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Future Development of ASEAN Power Grid: Innovation, Integration and Interconnections

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SYNOPSIS

ASEAN is one of the fastest developing economies in the world. With the rapid expansion of population and economic activities, the regional electricity demand is expected to boom. The pursuit of cross-border power transmission and trade between member states has been one of the key considerations to meet the increasing electricity demand. This can bring economic, environmental and energy security benefits to individual member states and the whole region. To achieve the full potential of the ASEAN Power Grid, the development of the power generation mix, technological innovations and transmission technologies are needed to be well embedded in the joint planning of infrastructure development.

KEY POINTS

- The decarbonisation goals and the booming energy demands in ASEAN make the transition to renewable energy essential.
- The development of energy storage systems plays an important role in supporting the integration of variable renewable energy generations.
- Smart grid developments will impact the modernisation of power grids, which can further support renewable integration and other energy efficiency improvements.
- Recent advancements in transmission technologies have enabled more efficient and reliable electricity transmission, offering improved solutions for energy distribution.

INTRODUCTION

Member states of the Association of Southeast Asian Nations (ASEAN) have long relied on fossil fuels to meet their energy demands. However, the transition from fossil fuels to renewable energy has become critically important as ASEAN countries have submitted their Nationally Determined Contributions (NDCs) under the 2015 Paris Agreement, outlining climate goals and decarbonisation plans to achieve low-carbon economies. ASEAN countries have established diverse renewable energy targets tailored to their unique energy landscapes as a key measure to meet their climate targets and drive energy transition and sustainable development. According to the *7th ASEAN Energy Outlook 2020–2050*, published by the ASEAN Centre for Energy in 2022, Indonesia aims to achieve 23% renewable energy in its primary energy mix by 2025 and 31% by 2050, while Malaysia targets 31% renewable energy share in its power capacity mix by 2025 and 40% by 2035. The Philippines plans to achieve a 35% renewable energy share in its power generation mix by 2030 and 50% by 2040, while Cambodia targets a 25% increase in renewable energy capacity by 2030. Myanmar has set a goal of 39% renewable energy in its electricity generation mix by 2030. Thailand seeks to achieve a 30% renewable energy share in its TFEC by 2037, and Vietnam aims to increase the RE share in power generation to 32% by 2030 and 43% by 2050. Laos leverages its hydropower resources, targeting 30% renewable energy in its total consumption by 2025.

In addition to the individual counties' renewable energy expansion targets, a regional initiative of cross-border grid interconnections called ASEAN Power Grid (APG) has been considered to maximise the region's renewable energy potential. This regional integration with the penetration of renewable energy can reduce greenhouse gas emissions more efficiently by connecting countries with high demand for renewable electricity and countries with excess renewable resources. It can also bring economic and energy security benefits by reducing capital investments in fossil fuel generation capacity for power reserves and diversifying the power generation mix.

ANALYSIS

Abundant Renewable Potential

ASEAN possesses substantial reserves of both fossil fuels and renewable energy resources, yet much of its renewable energy potential remains untapped. Renewable energy accounted for 15.6% of the total primary energy supply in the ASEAN region in 2022. Hydropower is the region's most significant renewable resource, with a 19.8% share of the total installed power generation capacity in 2020, particularly in the Greater Mekong Subregion, Malaysia, Indonesia, and the Philippines. Solar and wind power capacity has significantly increased since the late 2010s. Additionally, geothermal and bioenergy constitute only a small fraction of the power generation mix but hold promise for baseload power generation alongside hydropower. According to the International Energy Agency (IEA), Vietnam leads the region in renewable energy deployment, followed by Thailand, Indonesia, the Philippines, and Malaysia.

While ASEAN boasts abundant wind and solar resources, achieving renewable energy targets remains challenging due to the uneven distribution of these resources. For example, wind power is predominantly viable in Indonesia, Vietnam, and the Philippines, and solar photovoltaic potential varies significantly across geographical areas. These different conditions create surpluses in some countries and deficits in others. For countries with limited renewable energy options, meeting rising electricity demand in a sustainable manner presents a significant hurdle. Exploring the technological potential of renewable resources could provide more affordable and accessible power solutions for these nations.

Sharing renewable energy resources through regional grids offers a practical solution to address these disparities. This approach could help balance the power generation mix, thereby enhancing energy supply stability and mitigating risks associated with reliance on a single fuel source. However, one significant challenge of renewable energy generation lies in the intermittent nature of solar and wind power. Therefore, sufficient energy storage capacity is essential to store excess electricity during periods of high availability, along with an extensive transmission network to deliver power efficiently to load centres.

Emerging Energy Storage Systems

Energy storage systems (ESS) are pivotal in modernising energy grids and integrating renewable energy sources. Incorporating ESS into power grids offers several significant benefits. Typical renewable energy sources, such as solar and wind, are variable renewable energy (VRE) sources that are not easily dispatchable to match demand patterns. Their generation fluctuates significantly depending on the time of day and season. This intermittency can lead to electricity curtailment during peak production periods and destabilisation of the power grid at other times. ESS addresses this challenge by storing excess energy generated during periods of high production and discharging it during periods of high demand. By reducing reliance on dispatchable reserve capacities—often fossil-based and less efficient—ESS promotes a cleaner and more balanced power generation mix.

ESS also play a crucial role in enhancing grid stability and security. They can rapidly respond to fluctuations in grid frequency and provide reliable emergency power during outages, ensuring continuous operations for critical infrastructure. Additionally, by supplying or absorbing reactive power, ESS help maintain voltage levels within safe operating standards, further contributing to grid reliability.

ESS are integral to supporting decentralised energy systems, a growing global trend driven by renewable energy integration. Decentralised systems enable various stakeholders to act as both energy providers and consumers (or "prosumers"). Microgrids, supported by ESS, provide independence, resilience, and flexibility, making them an ideal solution for localised energy needs.

Several large-scale ESS projects highlight the global momentum in energy storage development. The world's largest ESS, the Moss Landing Energy Storage Facility in California, USA, began operations in July 2021 and expanded its capacity to 3 GWh by June 2023. In Southeast Asia, the region's largest ESS was launched in Singapore in December 2022, with a maximum storage capacity of 285 MWh, which is enough to meet the electricity needs of approximately 24,000 households for one day in a single discharge. Both projects utilise lithium-ion battery technology, showcasing its viability for large-scale applications.

Despite the benefits of ESS, the high costs of energy storage make renewable energy projects less cost-competitive with fossil fuels. However, improving grid infrastructure provides a straightforward opportunity to accelerate the deployment of renewable energy. By enhancing grid capabilities, regions can more effectively integrate renewable energy, moving closer to achieving climate targets and a sustainable energy future.

Modernising Smart Grid Technology

The global trends of transitioning to renewable energy and emerging technologies are reshaping the landscape of power grids, with electricity generation becoming increasingly decentralised. For instance, solar panels and wind turbines can be installed in more remote locations to support microgrids that are farther from main power plants. Various advanced grid services are evolving to modernise the grid and support the distributed generation sources. Among these, smart grid technology stands out as a transformative solution, combining advanced technologies and methods to enhance flexibility, availability, energy efficiency, and cost-effectiveness.

Digitalisation is one of the key components of smart grid development. It applies to electricity networks that use digital technologies, sensors, and software to better match the supply and demand of electricity in real time, while minimising costs and maintaining the stability and reliability of the grid. It involves upgrades to advanced metering technology as well as grid automation and control technologies. These improvements can enable further innovation across the value chain, from smart appliances to advanced energy storage technologies. Future energy system management could become more efficient with big data analytics, the Internet of Things (IoT), or even AI-driven energy management systems.

As the clean energy transition drives an increased level of electrification and the integration of VRE across sectors, ensuring grid reliability will become more challenging. Smart grid technologies can manage this transition effectively, reducing the need for costly new grid infrastructure while improving grid resilience and reliability. A smart grid should accommodate all generation and storage options, provide power quality tailored to various needs, optimise asset utilisation and operational efficiency, enhance resilience against disturbances, cyberattacks, and natural disasters, enable customer participation, and support the creation of new products, services, and markets. Smart grid development can also facilitate demand-side management and demand response programmes. With a higher penetration of smart metering technology, more end users could be targeted, resulting in a greater level of load shifting. This enables more efficient use of baseload capacity, minimising total system costs rather than just generation costs. Moreover, a more responsive load makes it easier to mitigate electrical system emergencies.

Harnessing Transmission Technology

High-voltage alternating current (HVAC) and high-voltage direct current (HVDC) are two essential technologies in modern power transmission. HVAC serves as the backbone of most national power grids in ASEAN since its mature technology and cost advantages make it particularly suitable for medium- to short-distance transmission. Its widespread infrastructure and reliable performance are highly effective for local and regional power distribution, supporting both domestic and neighbouring regional electricity needs. The dynamic regulation capabilities of HVAC systems allow grids to adjust transmission capacity in response to fluctuating electricity demand, thereby improving energy efficiency. For example, in Thailand and Vietnam, HVAC systems are extensively used to connect urban centres with remote rural areas, ensuring electricity supply even to the most distant villages.

In contrast, HVDC has emerged as a transformative technology for long-distance and high-capacity power transmission. HVDC systems can significantly reduce energy losses over long distances and connect asynchronous grids, making them ideal for cross-border electricity trade and the integration of large-scale renewable energy projects. In Indonesia, the planned Java-Sumatra HVDC interconnection aims to transfer Sumatra's abundant geothermal and hydropower resources to Java, the country's most populous island with high energy demand. This technology excels at connecting remote renewable energy sources to demand centres. Particularly, voltage source converter HVDC (VSC-HVDC) is well-suited to urban areas and off-grid systems because it places minimal reliance on strong grid support, lowers reactive power requirements, and has a smaller physical and environmental footprint due to less space for installation and reduced ecological impact. Furthermore, its rapid response to power fluctuations enhances the integration of renewable energy. For example, Laos relies on HVDC to export hydropower to Thailand and other neighbouring countries.

To advance the APG, optimising the coexistence of HVAC and HVDC technologies is essential. HVAC, while already forming the current backbone of ASEAN's national grids, needs further refinement to support regional interconnectivity and growing electricity demands. HVDC complements this by addressing the need for long-distance and high-capacity transmission. This combined approach could modernise the transmission infrastructure network of the APG.

CONCLUSION

Establishing interconnections among the power grids of the ASEAN member states is a vital strategy for generating economic benefits, enhancing energy security, and facilitating the transition towards renewable energy. With abundant renewable potential, ASEAN can leverage the emerging maturity of ESS, modernise smart grids, and harness developments in transmission technology to further support the advancement of the APG. While there may be diverse and occasionally conflicting norms, criteria, and interests related to the sharing of resources, multi-objective analysis considering socioeconomic benefits, energy security and renewable penetration could balance the varying interests of different countries. This could also facilitate the collaborative development of regional infrastructure to optimise the utilisation of various resources at different levels. This joint planning can synergise the deployment and dispatch of generation, transmission, and ESS, leading to a more efficient, resilient, reliable, and sustainable power system.

WHAT TO LOOK OUT FOR

- Expanding transmission capacity of ASEAN countries
- Strengthening cross-border frameworks, including regulatory, policy, and technical advancements under bilateral and multilateral agreements for the advancement of APG
- Facilitating VRE integration through the development of power trading markets, such as Vietnam's DPPA program and Thailand's RECs system

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