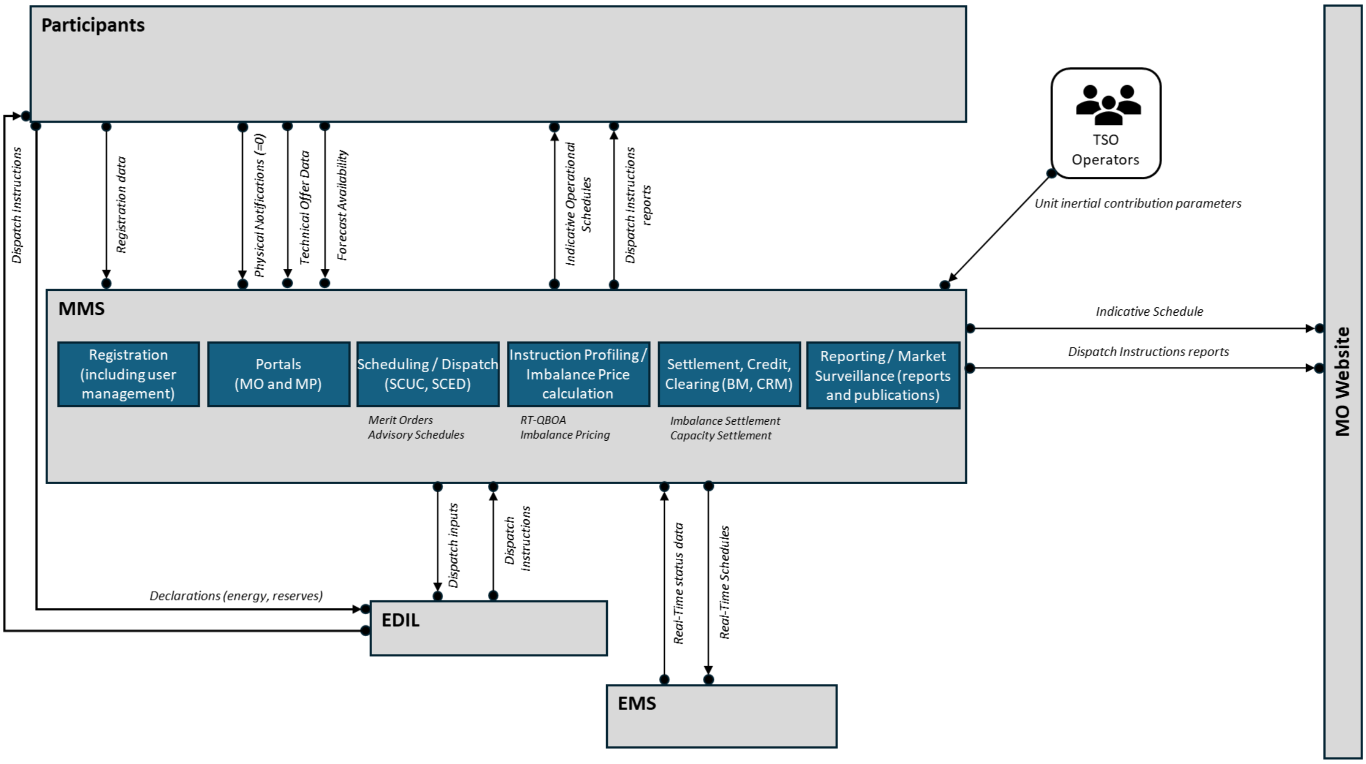

Figure 10: Principal Synchronous Condenser Dataflows

Participants with registered Synchronous Condenser Units will submit various data to the Balancing Market Interface (BMI, a component of MMS) including Physical Notifications (zero), Technical Offer Data and Commercial Offer Data (including Forecast Availability and zero PQ Pairs). The specific requirements for Synchronous Condensers related to the TOD and COD data types are detailed in Sections 3.2.2 and 3.2.3 of this document, and in TSC Appendix I, Tables 1 and 2, respectively. Real-time availability declarations for energy and reserve are provided via EDIL.

Data submitted for Synchronous Condenser Units (along with data for all other scheduled generator units) are made available to the Operational Scheduling process within MMS. Operational Scheduling includes Synchronous Condensers alongside all other generators, including conventional, renewables and storage. The Operational Scheduling optimisation determines optimal energy schedules subject to system constraints (including demand balance, reserve needs, inertia requirements and SNSP limits). Operational Scheduling is performed across three overlapping timeframes:

- LTS (Long Term Schedule) covers up to 30 hours, starting one hour in the future (30 min resolution)
- RTC (Real-Time Commitment) covers 3.5 hours, starting 30 mins in the future (15 min resolution)
- RTD (Real-Time Dispatch) covers one hour, starting 10 mins in the future (5 min resolution)

Once Indicative Operational Schedules (LTS, RTD, RTC) are determined, the MMS makes them available to market participants via the BMI and they are published on the SEMO website. MMS presents these schedules as dispatch advice to Control Centre Engineers, along with dispatch merit orders that are derived using current status data (from the EMS), current dispatch position (from EDIL) and current bids/offers (from MMS).

Control Centre Engineers use schedules and merit orders (in MMS), along with the real-time status (in the EMS) to determine Dispatch Instructions (DIs), including for Synchronous Condensers. DIs for Synchronous Condensers are sent from the TSO to the Synchronous Condenser operators via the Electronic Dispatch Instruction Logger (EDIL). DIs are subsequently available to market participants via the Balancing Market Interface (BMI, also referred to as the Market Participant Interface, MPI) and on the SEMO website.

Synchronous Condensers consume energy but supply no energy, so they are excluded from Imbalance Pricing and Imbalance Settlement Instruction Profiling and QBOA calculations and therefore will not appear in such reports. However, where applicable, data for Synchronous Condensers will be incorporated in existing reports and interfaces. This ensures that participants and stakeholders can access relevant information without the need for additional reporting structures. Key reports, such as those detailing unit capability, availability, operational scheduling, and dispatch outcomes, will be updated to include Synchronous Condenser data, as outlined in Appendix A.

4. Day in the Life

As part of the industry engagement with respect to the Scheduling and Dispatch Programme, “Day in the Life” overviews have been a valued part of each initiative highlighting the key stages of the approach. Figure 11 sets out the “Day in the Life” for SDP_06.

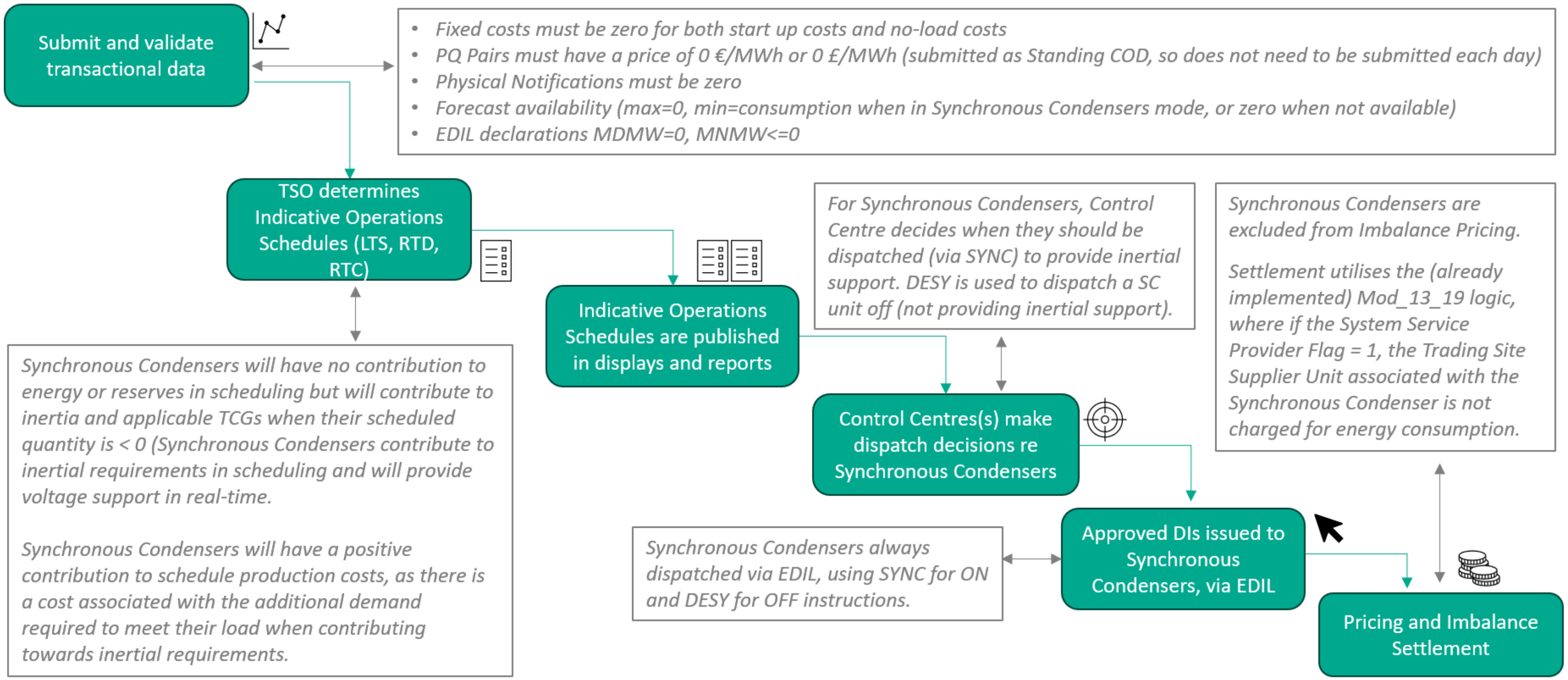

Figure 11: SDP_06 "Day in the Life"

Table 10 provides further explanation of the key stages of the "Day in the Life" diagram, highlighting how Synchronous Condensers will be treated.

Table 9: Explanation of SDP_06 "Day in the Life"

"Day in the Life" stage	Explanation

Submit and validate transactional data	• Fixed costs (Start Up Costs and No Load Costs) and Incremental / Decremental prices as part of PQ pairs must be zero (enabled via Standing COD)
	• Physical Notifications must be equal zero (which may be given effect by the Participant not submitting, resulting in defaulting to zero)
	• Availability limits via BMI to be submitted as:
	  ○ Forecast Availability Profile = 0
	  ○ Forecast Minimum Stable Generation Profile = 0
	  ○ Forecast Minimum Output Profile <=0 (0 if unavailable, otherwise representing the consumption load when operating)
	• EDIL declarations to reflect MDMW=0 (upper availability limit) and MNMW<=0 (lower availability limit)

TSO determines Indicative Operations Schedules (LTS, RTD, RTC)	• TSOs produce Operational Schedules using optimisation tools, for units including conventional units, renewable units, Demand Side Units, Pumped Storage Units, Battery Storage Units, Interconnectors and Synchronous Condenser Units. The Operational Scheduling optimisation takes account of constraints including supply/demand, unit technical capabilities, reserve requirements, SNSP, minimum inertia requirements and TCGs (including minimum regional unit constraints) • For other units, their contribution to the Operational Schedule production costs will be a combination of Fixed Costs and PQ curves (at the level of output determined by the optimisation) • For Synchronous Condensers, their contribution to the Operational Schedule production costs will be only the cost of other generator(s) scheduled to meet the additional load required when a Synchronous Condenser is operating (and providing the applicable System Services)
Indicative Operations Schedules are published in displays and reports	• Each Operational Schedule (all units, including Synchronous Condensers) is made available to participants via the BMI and is subsequently published via the SEMO website • Indicative Operations Schedules are utilised as decision support by the Control Centres
Control Centre(s) make dispatch decisions re: Synchronous Condensers	• Control Centres utilise Indicative Operations Schedules and Merit Orders to make dispatch decisions

“Day in the Life” stage	Explanation
Approved DIs issued to Synchronous Condensers via EDIL	• Dispatch Instructions are issued via EDIL (for dispatchable units). For all other units, any Dispatch Instructions are issued via the EMS Wind Dispatch tool.
Imbalance Pricing and Imbalance Settlement	• As Synchronous Condensers are not providing energy when they are delivering System Services to the grid, they are excluded from QBOA/Instruction Profiling and Imbalance Pricing. The effect of the additional generation required from other generators to meet the additional load required when Synchronous Condensers are operating will affect Imbalance Pricing • Synchronous Condensers will be treated in settlement according to Mod_13_19 (i.e. the Trading Site Supplier Unit associated with the Synchronous Condenser will not be charged for energy consumption)

Appendix A: Synchronous Condenser Key Reports

4.1.1 Synchronous Condensers: Unit Capability

Table 10 displays the reports that will give information about Synchronous Condenser Units and their technical capabilities as per registration data and Technical Offer Data.

Table 10: Incorporation of Synchronous Condensers into Existing Reports

Frequency	Report Ref.	Name	Member Private	Member Public	General Public	Content
Daily, only when a new Unit Registration is approved	REPT_035	List of Registered Units Reports	N	Y	Y	This report contains all Units registered to participate in the I-SEM. Note: where there is an approved change to the registration data for any Unit, then the report will contain two records for the Unit – one with a deregistration date of the end date of the superseded record and a second record with a registration date equal to the effective date of the new registration data.
Daily	REPT_011	Daily Technical Offer Data	N	Y	Y	This report will detail the relevant Technical Offer Data, for Units including Synchronous Condenser Units.
Daily	REPT_031	Unit Data Report	N	Y	Y	This report contains Generator Unit and Demand Side Unit Fuel Type for the previous Trading Day, including Synchronous Condenser Fuel Type.

4.1.2 Synchronous Condensers: Unit Availability

Table 11 displays reports that will provide information on availability for all Generator Units, including Synchronous Condenser Units.

Table 11: Incorporation of Synchronous Condensers into Existing Availability Reports

Frequency	Report Ref.	Name	Member Private	Member Public	General Public	Content
Hourly	REPT_101	Outturn Availability	N	Y	Y	This report will detail the availability declarations per Generator Unit including Synchronous Condenser Units for each hour.
Daily	REPT_012	Forecast Availability	N	Y	Y	This report will detail the forecast availability per Generator Unit including Synchronous Condenser Units for each Imbalance Settlement Period in the previous Trading Day.

4.1.3 Synchronous Condensers: Operational Scheduling

The Operational Schedule reports in Table 12 below contain scheduling information for all Dispatchable and Controllable Generator Units, including Synchronous Condenser Units.

Table 12: Incorporation of Synchronous Condensers into Existing Availability Reports

Frequency	Report Ref.	Name	Member Private	Member Public	General Public	Content
Automatically, after approval of each LTS Operational Schedule Run	REPT_001b	LTS Operational Schedule Report	N	Y	Y	This report will contain the LTS Operational Schedules all Dispatchable and Controllable Generator Units including Synchronous Condenser Units.
Automatically, after approval of each RTC Operational Schedule	REPT_002b	RTIC Operational Schedule	N	Y	Y	The report will contain the RTIC Operational Schedules for all Dispatchable and Controllable Generator Units

						including Synchronous Condenser Units.
Once per day	REPT_003b	RTID Operational Schedule	N	Y	Y	The report will contain the RTID Operational Schedules for all Dispatchable and Controllable Generator Units including Synchronous Condenser Units.

4.1.4 Synchronous Condensers: Dispatch Outcomes

Table 13 below contains the Dispatch Instructions for all Dispatchable and Controllable Generator Units including Synchronous Condenser Units.

Table 13: Incorporation of Synchronous Condensers into Dispatch Instruction Reports

Frequency	Report Ref.	Name	Member Private	Member Public	General Public	Content
Hourly	REPT_102	Hourly Dispatch Instructions Report	N	Y	Y	This report will be published on an hourly basis, containing all Dispatch Instructions for all Dispatchable and Controllable Generator Units including Synchronous Condenser Units, where the Issue Time is in the previous hour.
Daily	REPT_006	Daily Dispatch Instructions (D+1) Report	N	Y	Y	This report will contain the Dispatch Instructions for all Dispatchable and Controllable Generator Units including Synchronous Condenser Units.
Four days after Calendar Day	REPT_007	Daily Dispatch Instructions (D+4) Report	N	Y	Y	This report will contain the Dispatch Instructions for all Dispatchable and Controllable Generator Units including Synchronous Condenser Units.

4.1.5 SO Flagging for Inertia

The report in Table 14 below contains Imbalance Pricing information, including SO flags and associated constraint identifiers.

Table 14: Reports on Imbalance Pricing, including SO Flags

Frequency	Report Ref.	Name	Member Private	Member Public	General Public	Content
End of Imbalance Price calculation process for the corresponding Imbalance Pricing Period	REPT_050	Imbalance Price Supporting Information Report	N	Y	Y	This report will contain the real time QBOA/PBOA as well as Tagging and Flagging information based on the schedule outputs from RTID runs and real time dispatch instructions for each five-minute interval.