Technical Report

Powering Regional Grid Interoperability: The Crucial Role of Transmission System Operators in the LTMS-PIP

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March 2025

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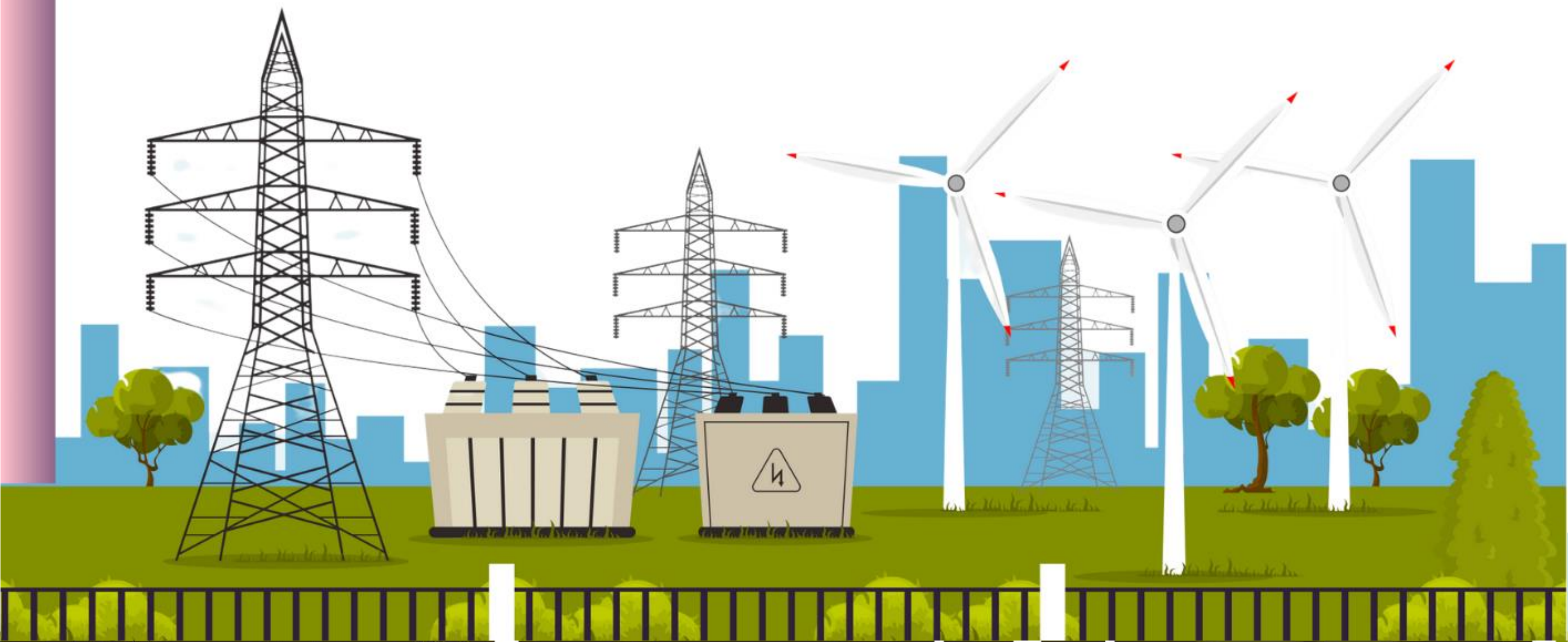

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Powering Regional Integration: The Crucial Role of Transmission System Operators in the LTMS-PIP is a technical report by the ASEAN Centre for Energy (ACE), developed with the support from the National Renewable Energy Laboratory (NREL) under the Global Power System Transformation Consortium (G-PST).

ACE would like to express its gratitude to Dato' Ir. Ts. Razib Dawood, Executive Director of ACE, for his leadership and support in advancing ASEAN's energy cooperation agenda. Special appreciation is also extended to Beni Suryadi, Head of Department of the Power, Fossil Fuel, Alternative Energy, and Storage (PFS), for his guidance in shaping this publication.

ACE acknowledges the authors of this report, led by Nadhilah Shani, with supported from Marcel Nicky Arianto, Akbar Dwi Wahyono, Muhammad Rialdo Farizky and Putri Aprilia Maharani, for their extensive research and analysis. Appreciation is also given to Muhammad Bayu Pradana Effendy for the contributions to the publication's design.

This study has benefitted from discussions with the representatives of ASEAN power utilities from four ASEAN Member States (AMS) under the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP). The representatives participated in the Community of Practice (CoP), titled *Role of Transmission System Operators for Successful Multilateral Energy Trading Under the Lao PDR – Thailand – Malaysia – Singapore (LTMS) Project* held virtually on 23 April 2024. This CoP session built upon the previous CoP program for Southeast Asia Grid System Operators, conducted in December 2022, which explored on Vietnam's experience in managing high fluctuations of Variable Renewable Energy (VRE) within its grid system.

The authors would like to extended their gratitude to the Heads of the ASEAN Power Utilities/Authorities (HAPUA) Working Group 5 (HWG-5), Secretariat of ASEAN Power System Operators (APSO) – Grid System Operator (GSO) of Tenaga Nasional Berhad (TNB), Global Power System Transformation Consortium (G-PST), the systems operators from Electricity Generation Authority of Thailand (Thailand), Electricite du Laos (Lao PDR), and GSO of Malaysia and Energy Market Authority (EMA) of Singapore for their guidance, collaborative effort reflects the dedication and their valuable contributions are truly appreciated.

The authors would also like to express their sincere appreciation to the European Network of Transmission System Operators for Electricity (ENTSO-E) and the Southern African Power Pool (SAPP) for their invaluable support in sharing international best practices for TSOs, have been instrumental in shaping the analysis presented in this work. Their expertise in addressing key challenges to ensure the smooth transfer of power in the European and Southern African power markets serves as a crucial reference for ASEAN's ongoing efforts in strengthening regional grid stability. ACE, therefore, is profoundly grateful for their commitment and assistance.

List of Acronyms and Abbreviations

ACOP	Actual Confirmation of Purchase
ACE	ASEAN Centre for Energy
AEC	ASEAN Economic Community
AERN	ASEAN Energy Regulatory Network
AMEM	ASEAN Ministers on Energy Meeting
APAEC	ASEAN Plan of Action on Energy Cooperation
APG	ASEAN Power Grid
CGM	Common Grid Model
COW	Confirmation of Wheeling
DAD	Daily Declaration
EDL	Électricité du Laos
EGAT	Electricity Generating Authority of Thailand
ACOW	Actual Confirmation of Wheeling
EMA	Energy Market Authority
EN	Energy Wheeling
ENTSO-E	European Network of Transmission System Operators for Electricity
ER	Emergency / System Constraint Report
FO	Fiber Optics
HAPUA	Heads of ASEAN Power Utilities/Authorities
HVDC	High Voltage Direct Current
IA	Interconnection Agreement
ICA	Importer Connection Agreement
ICCP	Inter-Control Centre Protocol
LTMS	Lao PDR-Thailand-Malaysia-Singapore
MCP	Market Clearing Price
MCV	Market Clearing Volume
MPT	Multilateral Power Trading

OBS	Observable Benchmarking Standards
OPDE	Operational Planning Data Environment
PDR	People's Democratic Republic
PIP	Power Integration Project
PLC	Power Line Communication
PPA	Power Purchase Agreement
PSO	Power System Operator
RCCs	Regional Coordination Centres
RES	Renewable Energy Sources
RTIFF	Regional Transmission Infrastructure Financing Fund
SIA	System Interconnection Agreement
SAPP	Southern African Power Pool
SCVCS	Static Var Compensator Voltage Control System
SPPA	Singapore Power Pool Authority
SVC	Static Var Compensators
SWEM	Singapore Wholesale Electricity Market
TST	Thailand Standard Time
TNB	Tenaga Nasional Berhad
TSOs	Transmission System Operator
WP	Weekly Plan

Executive Summary

Electricity market, communication mechanism and congestion management are of utmost importance among inter-TSO coordination task. To address these issues, APSO Secretariat has provided the CoP for multilateral energy trading (MPT) in the LTMS-PIP to advance the overall efficiency reliability of the energy trading process in the ASEAN Power Grid (APG) under the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II: 2021-2025.

This study focused on improving the coordination and communication mechanism for Transmission System Operators (TSOs) of LTMS-PIP also a more advanced trading models in grid system among power system operators. The aim was to facilitate MPT within the LTMS- PIP. The key discussion outlined as below:

1. Study on existing LTMS power system operators in coordinating and communicating to ensure the successful multilateral energy trading through Communication Mechanisms and Platform by System Operator at EGAT as wheelers of electricity in LTMS Project.
2. Experiences and best practices from the SAPP and the ENTSO-E, particularly in handling the operation of a rather more advanced power trading model.
3. Panel discussion of the existing LTMS coordination and communication mechanism in case of critical period occurs during the power transfer in the four countries involved.

The probability of levelling power trade in LTMS countries were explored in this study based on European experiences which advised to analyse both system operations and market dynamics in recent years, transitioning from a unilateral (one direction from Lao PDR to Singapore) to multi-lateral (many different directions). Developing its processes of ensuring a secure system operation in the region capable to transport energy to the market, which can have a positive impact on social welfare by increasing the share of renewable energy sources.

The challenge in the current practice LTMS certainly remain, particularly the emergency mainly due to trips of interconnection. This can occur a more complicated coordination as TSOs of LTMS will require to do some revisions and confirmation back and forth which may increase the risk of delay in energy trading. On the other hand, the SAPP's and resemblances to ASEAN could be relevant references in terms of levelling up the trading mechanism, such as adding real-time power flow into the platform. The new improvement is envisaged in mitigating the critical period to amplify the real time power flow in the region enables TSOs to be better prepared for sudden changes or emergencies.

The key outcomes from the CoP involving the international expert from ENTSO-E and SAPP, offer a valuable insights and best practices for the TSOs of LTMS countries. To ensure the efficiency, reliability and resilience of the TSOs, the intermittency issues should be addressed. This study includes the key outcomes and measures for each

AMS in creating an advanced framework in transmission system, highlights as following details:

1. To perform a web-based platform for real-time data sharing, power flow monitoring, and emergency response coordination that would help ensuring seamless information exchange and operational transparency among TSOs.
2. To determine the implications of the deployment method for trades in European power market based on cross-bidding zones. The method called “flow-based capacity calculation” to calculate the maximum capacity for cross-zonal exchanges between each of the bidding zones of the region and prevent bottlenecks in the grid stability.
3. To identify the strategy of regional coordination in Southern Africa with transfer limit on each border lines based on the system analysis and new transmission infrastructures through Regional Transmission Infrastructure Financing Fund (RTIFF) and applied soft measures such as installing Static Var Compensator Voltage Control System (SCVCS) and coordinated outages to mitigate congestion.
4. Study on the existing Regional Coordination Centres (RCCs) for cross-border capacity calculation, outage coordination, system adequacy analysis to align with the regional and market integration from ENTSO-E best practices.

The future role of TSOs in ASEAN involves in coordination bodies for energy trading across ASEAN countries, facilitating electricity flow and enabling efficient congestion management. It is also found in Southeast Asia the potential growth share of renewable energy in the power mix, to anticipate changes in renewable energy withdrawals and their impact on power flow, the ASEAN Grid System Operators should be ready to handle those challenges.

Recommendations in this study in investing advance communication that LTMS countries can implement include adopting best practices from the two other regions, adding renewable energy forecasting, real-time unit installed, grid flexibility and congestion management in market integration among TSOs of LTMS project could be practical solution in the future.

Background

The majority of ASEAN countries have embraced the transition to a low-carbon energy future as a cornerstone for interconnection projects. Regional electricity interconnections play a vital role in this transition, aiming to create an integrated regional electricity grid system. In a regional context, multilateral power trade is a key focus of the ASEAN Power Grid (APG) among ASEAN stakeholders and utilities to achieve the goal of the ASEAN Economic Community (AEC) 2025, enhancing connectivity, energy security, and sustainability.

During the early stages of multilateral and bilateral power exchange in ASEAN, there have been consistent efforts since the APAEC Phase I: 2016-2020 within the APG Program Area as one of the key action plans for energy capacity trading. A major initiative of the APG was initiated by HAPUA's strategy concentrated on expanding cross-border bilateral interconnections into sub-regional basis, namely: Northern Sub System (Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam), Southern Sub System (Indonesia, Malaysia, and Singapore) and Eastern Sub System (Brunei Darussalam, Indonesia, Malaysia, and Philippines) and finally to a fully integrated APG. This new strategy seeks to advance multilateral interconnections.

The first multilateral power trade pilot project, inaugurated at the 32nd ASEAN Ministers on Energy Meeting (AMEM) held in Vientiane, Lao PDR on 23 September 2014, was a significant milestone. The LTMS-PIP served as a pathfinder for cross-border power trade, optimally identifying the necessary new infrastructure or technology trends and marking the initial realisation of the APG programme in a broader MPT.

At the current stage, HAPUA is elevating its efforts with the ASEAN Energy Regulatory Network (AERN) to develop legal and regulatory practices, enhance technical standards through feasibility studies for individual project sponsors under infrastructure feasibility studies, and provide guidance on market outreach programmes. These initiatives aim to attract potential investors and creditors, identifying viable financing models to support the ongoing expansion of MPT in ASEAN.

How do the LTMS-PIP TSOs Communicate and Share Necessary Data and Information for Power Trading?

1.1 Agreement

LTMS-PIP is a large-scale program aiming at promoting regional energy cooperation and improving the efficiency of power trade across national boundaries. Given the project's complexity and scope, it is critical to ensure the confidentiality and security of communication protocols and data-sharing systems. To do this, several essential agreements have been reached with the participating TSOs and other stakeholders.

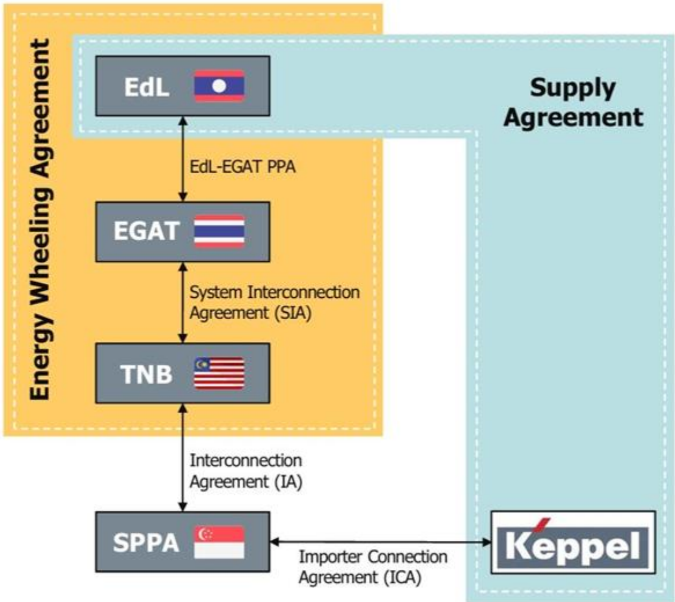

Figure 1 List of Agreements Involved [1]

Several agreements exist to maintain the confidentiality and security of communication protocols and data-sharing, which include:

A. **Energy Wheeling Agreement**
   1) **EDL-EGAT Power Purchase Agreement (PPA)**
      The EDL-EGAT PPA is an agreement regulates the purchase and transmission of EDL to EGAT. It specifies the pricing, quantity, timing, and technical details of the power exchanges between EDL and EGAT.
   2) **EGAT-TNB System Interconnection Agreement (SIA)**
      The EGAT-TNB SIA is an agreement that outlines the technical and operational characteristics required for delivering power from EGAT in Thailand to TNB in Malaysia. This applies to physical points of interconnection, operational infrastructures, and restorative actions between Thailand and Malaysia.

B. TNB-SPPA Interconnection Agreement (IA)

The TNB-SPPA IA is an agreement that provides for the connection of TNB's transmission network with Singapore Power Pool Authority (SPPA). The agreement allows for defining the capacity of energy transfer, technology standards and coordination systems, and manage power flow between Malaysia-Singapore more efficient. This agreement allows integrating both electricity markets and make them more competitive, as well as providing access to new types of energy.

C. SPPA-Keppel Importer Connection Agreement (ICA)

The SPPA-Keppel ICA is an agreement that lays out the framework for linking the SPPA to Keppel Infrastructure, including access, operating standards, and responsibilities for importing power into Singapore. It permits diverse energy sources, improving Singapore's energy security and market competitiveness.

D. EDL-Keppel Supply Agreement

The EDL-Keppel Supply Agreement describes the regulations under which EDL will supply power to Keppel Infrastructure for distribution to Singapore. It covers price, delivery schedules, quality standards, and dispute resolution, assuring consistent supply while also complementing Singapore's energy mix and sustainability objectives.

1.2 Communication Mechanism

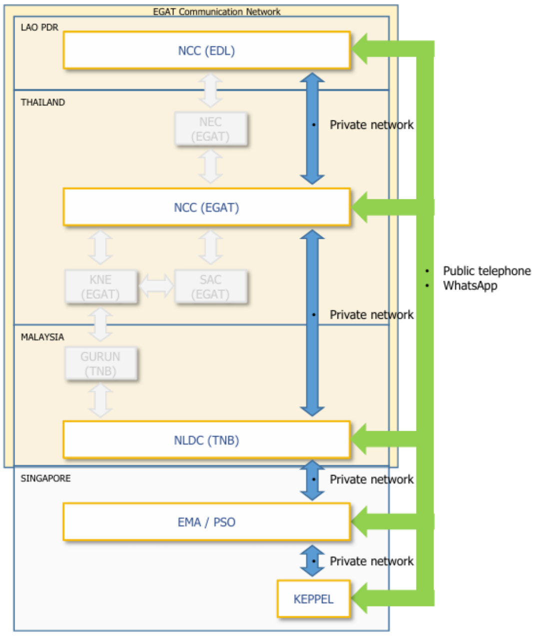

Figure 2 Communication Mechanism [1]

The communication method proposed for the LTMS-PIP is critical to maintaining smooth and stable operation across national boundaries. This system includes technologies designed to promote smooth information sharing and operational coordination among TSOs. Methods of communication mechanism among TSOs outlined as below:

A. Voice Communication

Voice communication among TSOs in the LTMS-PIP project utilise public and private telephone networks. Public telephone networks use internal connections to facilitate rapid information between TSOs. However, private telephone networks use technology like Power Line Communication (PLC) or Fiber Optics (FO). These private networks provide high privacy and stability, which are essential for maintaining secure and stable operational mechanisms.

B. LTMS Platform

LTMS-PIP utilise a dedicated document management platform for LTMS to facilitate a seamless coordination and operational efficiency of MPT. The platform allows for precise document retrieval throughout the use of keywords, ensures rigorous version historical tracking at utmost importance to uphold the integrity and accuracy of all LTMS documents.

The LTMS Platform is a web-based platform allowing stakeholders to submit real valuable information related to LTMS trading. For instance, the EDL is required to declare LTMS day-ahead sales, while importers must submit purchase orders to confirm transactions. Upon confirmation of the purchase, graphical representations will be provided for the System Operator (SO) to align power flows with the purchasing order.

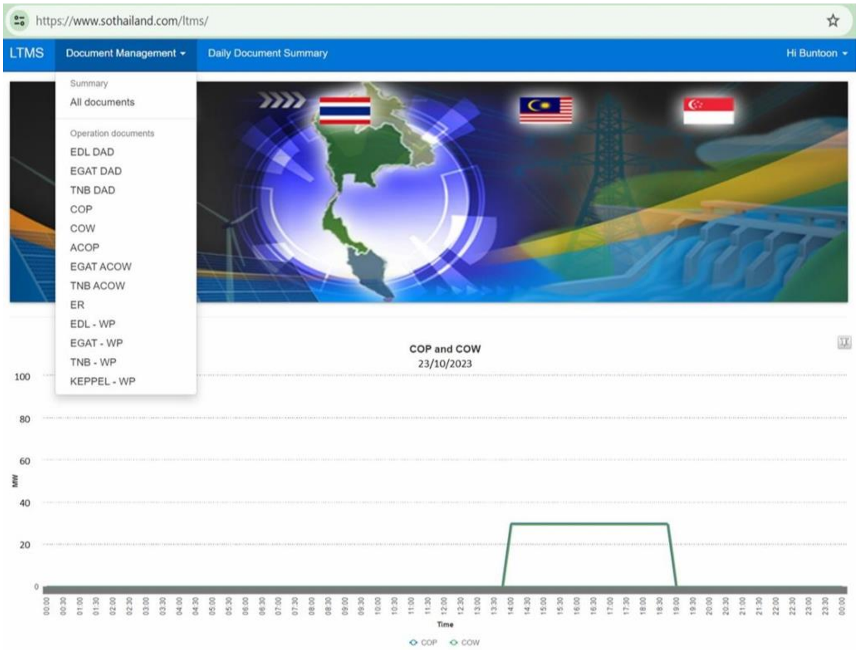

Figure 3 Platform for LTMS [1]

At the end of each trading day, actual transfer amounts are confirmed and documented for subsequent settlement, ensuring transparency and accountability within the trading framework. The platform also incorporates an emergency reporting channel that allow users to promptly report events that may affect LTMS trading. The platform is accessible at https://www.sothailand.com/LTMS/, implementing a sophisticated role-based access control system providing differential access and permission based on the hierarchical roles of users within the LTMS-PIP structure. The platform offers several key functions documents for LTMS:

1. EDL Daily Declaration (EDL DAD)
2. EGAT Daily Declaration (EGAT DAD)
3. TNB Daily Declaration (TNB DAD)
4. Confirmation of Purchase (COP)
5. Confirmation of Wheeling (COW)
6. Actual Confirmation of Purchase (ACOP)
7. EGAT Actual Confirmation of Wheeling (EGAT ACOW)
8. TNB Actual Confirmation of Wheeling (TNB ACOW)
9. Emergency / System Constraint Report (ER)
10. Weekly Plan (WP)

C. WhatsApp Group (Optional)

In addition to established communication channels, TSOs on the LTMS-PIP project use WhatsApp groups for real-time conversations, updates, and coordination. WhatsApp provides an informal and instantaneous environment for TSOs to collaborate and respond more effectively. While optional, these groups enhance current methods of communication and provide a dynamic exchange of information within the TSO community.

1.3 Daily Operational Process

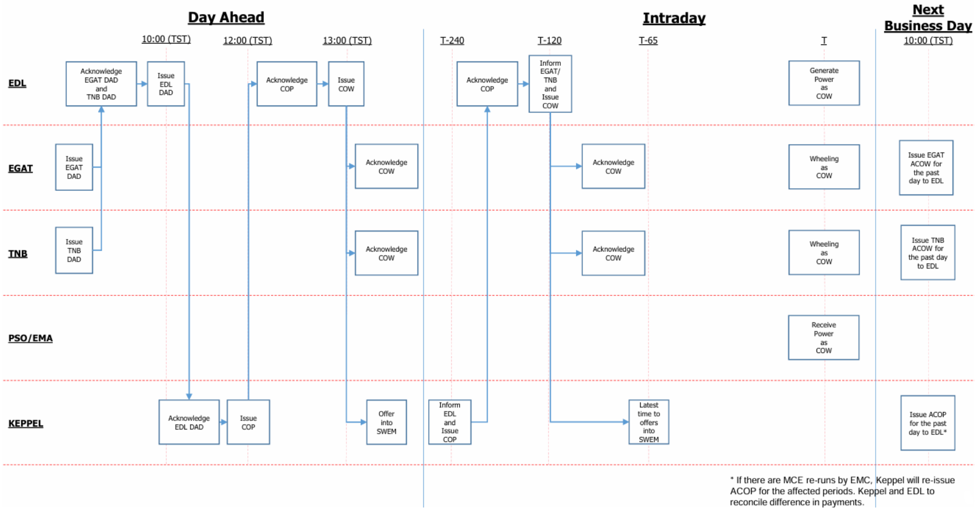

Figure 4 Overall Daily Operational Process [1]

Daily operational process in the LTMS-PIP project is divided into three categories based on timelines:

A. Day Ahead

The day ahead category refers to a specific period in the operational planning of energy networks and markets during which operations are concentrated on preparation for the following operational day. During the day ahead category of the LTMS-PIP project, EGAT and TNB send EGAT DAD and TNB DAD before 10:00 (Thailand Standard Time (TST)), describing scheduled energy transactions for the following operational day. Following that, EDL publishes its own EDL DAD about 10:00 (TST), recognising EGAT and TNB's pronouncements. Keppel Infrastructure subsequently accepts EDL's declaration and sends a COP at roughly 12:00 (TST), so confirming energy purchase agreements. Following that, EDL confirms the COP and publishes a COW in outlining energy transfers between linked systems, which EGAT and TNB both acknowledge. Finally, Keppel offers imported energy to the Singapore Wholesale Electricity Market (SWEM) under the COP and COW agreements. This procedure guarantees that TSOs coordinate in a timely manner, from initial planning to concluding energy transactions for the next operating day in connected power systems.

B. Intraday

The intraday category refers to a specific period in energy network and market operational planning, during which real-time adjustments to energy transactions occur within the operational day. During intraday category of the LTMS-PIP project, Keppel Infrastructure notifies EDL and COP within 240 minutes / 4 hours before the specified time (T-240). When EDL recognises the COP 120 minutes / 2 hours before that time (T-120), it notifies EGAT/TNB and verifies the COW, which EGAT and TNB also affirm. Keppel has through the last moment to submit these transactions to the SWEM. Throughout the day, EDL generates power in accordance with the COW agreements, while TNB and EGAT transmit the power. The Power System Operator (PSO) or EMA receives electricity in accordance with the COW agreements.

C. Next Business Day

Next business day refers to the immediately following working day, excluding weekends and public holidays, in the operational planning of energy networks and markets. At 10:00 TST, EGAT sends the previous day's ACOW to EDL, and TNB does the same at the same time. At 10:00 TST, Keppel also sends EDL the ACOP for the previous day. This process is used to reconcile and confirm energy transactions from the previous operating day, assuring accuracy and accountability among the LTMS-PIP project's participating TSOs.

How do the LTMS-PIP TSOs Mitigate Grid Capacity Bottlenecks caused by Congestions during Trading?

2.1 LTMS-PIP TSOs Strategy to Mitigate HVDC Failure

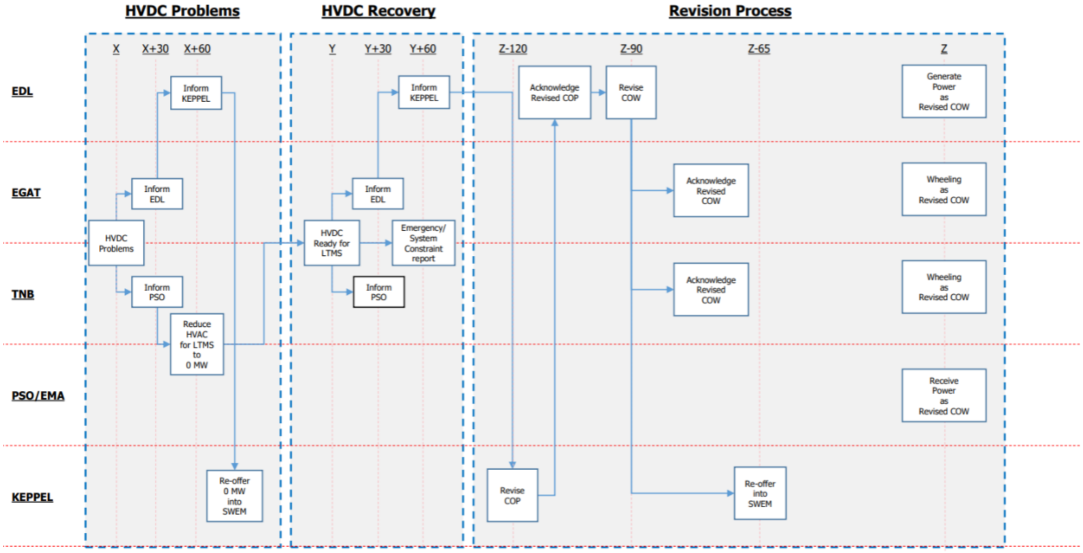

Figure 5 EGAT-TNB HVDC Trip or Control Failure or Stability Function Operated [1]

The coordination of an HVDC trip or control failure between EGAT and TNB differs into three stages:

A. HVDC Problems

When an HVDC fault occurs at time X between EGAT and TNB, EGAT must alert EDL in X+30 minutes. Simultaneously, TNB informs the PSO in X+30 minutes. Following that, EDL must alert Keppel of the issue in X+60 minutes. In response, PSO/EMA and TNB reduced the HVAC for LTMS to 0 MW. Keppel will then re-offer 0 MW to the SWEM, meaning no energy will be transported due to the HVDC fault.

B. HVDC Recovery

Once the HVAC has been dropped to 0 MW, TNB and PSO/EMA will recover the HVDC system in time Y. When the HVDC is ready for LTMS operation, EGAT alerts EDL in Y+30 minutes, while TNB alerts the PSO simultaneously. By Y+60 minutes, EGAT and TNB must have completed an emergency/system constraint report. EDL also informs Keppel that the HVDC system is now ready to restart operations.

C. Revision Process

After EDL notifies Keppel of the recovery, Keppel revises the COP within Z-120 minutes (about 2 hours). Z refers to the timeframe after the system recovery procedure. EDL acknowledges the amended COP and then revises the COW within Z-90 minutes (about 1 and a half hours). EGAT and TNB then accept the updated COW from EDL. Finally, Keppel re-offers the corrected energy transfer amount to the SWEM within Z-65 minutes, ensuring that the energy transactions are up to date and in line with the HVDC system's current operating condition.

2.2 LTMS-PIP TSOs Congestion Grid Management Strategy

A. System Constraint

When EGAT identifies a system constraint, they notify EDL and TNB X-120 minutes beforehand, indicating approximately 2 hours before the constraint is expected to occur. Following this, EDL informs Keppel at X-90, simultaneously with TNB notifying PSO. Based on EDL's information, Keppel then adjusts their SWEM offer to 0 MW. EGAT and TNB are tasked with reducing HVDC for LTMS to zero MW by time X. Once TNB notifies PSO at X-90, both TNB and PSO/EMA proceed to decrease HVAC for LTMS to 0 MW by X.

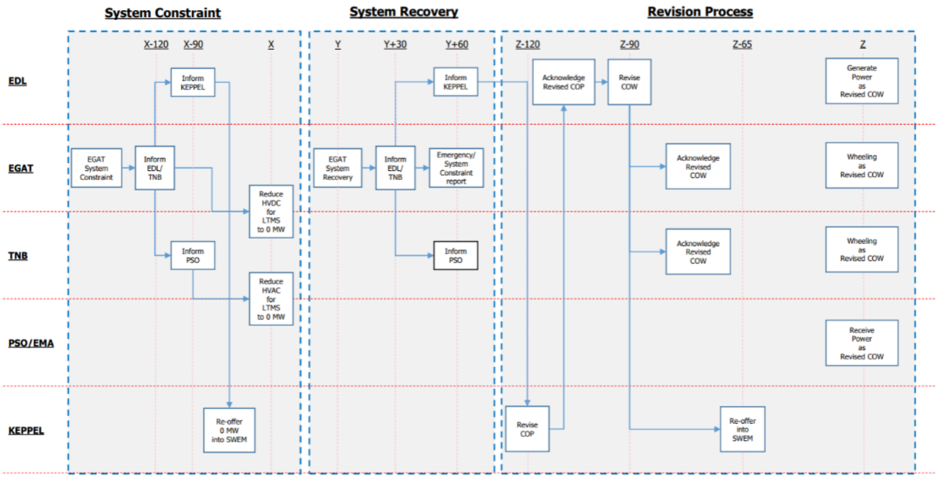

***Figure 6** EGAT System Constraint [1]*

B. System Recovery

Following the resolution of the system constraints, EGAT starts the system recovery at Y time. Y represents the time when the recovery process is initiated. EGAT tells EDL and TNB of the recovery at Y+30. EDL must notify Keppel by Y+60, whereas TNB notifies PSO at Y+60. EGAT also transmits an Emergency/System Constraint report at Y+60.

C. Revision Process

After EDL informs Keppel about the system recovery, Keppel must revise the COP by Z-120. Z here marks the beginning of the revision process following the system recovery. Subsequently, EDL acknowledges the updated COP and revises the COW by Z-90. EGAT and TNB acknowledge EDL's revised COW. Keppel then re-offers electricity to SWEM at Z-65 based on the revised COW. EDL generates power according to the revised COW, while EGAT and TNB facilitate wheeling as necessary. PSO/EMA receives electricity according to the revised COW, ensuring efficient energy transactions aligned with current HVDC system conditions.

How do the International Best Practices Manage to Mitigate the Challenges in MPT?

To ensure optimal management of the electricity transmission network and to allow trading and supplying electricity across borders in the European electricity grid, TSOs have a profound role within the structure of the ENTSO-E. ENTSO-E is the platform for cooperation between the TSOs of 36 countries, around 500.000 km of power lines and serving about 520 million citizens across Europe. ENTSO-E's role is to ensure that all TSOs work together seamlessly, sharing information and resources to manage and mitigate grid disturbances.

3.1 Case Study in the Role of ENTSO-E: The 2006 European Blackout

The European power system wasn't working out on November 4, 2006, where a cruise ship caused a major blackout impacted over 15 million households across multiple countries in Europe. The incident resulting in temporary shutdown, leading to cascading overloads throughout the transmission lines in Germany, France, Italy, Belgium, Spain, and Portugal. It was a planned outage of power line that was crossing a river because of cruise ship passing by which would have come close to the high or transmission line and at that time, no regional coordination between the TSOs was set up in a formalised way.

There was a two things combinate among TSOs leading into widespread blackouts where there was a misunderstanding and imperfect communication in terms of when exactly this outage would be happening, and top of that there was a deviation in the protection setting between 2 affected TSOs, which then in the consequence triggers to a cascades of a system split that result to a large-scale blackout for 100 minutes with a power imbalance of 10 GW. But TSOs have still been capable to quickly re-synchronise the two island that came up due to the system split to reconnect them within quite short time.

This one lesson learned before the severity of blackout escalate was the coordination between the TSOs must improve and must get to the next level with the real-time monitoring of the grid, demonstrating a comprehensive view of the entire European power network. Coordination between TSOs necessary for cross border capacity and security of supply considering the electrons do not stop at borders.

3.2 The 2006 European Blackout: Catalysing Regional Coordination and Security Initiatives

In the wake of the 2006 blackout, European TSOs recognised the necessity for concerted effort to increase regional coordination among TSOs. At the same time, technological developments allow for new forms of consumer participation and cross-border cooperation. The common goal of decarbonising the energy system creates new opportunities and challenges for market participants. The two first regional security coordination initiatives have been set up, which are called Coreso and TSCNET that are two independent companies owned by the TSOs provided the service of a different tasks to support the TSOs in coordinating the secure of power system to prevent large-scale outages.

Due to changes in EU regulations, regional security coordination initiatives have transitioned into mandated RCCs with an expanding set of tasks and activities. Since then, there have been 14 inter-TSO coordination tasks providing real-time operational coordination, outage planning, adequacy assessment, capacity calculation, and crisis management.

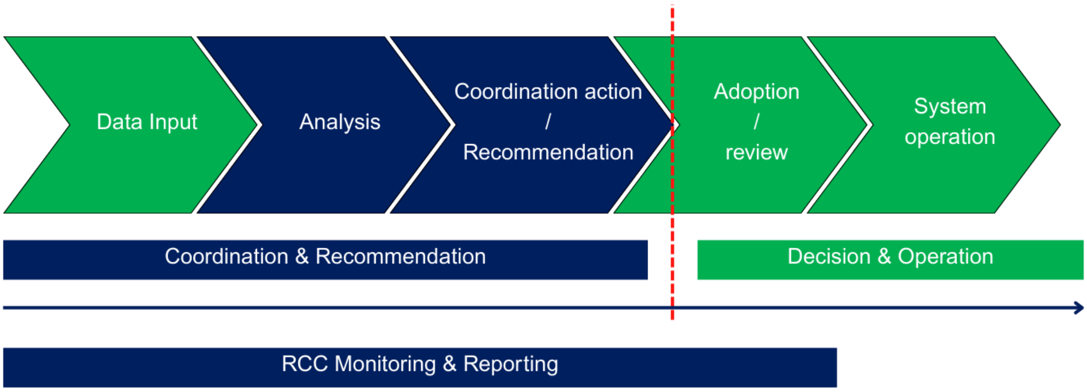

Figure 7 Roles and Responsibilities in RCCs of TSOs [2]

Figure 7 illustrates the responsibilities and roles of RCCs in the general context of TSOs activities. The process begins with the collection of data input and outputs from TSOs, likely encompassing a different kind of inputs, as follows:

1. **Grid models:** collection of national grid models, including detailed information on the current state of transmission network.
2. **Remedial actions:** Information on potential remedial actions, such as re-dispatching generation, load shedding, or activating reserves, which can be employed in case of grid disturbances.
3. **Transfer capacities:** Data on available transfer capacities between different countries that are crucial for cross-border electricity trading and maintaining grid stability.

From this data input, the RCCs analysis the data and develop the recommendations and proposed coordinated actions for the TSOs. These initiatives are then reviewed and potentially adjusted to meet the national requirements of each individual TSOs.

There are 5 core tasks assigned to TSOs that are essential for outage coordination regions and RES integration based on the Regulation (EU) 2019/943 about the internal market for electricity in Europe, this regulation consists of five main parts:

1. **Common Grid Model (CGM)** are available to all EU-TSOs to facilitate coordinated, cross border electricity trade and reliable operations of the European Electricity grid. CGM include a relevant data for efficient operational planning and capacity calculation in all operational planning timeframes between the year-ahead and intraday timeframes.

2. **Security analysis** performed for all operational planning timeframes, between the year-ahead and intraday timeframes increased a cross-border awareness of a secure system operation and mitigate potential risks to grid stability. As a result, RCCs detects a possible constraint design remedial action coordination and optimisation.
3. **Capacity calculation** performed for the day-ahead and intraday timeframes for cross-zonal capacities, aiming to ensure an efficient congestion management in accordance with the principles of congestion management.
4. **Outage coordination** carries out the following activities in the system operation region:
    a. Assess outage planning compatibility using all transmission system operators' year-ahead availability plans.
    b. Provide the transmission system operators in the system operation region with a list of detected planning incompatibilities and the solutions it proposes to solve the incompatibilities.
5. **Adequacy forecasts** involve assessing sufficient generation capacity to meet expected demand over different time horizons including seasonal, monthly and weekly assessment. This coordinated approach supports the plan for a potential shortfall condition.

According to the coordination tasks, substantial data needed is required to be shared among the TSOs. This also determines the exchange of internal and confidential information to be shared here is the Common Grid Model (CGM) and the Operational Planning Data Environment (OPDE) are fundamental enablers for reliable and efficient Grid Operations. The CGM is given to a common platform and then further utilised by the RCCs and TSOs to run the different regional coordination process.

3.3 Communication Mechanism of ENTSO-E

The purpose of the ENTSO-E Transparency Platform is to enable exchange of data between market players.

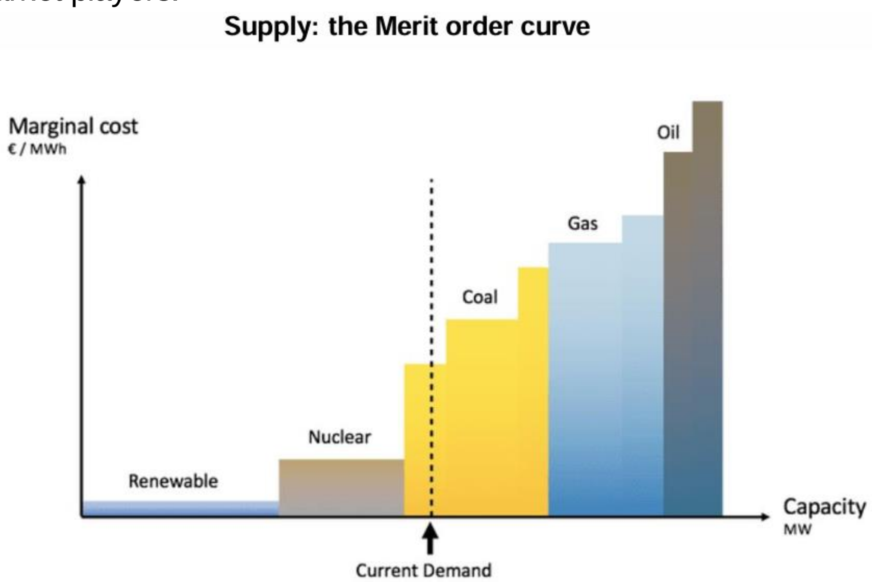

Figure 8 Supply: The merit order curve [3]

The basic principle in the European electricity market is equilibrium between the match supply and demand, achieved through a merit order curve. This mechanism prioritises energy sources, started with the market participants submitted their bids on their generation types based on the marginal costs, starting from renewables which have the lowest costs, followed by nuclear, coal, gas, and oil. The current demand of each generation types is different in terms of costs activated in the electricity market, determining the capacity required to meet the market needs.

A wide range of generation, load, transmission, and balancing data are available on this platform, which may be accessed through the [ENTSO-E Transparency Platform](). This platform is essential for stakeholders who need detailed insights into the operational and market aspects of the European electricity grid. Among these essential characteristics are:

1. **Real-Time & Historical Data**
   The platform offers both real-time and historical data, allowing users to track current conditions and analyse past trends. Real-time data provides up-to-the-minute information on electricity generation, load, and transmission, which is crucial for making informed decisions. Historical data enables users to identify patterns and trends over time, facilitating long-term planning and analysis.

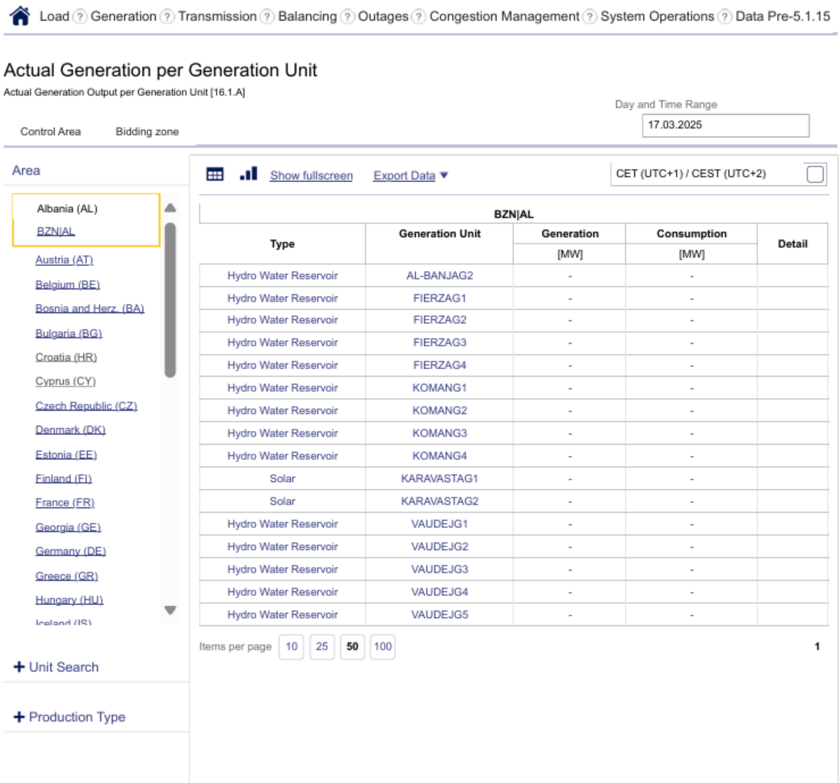

Figure 9 ENTSO-E Transparency Platform - Actual Generation per Production Type [4]

This interface is crucial for stakeholders who need to monitor and analyse real-time and historical generation data, enabling them to make informed decisions and ensure the stability and efficiency of the power grid.

2. **Market Information**
   The platform provides detailed information on market prices and volumes, which is essential for market participants to understand the dynamics of supply and demand. This information helps market players to optimise their trading strategies and make informed decisions about when to buy or sell electricity.
3. **System Operations**
   Users can access data on transmission system operations, including details about outages and congestion management. This information is vital for TSOs and other stakeholders to ensure the smooth operation of the grid and to plan maintenance activities without disrupting the supply of electricity.

   The increasing user base and the growing volume of data shared on the ENTSO-E Transparency Platform underscore its importance in maintaining operational efficiency and market transparency. By providing accessible and comprehensive data, the platform supports better decision-making, enhances the reliability of the electricity grid, and promotes a transparent and competitive market environment.

3.4 Managing Grid Congestion in ENTSO-E: Market-Based Strategies for Stability and Efficiency

In ENTSO-E, managing grid congestion involves ensuring that the demand for power is met while preventing the transmission system from becoming overloaded. This is accomplished through several market-based methods that focus on several market-based methods:

A. **Time Dimension**
   Grid congestion management in ENTSO-E involves ensuring the electricity supply meets demand without overloading the transmission system. This is achieved through several market-based mechanisms:

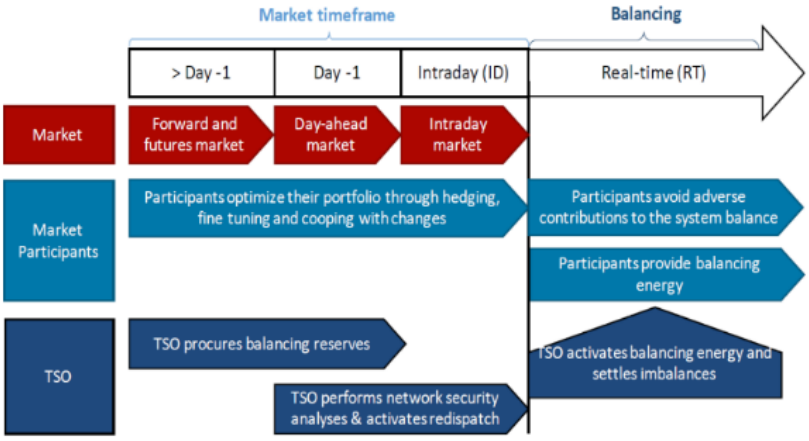

Figure 10 Congestion Management Strategy – Time Dimension [3]

Figure 10 illustrates the congestion management strategy focusing on the time dimension within the electricity market. The strategy is divided into different market timeframes as follows:

1. **Forward and Futures Market (> Day -1)**:
    - Participants optimise their portfolios through hedging, fine-tuning, and coping with changes.
    - TSOs procure balancing reserves in this phase.
2. **Day-Ahead Market (Day -1)**:
    - Participants continue to optimise their portfolios and prepare for the upcoming day's electricity demands.
    - TSOs perform network security analysis and activate redispatch if necessary to ensure grid stability.
3. **Intraday Market (Intraday)**:
    - Participants adjust their positions to respond to real-time changes and further optimise their portfolios.
    - TSOs maintain network security and make necessary adjustments to balance the grid.
4. **Real-Time (RT) Balancing**:
    - Participants aim to avoid adverse contributions to the system balance and provide balancing energy as needed.
    - TSOs activate balancing energy and settle imbalances to maintain the overall stability of the electricity grid.

This time-dimensional approach ensures that the electricity market operates efficiently by continuously optimising and balancing supply and demand, with TSOs playing a crucial role in maintaining grid stability throughout the process.

B. Merit Order Curve

The Merit order curve is a fundamental tool used to match electricity supply with demand. It ranks available electricity generation sources in ascending order of their marginal costs. The cheapest sources of electricity are used first, followed by more expensive ones, until the demand is met. This process determines the Market Clearing Price (MCP) — the price at which supply equals demand. Additionally, the Market Clearing Volume (MCV) is established, indicating the total amount of electricity traded at the MCP. By prioritising lower-cost generation, the merit order curve ensures cost-effective electricity supply and helps maintain grid stability by optimising resource utilisation.

C. Day-Ahead and Intraday Markets

The Day-Ahead and Intraday Markets are essential for adjusting electricity supply and demand in response to dynamic conditions, thereby aiding in real-time congestion management. In the Day-Ahead Market, electricity trading occurs one day before the actual delivery. Participants submit their supply and demand bids, allowing the market to establish prices and quantities for the next day. This advance trading enables better planning and helps identify potential congestion points in advance. The Intraday Market, on the other hand, allows for continuous trading closer to real-time. This market provides flexibility to adjust positions based on real-time changes in supply and demand, unexpected outages, or sudden demand spikes. By facilitating these adjustments, the Intraday Market helps manage congestion and ensures a balanced and stable grid.

D. Locational Dimension

Congestion management also involves considering the locational aspects of electricity generation and consumption. Electricity flows across the grid are influenced by the geographical distribution of generation sources and load centres. Intra-zone trades (within a bidding zone) are typically unrestricted, allowing for a single market price. However, inter-zone trades (between different bidding zones) are constrained by the transmission capacities connecting these zones. Managing these locational constraints is crucial to prevent overloading transmission lines and ensure efficient power flow. By accounting for locational dimensions, ENTSO-E can implement measures such as re-dispatching, where generation is adjusted in specific locations to alleviate congestion, and optimise the overall operation of the transmission network.

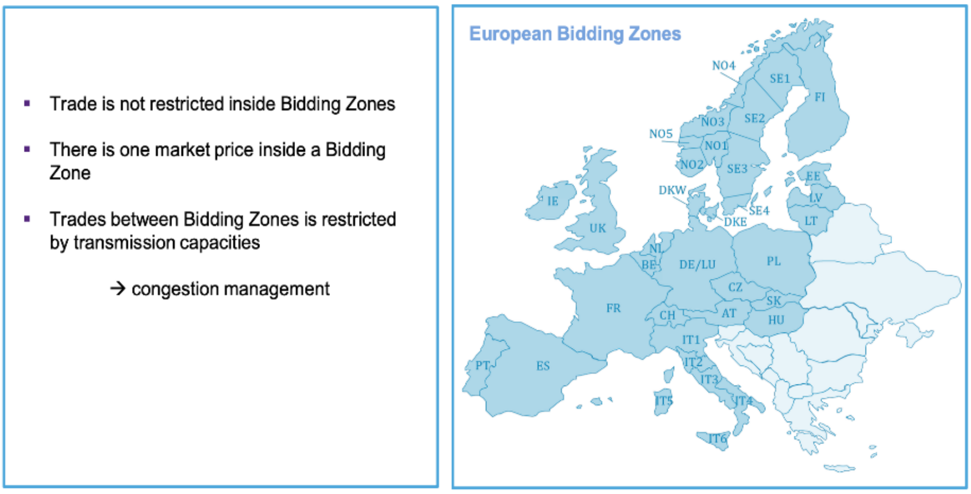

Figure 11 Congestion Management Strategy – Locational Dimension [3]

Figure 11 illustrates a congestion management strategy focusing on the locational dimension within the context of European bidding zones. The key points of the strategy are outlined on the left side of the image. Firstly, it highlights that trade is not restricted inside individual bidding zones, ensuring a single market price within each zone. This means that transactions within these zones are fluid and unhindered, fostering efficient market operations.

1. **Bidding Zones:** There is one market price within each bidding zone, and trades are unrestricted. However, trades between zones are limited by transmission capacities.
2. **Cross-Border Capacity Allocation:** Ensures that cross-border trades do not exceed the available transmission capacity.
3. **Flow-Based Market Coupling:** Optimises the use of transmission capacities by considering the physical flows of electricity, thereby managing congestion more efficiently.

However, when it comes to trades between different bidding zones, these transactions are limited by transmission capacities. This restriction is necessary to manage congestion and ensure the stability and reliability of the power grid. Congestion management in this context involves balancing supply and demand, preventing overloads, and maintaining optimal flow across the transmission network. By managing congestion through these strategies, the European power system can maintain stability while optimising the use of available transmission capacities, ultimately supporting a more resilient and efficient energy market.

3.5 SAPP's Grid Congestion Management: Soft Measures and Advanced Communication Mechanisms

SAPP employs several strategies to handle grid congestion, focusing on technical measures and operational coordination. One key approach is the use of Static Var Compensators (SVC) for voltage control. These devices help stabilise the grid by managing power flows, thereby reducing congestion. Another critical strategy involves coordinated outages, where planned outages are meticulously scheduled among TSOs to minimise their impact on the grid and prevent congestion.

several strategies to handle grid congestion, focusing on technical measures and operational coordination. Key approaches include:

1. **SVC:** Used for voltage control, these devices help to stabilise the grid and manage power flows, reducing congestion.
2. **Coordinated Outages:** Planned outages are coordinated among TSOs to minimise their impact on the grid and prevent congestion.
3. **Communication Mechanism:** SAPP utilises an online system viewer to monitor power flows across the grid. This system employs the Inter-Control Centre Protocol (ICCP), facilitating real-time data exchange and coordination among TSOs. The key benefits of this system include:
4. **Real-Time Monitoring:** Enables TSOs to monitor grid conditions and respond quickly to emerging issues.
5. **Data exchange:** Makes it easier for operational data to be shared, improving collaboration and decision-making.
6. **Grid Stability:** Assists in preserving grid stability by guaranteeing that every TSO has access to the same data and can efficiently coordinate their activities.

SAPP has implemented an advanced communication mechanism through an online system viewer, which monitors power flows across the grid. This system leverages the ICCP to facilitate real-time data exchange and coordination among TSOs. The benefits of this system are multifaceted. Real-time monitoring allows TSOs to swiftly identify and respond to emerging grid issues, ensuring more robust and proactive management. Overall, this system contributes significantly to grid stability by ensuring that all TSOs have access to consistent and comprehensive data, enabling them to efficiently coordinate their activities and maintain the integrity of the power network.

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