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India–ASEAN Power Trading and Regional Grid Connectivity: Status, Challenges, and Policy Innovations Required for Acceleration

Bhupendra Kumar SINGH
Chief, Energy Security, Confederation of Indian Industry

Venkatachalam ANBUMOZHI
Senior Research Fellow for Innovations, Economic Research Institute for ASEAN and East Asia (ERIA)

Rakesh Kumar AGARWAL
Ex-Executive Director, SJVN Limited and Consultant, Solar Energy Corporation of India

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Abstract: *Advancing power trade requires efficient grid connectivity. In 2018, India launched the One Sun, One World, One Grid (OSOWOG) initiative, which aims to connect India to Southeast Asia – facilitating increased power trade. Despite many challenges, such as regulatory disparities, infrastructure limitations, and geopolitical complexities, regional grid connectivity between India and Southeast Asia would bring many opportunities for investment, technology transfer, and employment generation. To achieve these, strategic interventions are required to harmonise regulatory frameworks, invest in advanced infrastructure, and foster diplomatic engagement.*

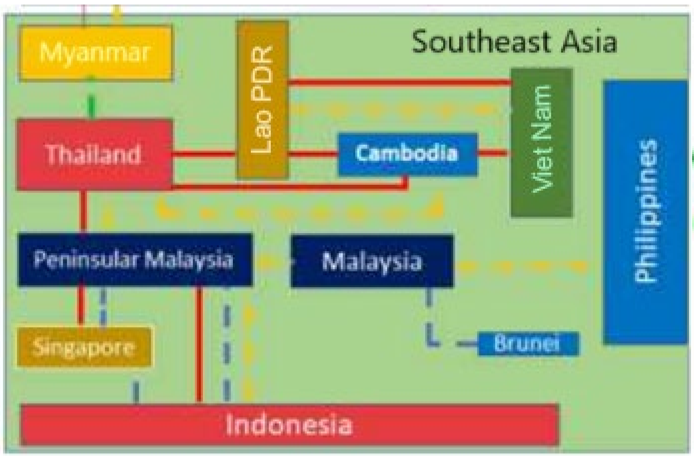
Keywords: Cross-border power trade, grid connectivity, energy security, sustainability, regional cooperation
JEL classifications: Q41,Q43, Q35, Q37, Q48

1. Introduction

India shares a deep and long-standing relationship with the Association of Southeast Asian Nations (ASEAN) Member States (AMS), built on economic, cultural, and geopolitical ties. The ASEAN–India Free Trade Area has significantly boosted trade and investment between India and ASEAN. Energy cooperation, especially in electricity trading, is a key part of this partnership and has the potential to enhance regional stability and economic growth.

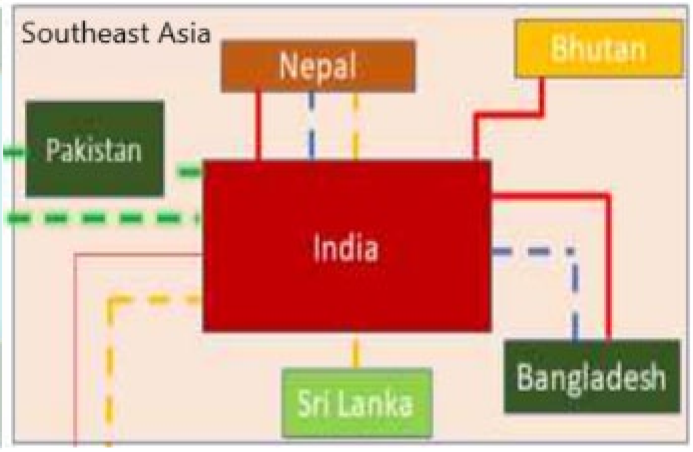
Cross-border power transfers between India and its neighbours occur through bilateral agreements, as shown in Figures 1 and 2. These agreements cover various aspects, including planning interconnections, system operations, commercial agreements, and regulatory matters.

Figure 1: Power Interconnections Within Southeast Asia



Source: Author.

Figure 2: Power Interconnections Within Southeast Asia



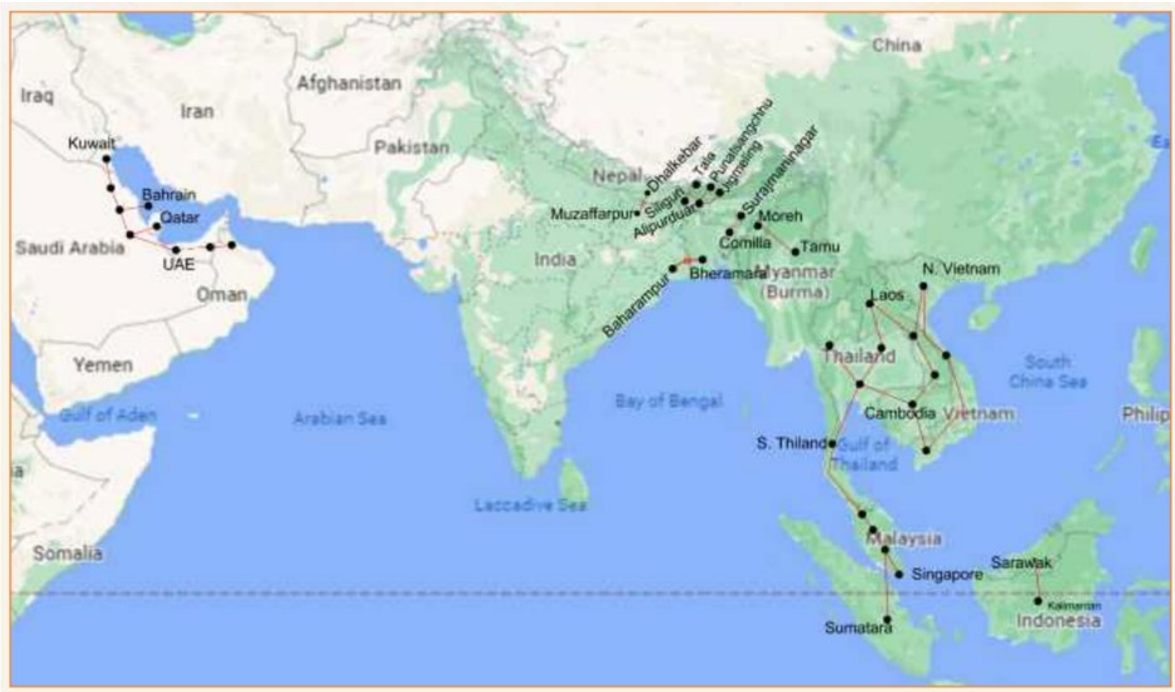
Source: Author.

India, strategically located in South Asia, shares borders with several South Asian Association for Regional Cooperation (SAARC)/Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) countries, such as Bhutan, Bangladesh, Myanmar, Nepal, and Sri Lanka. It plays a crucial role in planning interconnections with these countries, aiming for effective utilisation of regional resources and ensuring energy security for the entire region. The current and planned cross-border interconnections between India and its neighbouring countries reflect this commitment.

1.1. One Sun, One World, One Grid

The One Sun, One World, One Grid (OSOWOG) initiative was proposed by India's Prime Minister at the First Assembly of the International Solar Alliance in October 2018. The vision behind OSOWOG is based on the idea that the sun never sets. The initiative aims to connect regional grids to a common grid to transfer power generated from renewable energy, especially solar energy. Figure 3 shows the proposed interconnection between India and ASEAN.

Figure 3. Proposed Interconnections Between Indian and ASEAN



ASEAN = Association of Southeast Asian Nations.
Source: Central Electricity Authority (2023b).

Electricity interconnections and trading offer significant opportunities for diplomatic and economic engagement, providing a platform for dialogue and collaboration in areas of mutual interest. This cooperation can build confidence, strengthen ties, and foster trust amongst countries. Facilitating large-scale clean energy development diversifies the generation mix and supply, ensuring energy security and reducing carbon emissions towards net zero.

Optimal utilisation of unevenly distributed energy resources like hydropower and other renewable energies enhances operational efficiency. Economies in operation are achieved by harnessing peak demand diversity, sharing balancing reserves, improving load factors, and deferring investments in storage systems. Economies of scale are realised with large power plants near energy resources and streamlined transmission infrastructure. Grid stability improves with stable frequency and voltage profiles, reliable power system operation, and emergency support. Finally, a vibrant power market can normalise electricity prices, benefiting all participating countries.

Globally, there is a strong focus on transitioning to renewable energy to enhance energy security. With the sun always shining on one part of the planet, harnessing solar, wind, and water energy can produce enough clean power to meet global demand. To achieve this, we need to establish transnational electricity exchanges through interconnected grids. This vision of interconnected grids aims to ensure energy security and promote sustainability.

Recent trends show a significant shift from fossil fuels to clean energy, with growing investments in renewable energy sources. The idea of transnational grid connections, captured by the motto 'One Earth, One Family, One Future', is gaining momentum. It offers a promising solution to achieving energy security and tackling the climate crisis.

2.1 Framework for Cooperation on Developing Transnational Grid Connections for Energy Security

The development of transnational grid connections between India and AMS represents a transformative step towards ensuring regional energy security and cooperation. By establishing a robust framework for collaboration, these nations can effectively harness and share renewable energy resources, bolster economic growth, and enhance geopolitical stability. This framework encompasses political directives, feasibility studies, regulatory harmonisation, operational protocols, and sustainable capacity building – all aimed at creating an integrated and resilient energy network. Such an initiative not only addresses the pressing need for clean and reliable energy but also fosters a spirit of unity and mutual progress across the region.

2.1.1. Political/Governmental Direction

- Intergovernmental cooperation:
  - Facilitate government-to-government dialogue to establish a shared vision
  - Sign memoranda of understanding (MoUs) or charters to formalise commitments
  - Develop an institutional framework to support cooperation
  - Secure financing for the initiatives

2.1.2. Feasibility and Planning

- Technical studies for regional grid interconnections:
  - Identify optimal locations, capacities, and types of interconnection links
  - Establish common technical specifications
  - Conduct techno-economic studies to evaluate viability
  - Define operating parameters

- Develop detailed implementation plans

2.1.3. Rules and Regulations

- Regulatory and legal mechanisms:
  - Determine ownership and operational responsibilities
  - Set up licensing procedures
  - Establish tariff determination methods
  - Create network access procedures
  - Harmonise regulatory norms and establish a common minimum grid code and standards
  - Develop dispute settlement mechanisms

2.1.4. Monitoring Frameworks

- Commercial aspects:
  - Define modes of transactions (bilateral, trilateral, and multilateral)
  - Clarify ownership and operation and maintenance responsibilities
  - Plan for funding and recovery of capital expenditures and operational expenditures
  - Implement market mechanisms for power purchase agreements and transmission service agreements, and set up trading platforms
  - Ensure network access

2.1.5. Operations

- Operational framework:
  - Manage network control and operations
  - Schedule and conduct maintenance activities
  - Handle energy scheduling, accounting, metering, and billing
  - Oversee revenue collection and distribution
  - Provide communication and ancillary services

2.1.6. Sustainability

- Sustainable capacity building:
  - Focus on staffing requirements
  - Offer training and education programmes
  - Promote skill development initiatives
  - Share best practices
  - Foster technological advancements
  - Support renovation, innovation, and development efforts

3. Benefits of Regional Grid Interconnections

Energy cooperation is crucial for regional energy security, economic growth, and sustainable development. As energy demands rise, especially in developing economies, working together on power trading can help optimise resources and boost stability. By sharing electricity infrastructure across borders, neighbouring countries can enhance regional cooperation and integration, driving overall economic development.

The scope of energy cooperation between India and AMS encompasses energy diversification, increased energy security, and significant economic growth. Collaborative efforts in developing renewable energy projects, enhancing grid connectivity, and creating robust infrastructure can lead to a more stable, secure, and sustainable energy future for the region. By leveraging each country's strengths and resources, India and ASEAN can achieve the mutual goal of a green and sustainable energy transition.

3.1. Energy Diversification

3.1.1. Diversification of Energy Sources

Hydropower: Countries like Bhutan and Nepal have abundant hydropower resources. India could import hydroelectric power from these countries, diversifying its energy mix and reducing reliance on coal and other fossil fuels.

Solar and wind energy: AMS, particularly those with vast coastal areas and sunny climates, have significant potential for solar and wind energy. Collaborative projects can harness these renewable resources, providing clean energy alternatives.

Biomass and biofuels: Southeast Asia, with its extensive agricultural activities, has potential for biomass and biofuel production. India and AMS could collaborate on developing technologies and infrastructure for biomass energy, promoting sustainable energy practices.

3.1.2. Regional Grid Integration

ASEAN Power Grid: The ASEAN Power Grid (APG) initiative aims to connect the power systems of AMS. India's involvement in this regional grid integration could enhance the stability and reliability of power supply across borders.

Cross-border transmission lines: Building cross-border transmission lines with neighbouring countries like Bangladesh, Myanmar, and Sri Lanka could facilitate the exchange of electricity and balance supply and demand variations.

3.2. Energy Security

3.2.1. Reduced Dependency on Single Sources

Diversified supply sources: By importing electricity from multiple neighbouring countries and developing regional energy projects, India could reduce its dependency on a single energy source, enhancing overall energy security.

Strategic reserves and backups: Collaborative efforts can lead to the development of strategic energy reserves and backup systems, ensuring continuous and reliable energy supply during crises.

3.2.2. Enhanced Resilience to Supply Disruptions

Regional collaboration: In the case of natural disasters or geopolitical tensions, regional cooperation ensures mutual support and quick recovery. Shared infrastructure and resources can mitigate the impact of supply disruptions.

Interconnected grids: Interconnected grids allow for the transfer of electricity between countries, providing flexibility and resilience against localised power outages or shortages.

3.3. Economic Growth

- **Job creation:** Energy projects – including the construction of power plants, transmission lines, and renewable energy installations – generate employment opportunities. These projects create jobs in engineering, construction, operations, and maintenance, contributing to economic development.
- **Local economic development:** Energy infrastructure projects stimulate local economies by creating demand for goods and services. Investments in energy projects lead to the development of ancillary industries, boosting overall economic activity.
- **Cost savings and efficiency gains:** Regional cooperation in energy projects can achieve economies of scale, reducing costs for participating countries. Shared infrastructure investments spread costs and risks, making projects more economically viable.
- **Optimised resource utilisation:** Cross-border energy cooperation enables the optimal use of resources, balancing energy production and consumption across the region. Efficient resource utilisation reduces energy wastage and improves overall system efficiency.
- **Reduced energy costs:** Collaborative projects, especially in renewable energy, can lower the cost of energy generation. For instance, large-scale solar and wind projects

benefit from declining technology costs and increased efficiency, reducing overall energy prices.

3.3.1. Trade and Investment Opportunities

- **Increased trade volumes:** Energy cooperation can lead to increased cross-border electricity trade, enhancing economic ties and creating new markets for energy resources.
- **Foreign direct investment:** Joint energy projects attract foreign direct investment, stimulating economic growth and creating jobs in both India and AMS.
- **Public–private partnerships:** Encouraging public–private partnerships (PPPs) in energy projects can lead to the development of innovative and efficient energy solutions. PPPs can mobilise private sector resources and expertise, complementing public sector efforts.

3.3.2 Infrastructure Development

- **Transmission and distribution networks:** Developing robust transmission and distribution networks is essential for cross-border energy trade. These infrastructure projects generate economic activity, boost local economies, and create employment opportunities.
- **Renewable energy projects:** Investment in renewable energy projects, such as solar farms, wind turbines, and hydroelectric plants, drives technological innovation, infrastructure development, and economic diversification.

3.4. Environmental Sustainability

3.4.1. Reduced Carbon Emissions

- **Shift to renewable energy:** Collaboration on renewable energy projects helps reduce reliance on fossil fuels, lowering greenhouse gas emissions and contributing to global climate goals.
- **Cleaner energy mix:** By incorporating hydropower, solar, and wind energy into the regional energy mix, India and AMS can achieve a cleaner and more sustainable energy profile.
- **Compliance with global standards:** Regional energy cooperation encourages compliance with global environmental and sustainability standards. Adhering to these standards enhances the region’s reputation and attractiveness for international investments.

3.4.2. Sustainable Development Goals

- **Promoting green energy:** Joint efforts in promoting green energy contribute to achieving the Sustainable Development Goals (SDGs) related to affordable and clean energy, climate action, and sustainable economic growth.
- **Environmental protection:** Sustainable energy projects minimise environmental impacts, protecting biodiversity and natural resources and promoting environmental stewardship.

3.5. Regional Energy Exchange Platforms

- **Energy trading hubs:** Establishing regional energy trading hubs can facilitate efficient energy exchange and market integration. These hubs can serve as platforms for trading electricity, natural gas, and other energy commodities, enhancing market liquidity and price transparency.
- **Harmonised regulations:** Harmonising regulations and standards across the region can create a conducive environment for energy trade. Consistent policies and regulatory frameworks can attract investments and promote seamless cross-border energy transactions.

4. Status of Energy Trade and Integration with Neighbouring Countries (South and Southeast Asia)

On 18 December 2018, the Ministry of Power issued the Guidelines for Import/Export (Cross-Border) of Electricity 2018 with several key objectives: to facilitate the import and export of electricity between India and neighbouring countries; to develop a dynamic and robust electricity infrastructure for these exchanges; to promote transparency, consistency, and predictability in the regulatory mechanisms governing electricity trade; and to ensure reliable grid operation and transmission for cross-border electricity flows.

The Ministry of Power has appointed the Member (Power Systems) of the Central Electricity Authority as the Designated Authority under Clause 4.2 of the 'Guidelines for Import/Export (Cross-Border) of Electricity 2018'. On 26 February 2021, the 'Procedure for Approval and Facilitating Import/Export (Cross-Border) of Electricity' was issued.

4.1. SAARC Framework Agreement

The SAARC Framework Agreement for Energy Cooperation (Electricity) was signed by member countries of SAARC during the 18th SAARC Summit held at Kathmandu, Nepal on

26–27 November 2014. This agreement, amongst others, has enabling provisions for the following:

(i) Cross-border trading of electricity on a voluntary basis.

(ii) Planning of cross-border grid interconnection by government transmission planning agencies through bilateral/trilateral/mutual agreements, based on the needs of trade in the near future through studies and sharing technical information required for the same.

(iii) Building, owning, operating, and maintaining the associated transmission system of cross-border interconnections within the respective national boundaries and/or interconnected at mutually agreed locations.

(iv) Joint development of coordinated network protection systems incidental to the cross-border interconnection to ensure reliability and security of the grids of the member countries.

(v) Joint development of coordinated procedures for the secure and reliable operation of the interconnected grids and to prepare scheduling, dispatch, energy accounting, and settlement procedures for cross-border trade.

4.1.1. APG

The APG initiative aims to create a regional grid by connecting the power systems of AMS. This project enhances energy security, promotes renewable energy integration, and fosters regional stability by creating interdependencies and shared benefits.

4.1.2. South Asia Cross-Border Capacity

Table 1 shows capacity of power trade between India and neighbouring countries and Table 2 indicates electricity trade among India and South Asian Countries. Figure 4 depicts transmission connectivity between India and South Asia.

Table 1: Capacity of Power Trading Through Cross-Border Links Between India and Neighbouring Countries

Country	Existing (MW)	Under Construction (MW)	Planned (MW)	Total (MW)
India-Bangladesh	1160	0	0	1160
India-Bhutan	2070	2220	0	4290
India-Myanmar	3	0	250	253
India-Nepal	1000	1970	0	2970
India-Sri Lanka	0	0	500	500
Total	4233	4190	750	9173

MW = megawatt.
Source: Grid Controller of India Limited (2024).

Table 2: Import and Export Power Trade Between India and South Asian Countries, April, May, and June 2024

16. Transnational Electricity Trade with Bhutan, Nepal, Bangladesh, and Myanmar April 2024 to March 2025 Transnational Exchange ('Export from'/'Import to' India)								
MONTH	BHUTAN		NEPAL		BANGLADESH		MYANMAR	
	Energy Exported (MU)	Energy Imported (MU)	Energy Exported (MU)	Energy Imported (MU)	Energy Exported (MU)	Energy Imported (MU)	Energy Exported (MU)	Energy Imported (MU)
APR'24	86.47	18.58	346.08	0.00	694.34	0.00	0.76	0.00
MAY'24	51.37	68.17	271.84	3.92	655.55	0.00	0.74	0.00
JUN'24	0.00	520.23	20.51	152.32	709.14	0.00	0.87	0.00
Total	**137.84**	**606.98**	**638.42**	**156.24**	**2,059.03**	**0.00**	**2.37**	**0.00**
*Based on daily operational data								

MU = million units of electricity.
Source: Grid Controller of India Limited (2024).

Table 3: Power Trade in South Asia (Imports), June 2024

Imports from Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	Imports from Bhutan								Imports from Bangladesh		Imports from Nepal			Imports from Myanmar
	400 kV Tala–Binaguri I,II & IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur–Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
1-Jun-24	1.63	0.00	0.00	0.00	2.12	3.18	0.56	0.00	0.00	0.00	0.00	2.38	0.00	0.00
2-Jun-24	1.64	0.00	0.00	0.00	1.66	2.49	0.59	0.00	0.00	0.00	0.00	2.06	0.00	0.00
3-Jun-24	1.41	0.00	0.00	0.00	1.79	2.69	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-Jun-24	0.14	0.00	0.00	0.00	2.38	3.58	0.00	0.00	0.00	0.00	0.00	2.98	0.00	0.00
5 Jun-24	2.48	0.18	0.00	0.00	2.77	4.17	1.09	0.00	0.00	0.00	0.00	1.87	0.00	0.00
6-Jun-24	0.57	0.00	0.00	0.00	2.29	3.45	1.13	0.00	0.00	0.00	0.00	2.64	0.00	0.00
7-Jun-24	0.20	0.00	0.00	0.00	1.65	2.48	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Imports from Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	Imports from Bhutan								Imports from Bangladesh		Imports from Nepal			Imports from Myanmar
	400 kV Tala–Binaguri I,II & IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur–Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
8-Jun-24	0.00	0.00	0.00	0.00	1.97	2.96	1.04	0.00	0.00	0.00	0.00	2.05	0.00	0.00
9-Jun-24	0.35	0.00	0.00	0.00	2.00	3.01	0.82	0.00	0.00	0.00	0.00	0.53	0.00	0.00
10-Jun-24	0.09	0.00	0.00	0.00	1.55	2.32	1.05	0.00	0.00	0.00	0.00	2.00	0.00	0.00
11-Jun-24	0.45	0.00	0.00	0.00	1.57	2.36	0.94	0.00	0.00	0.00	0.00	2.74	0.00	0.00
12-Jun-24	0.94	0.00	0.00	0.00	3.15	4.74	1.07	0.01	0.00	0.00	0.00	3.68	0.00	0.00
13-Jun-24	3.29	0.30	0.00	0.00	4.94	7.43	1.18	0.00	0.00	0.00	0.00	4.50	0.00	0.00
14-Jun-24	5.62	1.66	0.00	0.00	6.02	9.04	1.12	0.43	0.00	0.00	0.00	6.12	0.00	0.00

Imports from Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	Imports from Bhutan								Imports from Bangladesh		Imports from Nepal			Imports from Myanmar
	400 kV Tala–Binaguri I,II & IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur–Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
15-Jun-24	5.92	2.03	0.00	0.00	3.98	5.99	0.80	0.00	0.00	0.00	0.00	7.32	0.00	0.00
16-Jun-24	8.25	3.14	0.21	0.00	4.22	6.34	0.79	0.06	0.00	0.00	0.00	6.20	0.02	0.00
17-Jun-24	9.65	3.07	0.07	0.00	4.05	6.10	0.82	0.08	0.00	0.00	0.00	6.20	0.03	0.00
18-Jun-24	8.75	3.25	0.00	0.00	3.85	5.79	0.78	0.01	0.00	0.00	0.00	8.69	0.03	0.00
19-Jun-24	10.02	3.23	0.00	0.00	3.94	5.91	0.73	0.00	0.00	0.00	0.00	11.63	0.03	0.00
20-Jun-24	14.41	3.67	0.23	0.00	5.58	8.40	0.92	0.19	0.00	0.00	0.00	12.26	0.23	0.00
21-Jun-24	10.92	3.08	0.35	0.00	6.17	9.28	1.23	0.41	0.00	0.00	0.00	11.61	0.21	0.00

Imports from Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	Imports from Bhutan								Imports from Bangladesh		Imports from Nepal			Imports from Myanmar
	400 kV Tala–Binaguri I,II & IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur–Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
22-Jun-24	8.63	1.75	0.01	0.00	4.40	6.61	1.26	0.00	0.00	0.00	0.15	11.15	0.04	0.00
23-Jun-24	9.38	2.00	0.16	0.00	4.34	6.52	1.25	0.25	0.00	0.00	0.00	10.03	0.03	0.00
24-Jun-24	8.63	2.29	0.41	0.00	5.69	8.56	0.98	0.42	0.00	0.00	0.00	7.67	0.01	0.00
25-Jun-24	15.45	1.48	0.49	0.00	6.60	9.24	1.07	0.34	0.00	0.00	0.00	10.86	0.01	0.00
26-Jun-24	13.64	3.37	0.43	0.00	6.25	9.39	0.90	0.40	0.00	0.00	0.00	10.84	0.15	0.00
27-Jun-24	12.49	3.96	0.41	0.00	5.99	9.01	1.30	0.27	0.00	0.00	0.11	10.62	0.06	0.00
28-Jun-24	10.03	2.59	0.00	0.00	6.32	9.49	1.24	0.32	0.00	0.00	0.09	11.39	0.03	0.00

Imports from Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	**Imports from Bhutan**								**Imports from Bangladesh**		**Imports from Nepal**			**Imports from Myanmar**
	400 kV Tala– Binaguri I,II & IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur– Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
29-Jun-24	13.43	3.41	0.96	0.00	6.67	10.00	1.14	0.40	0.00	0.00	0.56	11.97	0.05	0.00
30-Jun-24	13.88	3.59	0.78	0.00	6.77	10.16	1.02	0.36	0.00	0.00	0.82	11.69	0.01	0.00
Total	**192.31**	**48.05**	**4.53**	**0.00**	**120.67**	**180.69**	**27.86**	**3.95**	**0.00**	**0.00**	**1.73**	**193.69**	**0.94**	**0.00**
Based on SEM/Energy meter data for links where available (*Mangdechu generation receipt at APD through a bypassed arrangement at 400 kV Punatsanchu station)														

APD = avalanche photodiode, D/C = direct current, kV = kilovolt, MU = million units of electricity, SEM = storage energy mechanism.
Note: Totals may not be exact due to rounding.
Source: Grid Controller of India Limited (2024).

Table 4: Power Trade in South Asia (Exports), June 2024

Exports to Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	Exports to Bhutan								Exports to Bangladesh		Exports to Nepal			Exports to Myanmar
	400 kV Tala–Binaguri I,II &IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur– Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
1-Jun-24	0.00	0.18	2.15	1.40	0.00	0.00	0.00	0.31	21.16	2.04	0.99	0.00	1.56	0.03
2-Jun-24	0.00	0.20	2.39	1.55	0.00	0.00	0.00	0.39	21.14	2.11	0.92	0.00	1.50	0.03
3-Jun-24	0.00	0.31	2.29	1.60	0.00	0.00	0.00	0.47	21.18	1.91	1.04	0.14	2.04	0.03
4-Jun-24	0.00	0.82	1.90	1.52	0.00	0.00	0.00	0.23	21.48	1.99	1.06	0.00	1.61	0.03
5 Jun-24	0.00	0.00	1.89	1.31	0.00	0.00	0.00	0.19	21.40	2.10	1.11	0.00	1.89	0.03
6-Jun-24	0.00	0.87	2.70	1.27	0.00	0.00	0.00	0.19	21.55	2.01	1.04	0.00	1.27	0.03

Exports to Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	Exports to Bhutan								Exports to Bangladesh		Exports to Nepal			Exports to Myanmar
	400 kV Tala–Binaguri I,II &IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur–Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
7-Jun-24	0.00	1.06	2.02	0.35	0.00	0.00	0.00	0.11	21.55	1.69	0.95	0.06	1.77	0.03
8-Jun-24	0.52	1.42	2.49	0.00	0.00	0.00	0.00	0.10	21.48	1.85	1.05	0.00	1.75	0.03
9-Jun-24	0.00	1.00	2.79	0.00	0.00	0.00	0.00	0.22	21.48	2.10	1.07	0.00	1.78	0.03
10-Jun-24	0.00	1.06	2.33	0.00	0.00	0.00	0.00	0.09	21.40	1.85	1.06	0.00	1.99	0.03
11-Jun-24	0.00	0.80	2.86	0.00	0.00	0.00	0.00	0.05	21.33	1.97	1.08	0.00	1.77	0.03
12-Jun-24	0.00	1.37	2.36	0.00	0.00	0.00	0.00	0.00	21.49	2.08	1.06	0.00	1.99	0.01
13-Jun-24	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.24	21.56	1.65	1.02	0.00	2.20	0.01

Exports to Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	**Exports to Bhutan**								**Exports to Bangladesh**		**Exports to Nepal**			**Exports to Myanmar**
	400 kV Tala– Binaguri I,II &IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur– Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
14-Jun-24	0.00	0.00	0.68	0.04	0.00	0.00	0.00	0.00	16.82	1.50	0.92	0.00	2.24	0.02
15-Jun-24	0.00	0.00	0.27	0.41	0.00	0.00	0.00	0.08	21.35	1.64	1.00	0.00	1.91	0.02
16-Jun-24	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	21.20	1.68	0.96	0.00	0.00	0.03
17-Jun-24	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	22.17	1.76	0.85	0.00	0.00	0.09
18-Jun-24	0.00	0.00	0.19	0.82	0.00	0.00	0.00	0.00	22.49	1.73	1.01	0.00	0.00	0.03
19-Jun-24	0.00	0.00	0.11	0.84	0.00	0.00	0.00	0.00	22.55	1.34	0.86	0.00	0.00	0.03
20-Jun-24	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	22.54	1.39	0.06	0.00	0.00	0.03

Exports to Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	**Exports to Bhutan**								**Exports to Bangladesh**		**Exports to Nepal**			**Exports to Myanmar**
	400 kV Tala–Binaguri I,II &IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur–Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
21-Jun-24	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	22.43	1.59	0.45	0.00	0.00	0.01
22-Jun-24	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.19	22.43	1.85	0.00	0.00	0.00	0.02
23-Jun-24	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	22.32	2.00	0.66	0.00	0.00	0.03
24-Jun-24	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	22.31	2.13	0.80	0.00	0.00	0.03
25-Jun-24	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	22.43	2.14	0.89	0.00	0.00	0.04
26-Jun-24	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	22.40	1.96	0.58	0.00	0.00	0.03
27-Jun-24	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	22.03	2.04	0.00	0.00	0.00	0.03

Exports to Neighbouring Countries during Jun 2024 (All figures in MU)														
Date	**Exports to Bhutan**								**Exports to Bangladesh**		**Exports to Nepal**			**Exports to Myanmar**
	400 kV Tala–Binaguri I,II &IV	400 kV Binaguri – Malbase	220 kV Birpara – Chuka D/C	220 kV Birpara – Malbase	400kV Punatsanchu – Alipurdwar D/C*	400kV Jigmelling – Alipudwar D/C	132 kV Rangia – Motanga	132 kV Salakati – Gelephu	400 kV Behrampur – Bheramara 1,2,3&4	132 kV Surjyamaninagar – Comilla D/C	132 kV Tanakpur– Mahendranagar	400 kV Muzaffarpur – Dhalkebar	From BIHAR Source	11 kV Moreh – Tamu
28-Jun-24	0.00	0.00	1.35	0.60	0.00	0.00	0.00	0.00	22.13	1.75	0.00	0.00	0.00	0.03
29-Jun-24	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	22.40	1.79	0.00	0.00	0.00	0.03
30-Jun-24	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	22.57	1.67	0.00	0.00	0.00	0.03
Total	**0.52**	**9.08**	**31.84**	**16.02**	**0.00**	**0.00**	**0.00**	**2.86**	**650.77**	**55.34**	**22.48**	**0.20**	**27.26**	**0.87**

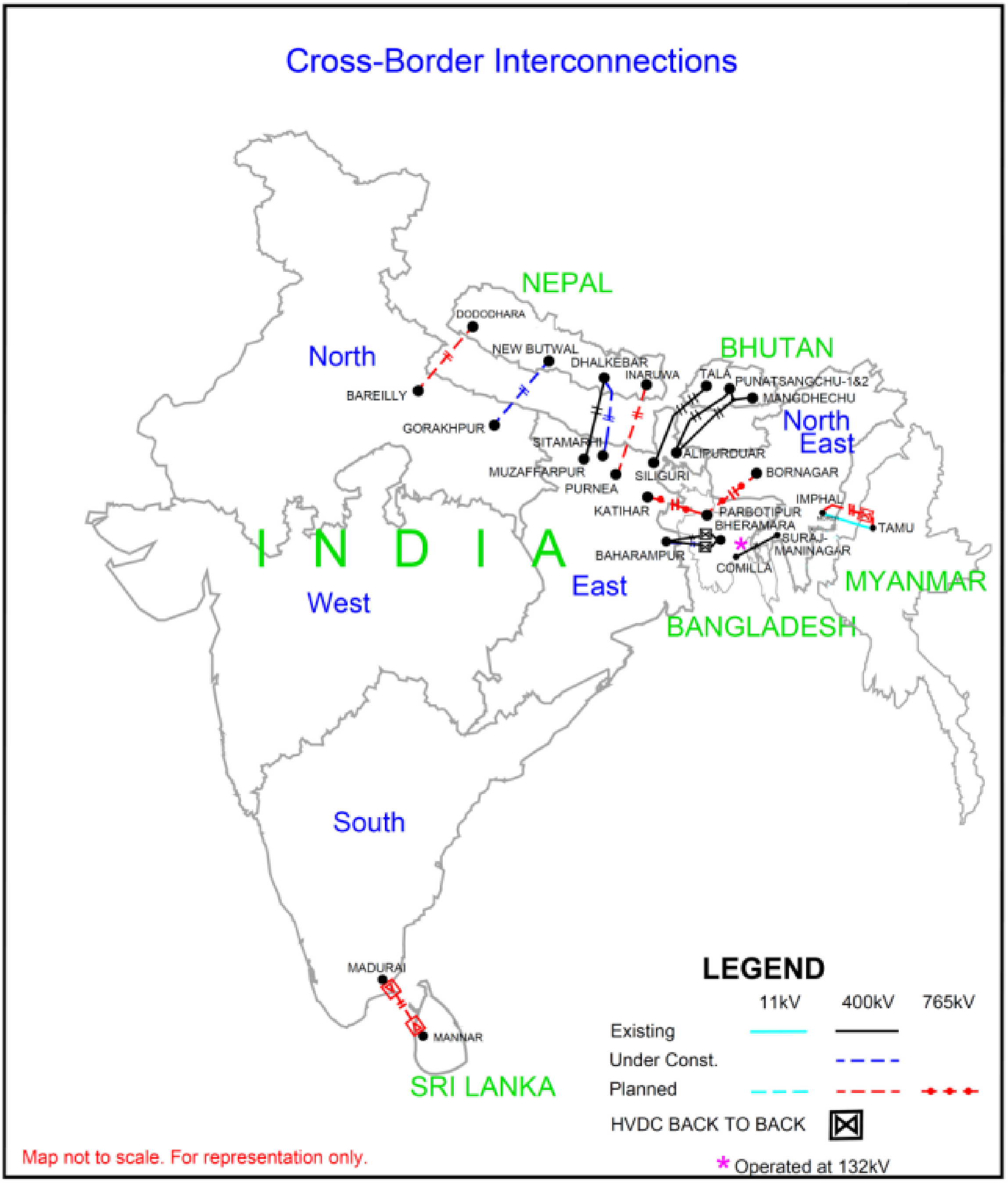
Note: Totals may not be exact due to rounding.
Source: Grid Controller of India Limited (2024).

Table 5: Power Trade in South Asia

Power Market Information Exchanges Through Power Exchanges, June 2024			
S No.	**Regional Entity**	**Through Power Exchanges** (MU) (DAM + HP DAM +RTM)	
Through NR Region			
1.	NEA Nepal, Upper Chameliya HPP (NR)	2.24	0.00
2.	NEA Nepal, Upper Kalangaggad HPP new (NR)	2.02	0.00
3.	NEA Tanakpur (NR)	0.00	14.63
Through ER Region			
1.	Basotho HPP, Bhutan	14.58	0.00
2.	Chilime HPP, NEA	4.71	0.00
3.	Chuzachen HEP	0.17	0.00
4.	Devighat, NEA	3.00	0.00
5.	Kaligandaki, NEA	41.16	0.00
6.	Kabeli B1 HPP, NEA	1.47	0.00
7.	Likhu IV NEA	1.05	0.00
8.	Marsyangdi	22.06	0.00
9.	NEA Bihar STU	0.00	27.78
10.	NEA Upper Dordi HPP, NEA	1.72	0.00
11.	NEA Muzaffarpur	0.00	17.86
12.	NEA Middle Marsyangdi	21.51	0.00
13.	Nikachhu HPP	4.92	0.00
14.	Solu HPP, NEA	5.46	0.00
15.	Trishuli Nepal NEA	5.89	0.00

Sources: Grid Controller of India Limited (2024); IEX; and PXIL.

Figure 4: Cross-Border Interconnection Links in South Asia



HVDC = high-voltage direct current, kV = kilovolt.
Source: Central Electricity Authority (2023b).

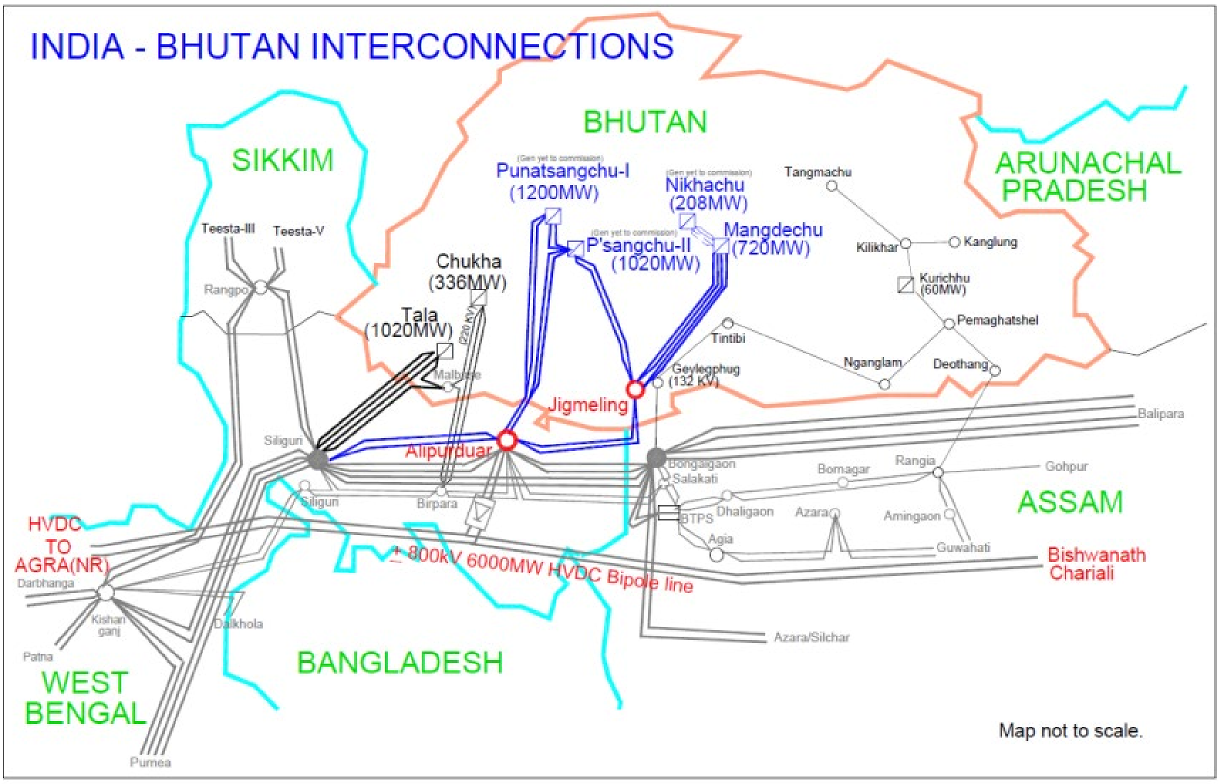
4.2. Interconnections Between India and Bhutan

4.2.1. Agreement on Cooperation in Hydropower

The governments of India and Bhutan signed an agreement on ‘Cooperation in the Field of Hydroelectric Power’ on 28 July 2006. The agreement, amongst others, envisages the development and construction of hydropower projects and associated transmission systems as well as trade in electricity between the two countries, both through public and private sector participation.

India and Bhutan signed an agreement to develop 10,000 megawatts (MW) of hydropower projects in Bhutan with Indian assistance by 2020. Major projects under this agreement include Tala (1,020 MW), Chukha (336 MW), and Kurichhu (60 MW). The power generated is exported to India, generating significant revenue for Bhutan and providing clean energy to India.

Figure 5: India–Bhutan Interconnections



BTPS = Ballari Thermal Power Station, HVDC = high-voltage direct current, kV = kilovolt, MW = megawatt, NR = Northern Region.
Source: Central Electricity Authority (2023b).

4.2.2 Hydropower Development and Trade Agreement

- **Date:** 2009
- **Details:** This agreement outlines the framework for joint ventures and bilateral cooperation in developing hydropower projects. The agreement covers financing, construction, and power purchase agreements, ensuring that a significant portion of the power generated is sold to India.

In 2024, about 2,070 MW of power was exported to India from existing hydropower projects in Bhutan. The associated cross-border transmission system for evacuation and transfer of power from these Hybrid Energy Power Systems (HEPSs) is operated in synchronism with the Indian Grid.

India and Bhutan have a strong energy partnership, primarily focused on hydropower. Bhutan exports about 70% of its hydroelectric power to India. Major projects include the Chukha, Tala, and Mangdechhu hydroelectric plants.

4.2.3. Current Projects

Chukha HEP (336 MW):

- Chukha (Bhutan)–Birpara (West Bengal) 220-kilovolt (kV) direct current (D/C) line
- Chukha (Bhutan)–Birpara (West Bengal) via Singhigaon (Bhutan) 220 kV series compensation (S/C) line

Kurichu HEP (60 MW):

- Kurichu (Bhutan)–Gelephu (Bhutan)–Salakati (Assam) 132 kV S/C line

Tala HEP (1020 MW):

- Tala (Bhutan)–Siliguri (West Bengal) 400 kV 2 x D/C lines (one of the circuits of a D/C line is LILOed at Malbase S/S in Bhutan)

Dagachu HEP (126 MW):

- Power from Dagachhu HEP is exported to India using the transmission system associated with Chukha and Tala HEPs through the Dagachhu–Tsirang–Rurichhu–Chukha 220 kV S/C line.

Mangdechu HEP (720 MW):

- Jigmeling–Alipurduar 400 kV D/C (Quad) line

Punatsangchu I HEP (1,200 MW):

- Punatsangchu I–Alipurduar 400 kV D/C (Quad) line

Punatsangchu II HEPS (1,020 MW):

- Punatsangchu II–Alipurduar 400 kV D/C (Quad) line

  (Punatsanghu I and II HEPSs are yet to be commissioned, but the associated transmission line works have been completed)

Power from the HEPSs in Bhutan along with other hydro projects in Sikkim and the Northeast Region could be transferred to other parts of India through the high-capacity multiterminal ±800 kV, 6,000 MW Biswanath–Chariali–Alipurduar–Agra high-voltage direct current (HVDC) bipole link.

4.2.4. Future Planning

- Additional projects like the Punatsangchhu I and II and Kholongchhu are in the pipeline:
  - Punatsangchhu I (1,200 MW), Punatsangchhu II (1,020 MW), Kholongchhu (600 MW).
- Focus on increasing capacity and improving grid infrastructure to facilitate higher exports:
  - Increasing hydroelectric capacity and grid infrastructure.

4.3. India–Nepal

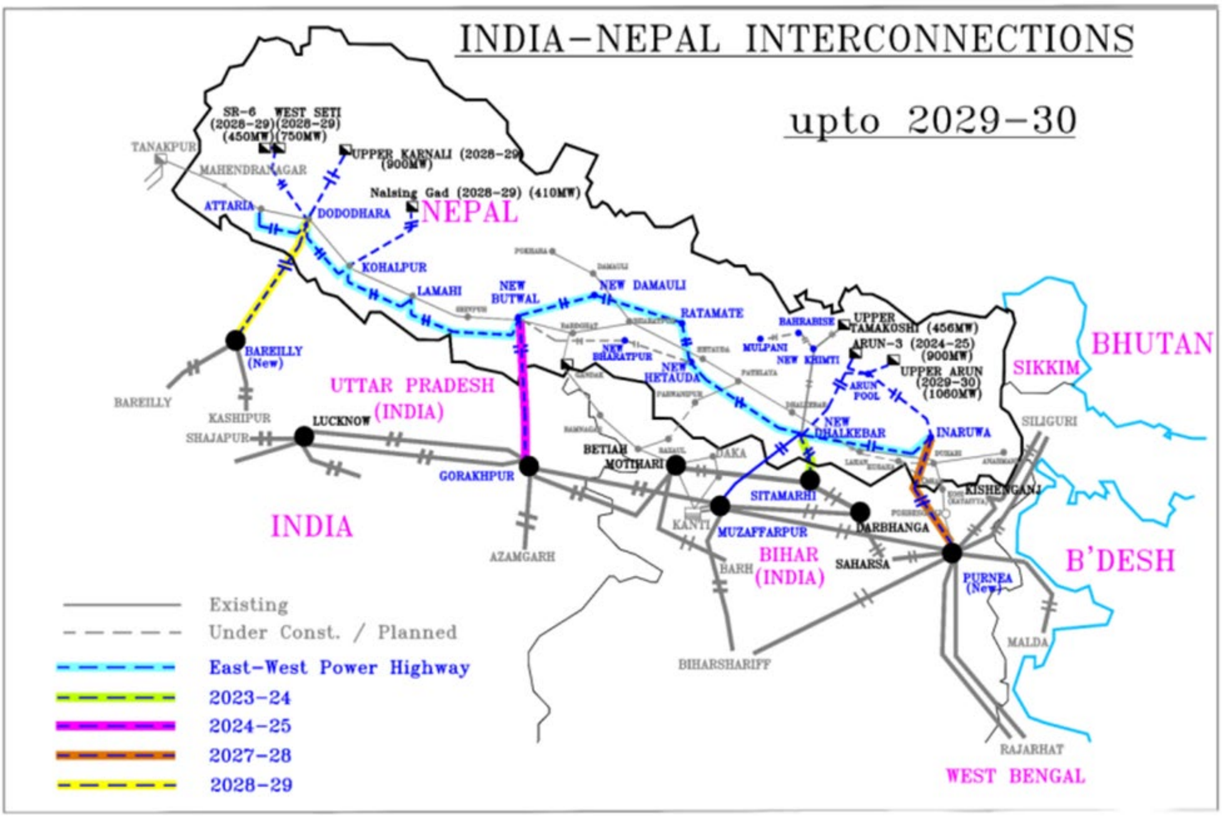
4.3.1. Agreement on Cooperation in Hydropower

The governments of India and Nepal signed an agreement on 'Electric Power Trade, Cross-Border Transmission Interconnection and Grid Connectivity' on 21 October 2014. The agreement, amongst others, envisages cooperation in the power sector, including developing transmission interconnections, grid connectivity, and power exchange and trading through the governmental, public, and private enterprises of the two countries on mutually acceptable terms.

4.3.2. Power Trade Agreement

The agreement facilitates power trading between India and Nepal, enabling the exchange of up to 600 MW of electricity. Key infrastructure includes the Dhalkebar–Muzaffarpur (400 kV) transmission line, enhancing cross-border electricity trade.

Figure 6: India–Nepal Interconnections



Source: Central Electricity Authority (2023b).

4.3.3. MoU on Power Sector Cooperation

- **Date:** 2018

  Details: This MoU focuses on enhancing cooperation in the power sector, including the development of transmission infrastructure, hydropower projects, and regulatory frameworks. Key projects include the Arun III (900 MW) and Upper Karnali (900 MW) hydropower projects.

Nepal and India share extensive power trade agreements, with several transmission lines connecting the two countries. Nepal imports around 600 MW from India during dry seasons and exports surplus during wet seasons. Significant projects include the Dhalkebar–Muzaffarpur line, which enhances cross-border electricity trade.

4.3.4. Current Projects

The current capacity of 1,000 MW in India–Nepal cross-border interconnections are at the 11 kV, 33 kV, 132 kV, and 400 kV voltage levels. Details are given below.

Existing links

- Muzaffarpur (India)–Dhalkebar (Nepal) 400 kV D/C (twin) line

- Tanakpur HEP–Mahendra Nagar 132 kV S/C line

Links under implementation

- Gorakhpur (India)–New Butwal (Nepal) 400 kV D/C (Quad) line
- Arun III HEPS (Nepal)–Dhalkebar (Nepal)–Sitamarhi (India) 400 kV D/C (quad) line for evacuating power from Arun III (900 MW) HEPS and other hydro projects

Planned links

- Dododhara–Bareilly (new) 400 kV D/C (quad) line
- Inaruwa–Purnea (new) 400 C D/C (quad) line

State grids – Nepal

Several interconnections at 132 kV and below voltage level exist/planned between Nepal and the state grids of Bihar, Uttar Pradesh, and Uttarakhand.

Existing links

Bihar State Power Transmission Company Limited–Nepal

132 kV links

- Kataiya–Kusaha S/C line
- Ramnagar–Gandak/Surajpura (Nepal) S/C line
- New 132 kV Katiya–Kusaha S/C on D/C line
- New 132 kV Raxaul–Parwanipur S/C on D/C line

33 kV links

- Kataiya–Inarwa (Biratnagar) S/C (not in service) line
- Kataiya–Rajbiraj S/C line
- Jaynagar–Sirha (Bishnupur) S/C line
- Sitamarhi–Jaleshwer S/C line
- Raxaul–Birganj S/C line

Uttar Pradesh Power Transmission Company Limited–Nepal: 33 kV links

- Nanpara–Nepalgunj S/C line
- Paliya–Dhangadi line

Uttarakhand Power Company Limited–Nepal: 11 kV links

- Pithoragarh–Baitadi line
- Dharchula–Jalujavi line
- Dharchula–Huti line

- Pithoragarh–Pipli line

4.3.5. Planned/Under Implementation Links

Bihar (Bihar State Power Transmission Company Limited) – Nepal

- Stringing of second circuit of Kataiya (India)–Kushaha (Nepal) 132 kV line
- Stringing of second circuit of Raxaul (India)–Parwanipur (Nepal) 132 kV line

Uttar Pradesh (Uttar Pradesh Power Transmission Company Limited) – Nepal

- Nanpara (India)–Kohalpur (Nepal) 132 kV D/C line
- New Nautanwa (Uttar Pradesh–Mainhiya (Nepal) 132 kV D/C line

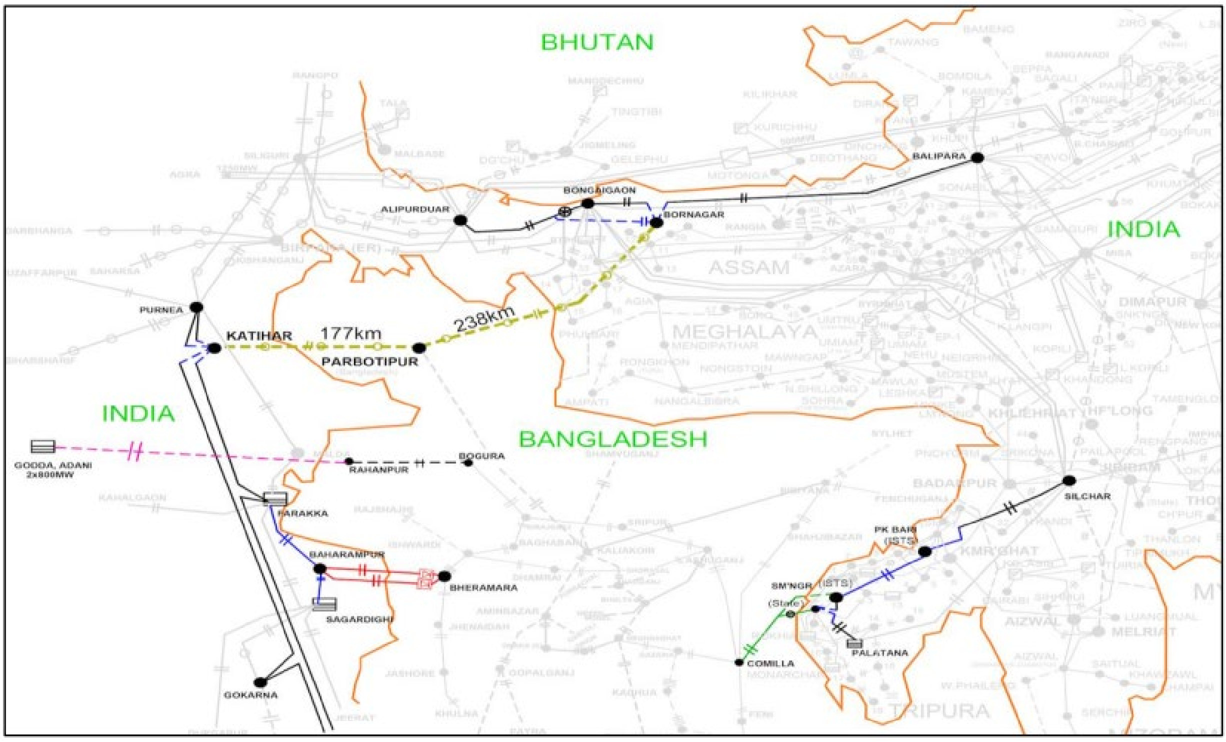
Future planning

- Plans to develop hydropower further in Nepal and enhance export capacity to India.
- Ongoing projects like the Arun III (900 MW) and Upper Karnali (900 MW) are expected to boost power production and trade.
- **Capacity enhancement:** enhancing hydropower capacity and establishing additional transmission lines.

4.4. India–Bangladesh

The governments of India and Bangladesh signed an MoU on 'Cooperation in Power Sector' on 11 January 2010. The MoU, amongst other things, envisages cooperation in power generation, transmission, energy efficiency, the development of various types of renewable energy, and the establishment of grid connectivity between the two countries (Figure 7).

Figure 7: India–Bangladesh Interconnections



km = kilometre.
Source: Central Electricity Authority (2023b).

4.4.1. MoU on Power Cooperation

- **Details:** The MoU outlines cooperation in power generation, transmission, and distribution. Major projects include the Baharampur–Bheramara (500 MW HVDC) transmission line and the Tripura–Comilla (160 MW) interconnection, enabling significant power export from India to Bangladesh.

4.4.2. Agreement on Power Purchase

- **Date:** 2013
- **Details:** This agreement allows Bangladesh to import power from India to meet its growing energy demands. The agreement focuses on both short-term and long-term power purchase contracts, enhancing energy security and stability.

India exports power to Bangladesh through several interconnections, including the Baharampur–Bheramara and Tripura–Comilla lines. Power trade agreements have been in place since 2010, significantly enhancing Bangladesh's power supply.

4.4.3. Current Projects

India supplies 1,160 MW of power to Bangladesh through the links listed below.

Existing links:

- Baharampur (India)–Bheramara (Bangladesh) 2 x 400 kV D/C line along with a 2 x 500 MW HVDC back-to-back station at Bheramara
- Surajmaninagar (Tripura)–Bangladesh (Comilla) 400 kV D/C line (operated at 132 kV)

Planned links:

- 765 kV D/C Katihar (India)–Parbotipur (Bangladesh)–Bornagar (India) cross-border link

4.4.4. Future Planning

- Initiatives to increase power trading capacity and establish additional interconnections like the Katihar–Parbatipur–Bornagar link
- Potential projects include linking the Northeastern Grid of India to Bangladesh's grid.
- **Capacity enhancement:** increasing power trading capacity and exploring renewable energy cooperation

4.5. India–Myanmar

The governments of India and Myanmar signed an MoU on 'Cooperation in the Field of Power Sector' on 19 October 2016. The MoU, amongst other things, envisages cooperation in the power sector, including investments for mutual benefit, cooperation in power generation, transmission, energy efficiency and development of various types of renewable energy including hydropower, trading and transfer of power at a mutually agreed price and procedure, consultancy services, training, research and development programmes for the development of human resources, and enhancement of productivity and efficiency in the power sector. The Figure 8 shows India–Myanmar interconnections.

Figure 8: India–Myanmar Interconnections

kV = kilovolt.
Source: Central Electricity Authority (2023b).

4.5.1. MoU on Energy Cooperation

- **Details:** The MoU focuses on collaboration in the energy sector, including electricity trade, transmission infrastructure, and renewable energy projects.

4.5.2. Agreement on Cross-Border Electricity Trade

- **Date:** 2017
- **Details:** This agreement facilitates electricity trade between India and Myanmar, focusing on developing transmission infrastructure and regulatory frameworks to support cross-border energy flows.

4.5.3. Current Interconnection with India

India provides 2–3 MW in power (since 5 April 2016) from Manipur (India) to Myanmar through an 11 kV transmission line from Moreh in Manipur (India) to Tamu Town in Myanmar.

4.5.4. Future Planning with India

A 500 MW HVDC interconnection between India (Imphal) and Myanmar (Tamu) has been agreed. Additionally, low-voltage radial interconnections between India and Myanmar from Indian states (Arunachal Pradesh, Manipur, Mizoram, and Nagaland) are under consideration.

- Imphal (India)–Tamu (Myanmar) high-capacity alternating current (AC) line along with 1 x 500 MW HVDC back to back
- Nampong (Arunachal Pradesh, India)–Pansong (Myanmar) 11 kV S/C radial line
- Behiang (Manipur, India)–Cikha (Myanmar) 11kV S/C radial line
- Zokhawthar (Mizoram, India)–Rikhawdar (Myanmar) 11 kV S/C radial line
- Various 11 kV S/C lines from Nagaland, India to Myanmar

New hydropower projects and enhanced grid connectivity will strengthen the energy cooperation. To achieve this, building robust infrastructure for cross-border transmission and cooperation is necessary.

Myanmar–India interconnection: high-voltage, high-capacity (conceptual stage; potential operation by 2031)

4.6. India–Sri Lanka

A detailed project report for a HVDC link between Madurai (India) and Mannar (Sri Lanka), with 2 x 500 MW HVDC terminals based on voltage source converter technology, is being finalised. Figure 9 shows India–Sri Lanka transmission interconnections.

Figure 9: India–Sri Lanka Interconnections

km = kilometre.
Source: Central Electricity Authority (2023b).

4.6.1. MoU on Energy Cooperation

- **Date:** 2010
- **Details:** The MoU outlines cooperation in power generation, renewable energy, and transmission infrastructure. It includes feasibility studies for an undersea power transmission link between India and Sri Lanka.

4.6.2. Agreement on Renewable Energy Projects

- **Date:** 2016
- **Details:** This agreement focuses on developing renewable energy projects, particularly wind and solar, to enhance energy cooperation and sustainability.

4.6.3. Sri Lanka–India Energy Cooperation

- **Undersea power transmission link:** feasibility studies conducted for potential undersea cable.
- **Power export/import:** no direct power export/import between the countries.

4.6.4. Current Projects

- Feasibility studies for undersea power transmission link
- No current direct power export/import

4.6.4. Future Planning

- **Undersea power cable:** proposal to connect India and Sri Lanka via undersea cable
- **Renewable energy projects:** potential collaboration on wind and solar energy projects

4.7. Current Status and Plans for Energy Connectivity Between India and AMS

India is focusing on enhancing its energy connectivity with several AMS, including Singapore, Indonesia, and Thailand. Below is a detailed overview of existing and future plans for these interconnections.

4.7.1. India–Thailand–Lao PDR

Existing Connectivity

- **Indirect connectivity:** India and Thailand do not share a direct power transmission line. Energy cooperation is primarily through regional initiatives under ASEAN and BIMSTEC.

Future Plans

- **Objective:** Enhance connectivity to facilitate power trading and integration with Thailand's grid, supporting regional energy security.
- **Trilateral cooperation:** The India–Myanmar–Thailand Trilateral Highway project includes provisions for energy cooperation, which could facilitate future grid connectivity.
- **Renewable energy investments:** Thailand has a strong renewable energy sector. India and Thailand are exploring joint ventures in solar and wind energy projects.

Voltage level: 400–500 kV AC or HVDC, depending on the final design

Capacity: 500–1,000 MW

Route length: estimated 1,000 kilometres (km), with potential for a combination of overland and undersea segments

Type of interconnection: combination of overhead lines and undersea cables, or HVDC technology

Tentative Schedule

- **Feasibility studies and planning:** 2024–2025
- **Detailed design and approvals:** 2025–2027

- **Construction:** 2027–2029
- **Operational:** potentially by 2030

4.7.2. India–Singapore

Existing Connectivity

- **Energy services:** Singaporean companies provide energy services and technological solutions to the Indian market.

Future Plans

- **Objective:** Facilitate energy trading and integration into the regional power grid, potentially using undersea cables or advanced transmission technologies.
- **Smart grids and technology:** Collaboration on smart grid technologies and energy storage solutions is a key area of interest. Both countries aim to enhance grid efficiency and reliability.
- **Investment in renewables:** Singaporean investors are increasingly looking at opportunities in India's renewable energy sector, particularly in solar and wind energy projects.
- **Voltage level:** likely high voltage, possibly 500 kV or higher
- **Capacity:** conceptual stage; potential capacities could range from 500 MW to 1,000 MW, depending on the final design and technology used.
- **Route length:** estimated 1,000 km or more, involving undersea cable or a combination of overland and undersea segments
- **Type of interconnection:** likely undersea cable or a hybrid system combining undersea cables and overhead lines

Tentative Schedule

- **Feasibility studies and planning:** 2024–2026
- **Detailed design and approvals:** 2026–2028
- **Construction:** 2028–2030
- **Operational:** Potentially by 2031

4.7.3. India–Viet Nam

Existing Connectivity

- **Limited direct connectivity:** Currently, there is no direct power transmission line between India and Viet Nam. Cooperation is primarily through bilateral agreements and regional platforms.

Future Plans

- **Renewable energy projects:** Viet Nam's growing renewable energy sector presents opportunities for collaboration. Indian companies are exploring investments in wind and solar power projects in Viet Nam.

4.7.4. India–Indonesia

Existing Connectivity

- **Coal trade:** Indonesia is a major supplier of coal to India, providing a significant portion of India's coal imports for power generation.
- **Liquefied natural gas imports:** India imports liquefied natural gas from Indonesia, enhancing its energy security and diversification of energy sources.

Future Plans

- **Objective:** Develop an interconnection to facilitate electricity exports from Indonesia to India, potentially using HVDC technology.
- **Renewable energy collaboration:** Indonesia's vast renewable energy potential, particularly in geothermal and solar power, presents opportunities for joint projects and investments by Indian companies.
- **Technological cooperation:** Both countries are exploring cooperation in energy-efficient technologies and grid modernisation to improve energy security and sustainability.
- **Voltage level:** likely 500 kV DC (HVDC) or higher
- **Capacity:** estimated 1,000–2,000 MW, depending on the project scope and technology used
- **Route length:** about 2,000 km, including undersea segments across the Indian Ocean
- **Type of interconnection:** likely undersea HVDC cable
- **Tentative Schedule:**
    - **Feasibility studies and planning:** 2024–2026
    - **Detailed design and approvals:** 2026–2028
    - **Construction:** 2028–2032
    - **Operational:** Potentially by 2033

4.8. Status of Grid Interconnection in AMS

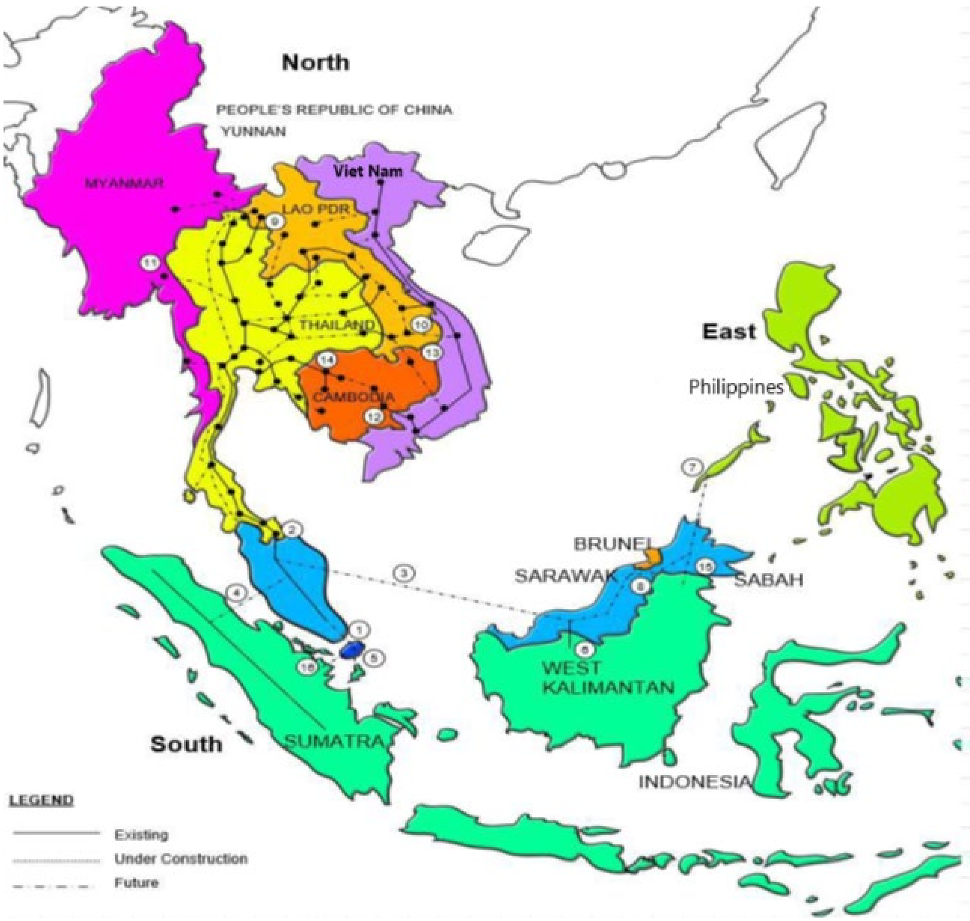
The current status and future plans for energy connectivity between India and these AMS highlight the potential for enhancing regional energy security, promoting economic growth, and achieving sustainable development. Overcoming technical, political, and economic challenges will be crucial for realising the full benefits of these cooperative efforts.

4.8.1. APG

The APG initiative aims to create a regional grid by connecting the power systems of AMS. This project enhances energy security, promotes renewable energy integration, and fosters regional stability by creating interdependencies and shared benefits.

The ASEAN Centre for Energy plays a pivotal role in fostering energy cooperation amongst AMS and their partners, including India. Below is a detailed action plan to enhance energy cooperation, focusing on the strategic goals of energy security, sustainability, and economic growth.

Figure 10: ASEAN Power Grid



Source: Ambumozhi, V. and B.K. Singh, eds. (2024), Cross-Border Integration of Renewable Energy Systems: Experiences, Impacts, and Drivers, London: Routledge.

The ASEAN region is rich in variable renewable energy (VRE), with estimated potential of 8,119 gigawatts (GW) for solar and 342 GW for wind. In 2020, the installed capacity was around 22.8 GW for solar and 2.5 GW for wind. Details of the transmission interconnections of the three APG corridors for regional multilateral power trading are outlined below and shown in Figure 11.

Northern System: Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam

Southern System: Indonesia, Malaysia, and Singapore

Eastern System: Brunei Darussalam, Indonesia, Malaysia, and the Philippines

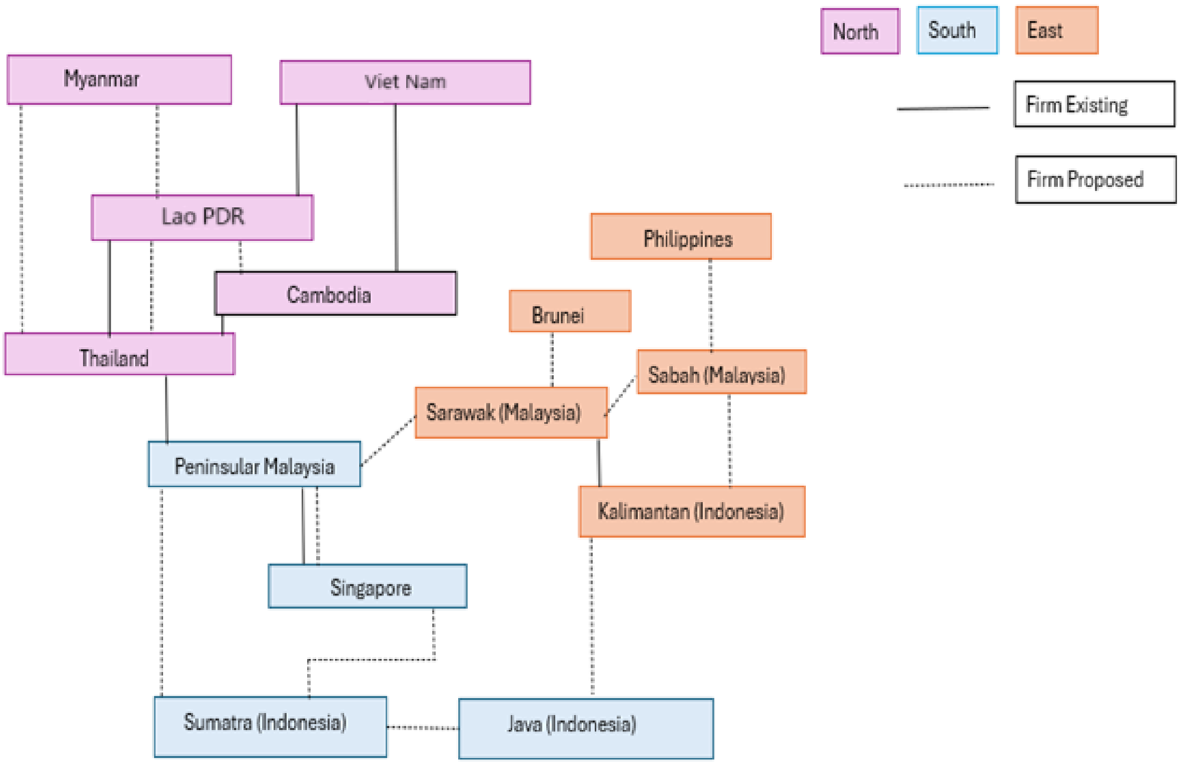
Capacity

Existing: 7,720 MW

Ongoing: 555–625 MW

Future: 17.6 GW by 2040

Figure 11: Subregions as a Reflection of APG Shape and their Respective Constituent AMS



AMS = ASEAN Member State/s, APG = ASEAN Power Grid, ASEAN = Association of Southeast Asian Nations.
Source: Author Creation.

ASEAN's vision is to integrate the national power systems of its 10 Member States to enable cross-border bilateral power trade by constructing regional power interconnections. The APG aims to enhance integration, leading to a Southeast Asian power grid system for energy security and transitioning to renewables through efficient resource sharing. The APG is a big step for the development of hard and soft infrastructure, i.e. transmission facilities and electricity trading mechanisms at the bilateral level, and is envisioned to scale up to trade within three subregions as depicted in Figure 11.

Eight bilateral interconnections (Table 6) out of 18 APG interconnections have been completed and are in operation, linking Singapore and Peninsula Malaysia, Thailand, and Peninsula Malaysia, and via Thailand to Cambodia, the Lao PDR, and Viet Nam – bringing cross-border transfer capacity to 7,720 MW. Six APG projects are under construction.
The transmission of renewable energy to Singapore from the Lao PDR via Thailand and Malaysia is a milestone in ASEAN cross-border power trade. Singapore started to import 100 MW of renewable energy on 23 June 2022 and targets increasing this to 4 GW by 2030.
The Lao PDR–Thailand–Malaysia–Singapore Power Integration Project serves as ASEAN's pilot project in addressing technical, legal, and financial issues of multilateral electricity trade. It can supply up to 100 MW of hydropower from the Lao PDR. Initially, the power was being delivered only to Malaysia, but it is now being supplied to Singapore.

The Trans Borneo Power Grid: Sarawak–West Kalimantan Interconnection Project in the Brunei Darussalam–Indonesia–Malaysia–Philippines East ASEAN Growth Area (BIMP-EAGA) subregion (commissioned in January 2016) entails a 275 kV transmission line between Sarawak in Malaysia and West Kalimantan in Indonesia on the island of Borneo.

Table 6: Transmission Links in Southeast Asia

Transmission link	No. of connections
Lao PDR–Viet Nam	2
Cambodia–Viet Nam	1
Lao PDR–Cambodia	1
Thailand–Cambodia	1
Lao PDR–Thailand	17
Thailand–Malaysia	2
Malaysia–Singapore	1

Source: Authors.

4.8.2. Transmission Links in Southeast Asia

Table 7 shows the transmission links in Southeast Asia.

Table 7: Transmission Links in Southeast Asia

Lao PDR – Viet Nam	
1	Xekaman 3 – Thanmy
2	Xekaman 1 – Pleiku
Cambodia – Viet Nam	
3	Chau Doc – Phnom Penh
Lao PDR – Thailand	
4	Vientiane - Nong Khai
5	Oakxan – Bueng Kan
6	Thakhek – Nakhon Phanom
7	Savannakhet – Mukhadan 2
8	Bang Yo – Sirindhorn
9	Na Bong – Udon Thani 3
10	Nam Thenu 2 – Savannakhet, Rot Et 2
11	Hoouay Ho – Ubon Ratchathani 2
12	Thakhek – Nakhon Phanom 2
13	Houay Ho – Ubon Ratchathani 2
14	Hongsa – Nan
15	Xaiyaburi – Thali
16	Thanaleng – Nong Khai
17	Phone Tong – Nong Khai
18	Pakbo – Mukdahan 2
19	Xe-Pain Xe-Namnoy – Ubon Ratchathani 3
20	Bangyo – Sirindhorn 2
Lao PDR – Cambodia	
21	Ban Hat – Khamponsalao
Thailand – Cambodia	
22	Watthana Nakhon – Siam Preap
Thailand – Malaysia	
23	HDVC Khlong Ngae – Gurun
24	Sadao – Bukit Keteri/Chuping
Malaysia – Singapore	
25	Plentong – Seneko
Malaysia – Indonesia	
26	Mambong – Bengkayan

HVDC = high-voltage direct current.
Note: Excluded links between China and South Asia.
Source: Author Tabulation.

4.8.3. ASEAN Plan of Action for Energy Cooperation, Phase II: 2021–2025

The ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II, 2021–2025 outlines the strategic directions and initiatives for energy cooperation amongst AMS. This phase builds upon the achievements of the previous phase and aims to address new challenges and opportunities in the regional energy landscape. The plan focuses on seven key programme areas: grid connectivity, renewable energy, energy efficiency, clean coal technology, nuclear energy, policy planning, and energy security.

ASEAN aims to achieve a sustainable, secure, and integrated energy future for the region. Effective implementation of this action plan requires coordinated efforts, strong institutional frameworks, and the active participation of all stakeholders, including AMS, international partners, and the private sector.

The ASEAN Interconnection Masterplan Study (AIMS) Phase III focuses on advancing the regional power grid through detailed planning and the implementation of cross-border interconnections. Below is an overview of the identified projects:

➢ **Lao PDR–Thailand–Malaysia–Singapore Power Integration Project**

Objective: Facilitate multilateral electricity trading amongst the Lao PDR, Thailand, Malaysia, and Singapore.

Status: Ongoing. The project is in various stages of planning and implementation, with some sections operational and others under development. This project aims to enhance regional energy security and promote the integration of renewable energy sources.

➢ **Lao PDR–Thailand Interconnection**

- **Voltage level:** 500 kV
- **Capacity:** 1,000 MW
- **Route length:** about 400 km
- **Type of interconnection:** overhead lines
- **Tentative time schedule:** ongoing construction, with full operation expected by 2025

➢ **Thailand–Malaysia Interconnection**

- **Voltage level:** 300 kV
- **Capacity:** 300 MW (2 x 150 MW)
- **Route length:** about 500 km
- **Type of interconnection:** overhead lines
- **Tentative time schedule:** phase 1 operational by 2024; full expansion by 2026

➢ **Thailand–Singapore Interconnection**

- **Voltage level:** 500 kV

- **Capacity:** integrated into broader Lao PDR–Thailand–Malaysia–Singapore Power Integration Project
- **Route length:** estimated 1,000 km (including various segments)
- **Type of interconnection:** combination of overhead lines and potentially undersea cables
- **Tentative time schedule:** early stages, with feasibility studies and planning expected to continue through 2024, with implementation in phases beyond 2025

➢ **Indonesia–Malaysia (Sumatra–Peninsular Malaysia) Interconnection**

Objective: Connect Sumatra (Indonesia) with Peninsular Malaysia to support electricity trade and enhance grid stability.

Status: Planning stage. The project aims to enhance grid connectivity, support electricity trade, and improve energy security in the region.

Sumatra–Peninsular Malaysia

- **Voltage level:** 275 kV
- **Capacity:** 600 MW
- **Route length:** about 250 km
- **Type of interconnection:** undersea cable
- **Tentative time schedule:** feasibility studies and environmental impact assessments in progress; expected completion and operation by 2026

➢ **Viet Nam–Lao PDR–Thailand Power Interconnection**

Objective: Enhance cross-border electricity trade between Viet Nam, the Lao PDR, and Thailand.

Viet Nam–Lao PDR Interconnection

- **Voltage level:** 220 kV
- **Capacity:** 200 MW
- **Route length:** about 150 km
- **Type of interconnection:** overhead lines
- **Tentative time schedule:** construction expected to be completed by 2025

Lao PDR–Thailand Interconnection

- **Voltage level:** 500 kV
- **Capacity:** 1,000 MW
- **Route length:** about 400 km

- **Type of interconnection:** overhead lines
- **Tentative time schedule:** expected completion by 2026

➢ **Cambodia–Viet Nam (Bavet–Moc Bai) Interconnection**

Objective: Connect Cambodia and Viet Nam for cross-border electricity trade.

Bavet–Moc Bai Interconnection

- **Voltage level:** 115 kV
- **Capacity:** 100 MW
- **Route length:** about 70 km
- **Type of interconnection:** overhead lines
- **Tentative time schedule:** completed and operational since 2021

ASEAN Power Trading Capacity: Bilateral and Multilateral

Subregional Level

At the subregional level, power trading involves direct electricity exchanges between neighbouring countries or within smaller regional groupings. The capacities and details of these interconnections are outlined below:

Thailand–Lao PDR–Cambodia–Viet Nam

- ➢ **Thailand–Lao PDR:**
  - **Capacity:** about 1,700 MW
  - **Details:** The primary interconnections are:
    - **Houay Ho–Udon Thani Line:** 2 x 115 kV, 140 MW
    - **Xepian–Xepam Line:** 230 kV, 140 MW
    - **Lao PDR–Thailand Interconnection Line:** 500 kV, 1,000 MW
- ➢ **Lao PDR–Cambodia:**
  - **Capacity:** about 300 MW
  - **Details:** The interconnection involves:
    - **Xekaman 1 Project:** connects the Lao PDR to Cambodia with 115 kV lines, exporting power from Lao PDR hydropower plants to Cambodia
- ➢ **Thailand–Cambodia:**
  - **Capacity:** about 100 MW
  - **Details:** The primary interconnection is:
    - **Aranyaprathet–Poipet Line:** 115 kV, 100 MW
- ➢ **Lao PDR–Viet Nam:**

- **Capacity:** About 200 MW
- **Details:** The main interconnections are:
  - **Xekaman 1 to Viet Nam:** 115 kV line connecting to Viet Nam's power grid

Brunei Darussalam

Brunei has installed capacity of 0.9 GW and peak demand of 0.6 GW. The generation is predominantly gas-based. The highest transmission voltage is 66 kV, which will be upgraded to 275 kV in the near future. Brunei is not connected to any other AMS, but it is expected to be connected to Sarawak as part of the APG in the future. The Brunei Darussalam–Indonesia–Malaysia–Philippines Power Integration Project (BIMP-PIP) was launched in September 2023.

Singapore

Singapore is a major country in the southern region of the APG. It has installed generation capacity of 11 GW and peak demand of 7.6 GW. The generation is prominently gas-based, with a small percentage of VRE and biomass. The highest transmission voltage is 400 kV. The country has started to import 100 MW and targets increasing this to 4 GW by 2030.

Philippines

The government-owned National Grid Corporation of the Philippines is the concessionaire granted a franchise to operate, manage, maintain, and operate transmission networks in three islands/areas (Luzon, Visayas, and Mindanao). Luzon's network consists of a 500 kV transmission line and is a major load centre in the Philippines, whereas the highest voltage in the Visayas network is 230 kV. Luzon and Visayas are connected by a HVDC link of more than 350 KV with a maximum transmission capacity of 440 MW and provision to upgrade to 880 MW in the future. The highest voltage level in Mindanao is 138 kV, and the network operates in island mode without any interconnection to the other two island networks.

Myanmar

Myanmar has installed generation capacity of about 5.2 GW and a peak load of 4.5 GW. The northern and eastern parts of the country are very rich in hydro resources, so the major share of the generation is hydro-based.

The country's grid is not connected to any AMS. However, as part of the APG, Myanmar plans to connect to Thailand and the Lao PDR. For the interconnection with the Lao PDR, a nearby substation – Kengton, in the eastern part of Myanmar – has been identified. Hutgyi substation, in the southern part of Myanmar, has been identified as the most suitable connection point for interconnection with Thailand.

Lao PDR

The Lao PDR has installed generation capacity of about 5.5 GW and a current peak load of around 1.6 GW. Surplus power is exported to neighbouring countries. Most of the installed generation in the Lao PDR is hydro-based, with a small percentage of coal, VRE, and bio-based generation.

The power transmission is mainly at 230 kV and 115 kV and operated by Électricité du Laos. Currently, power from IPP (E) in the Lao PDR is exported to Thailand and the northern region of Viet Nam. The Lao PDR has 20 connection points (cross-border links) with Thailand, Viet Nam, and Cambodia.

Thailand

Thailand has installed generation capacity of 50 GW and a peak load of about 33 GW. Gas-based generation makes up the largest percentage of the capacity, followed by hydro, coal, and VRE. It also has a small percentage of bio-based generation.

The highest transmission voltage in the existing Thailand grid is 500 kV. Thailand is connected to the Lao PDR, Cambodia, and Peninsular Malaysia. However, as part of the APG, it plans to connect to Myanmar.

Viet Nam

Viet Nam installed generation capacity is 58 GW of which there is about 41 GW in the northern AMS. Hydro and coal-based generation predominate in Viet Nam relative to gas-based generation. It is also a renewable-rich country in terms of solar and wind resources, and has some bio-based generation.

The transmission system's highest voltage is 500 kV. Viet Nam is connected to Cambodia and the Lao PDR via 220 kV high-voltage AC transmission lines. A key project – the Quang Trach–Pho Noi 500 KV transmission line, which will pass through nine provinces – will improve energy security in the northern part of the country.

Cambodia

Cambodia has installed generation capacity of about 2.2 GW and a peak load of 1.5 GW. The primary generation resource in Cambodia is hydro. The country has two coal-based plants and two diesel/heavy fuel oil-based plants. The power transmission is mainly 230 kV and 115 kV.

Cambodia is connected to Viet Nam at Chau Doc substation via a 220 kV double circuit line (Chau Doc–Takeo) and to Thailand at Aranyaprathet via a 115 kV single circuit line (Aranyaprathet–GS-IE).

It is also connected to a dedicated plant – Don Sahong generating station in the Lao PDR – by a 500 kV D/C line from Stung Treng to Banhat substation, which is charged to 230 kV. However, there is a plan to connect Cambodia directly to the Lao PDR grid through this transmission corridor in 2025. Considering the load generation locations and transmission system, it is represented as three regional equivalent models (North, South, and West).

The 'North' area is dominated by hydro generation, with potential to connect to the Lao PDR, whereas the 'West' has primarily thermal generation and a few hydro plants. South Cambodia is the primary load centre, with limited oil/heavy fuel oil-based generation. Each area is represented by a 230 kV node with equivalent generation (segregated fuel/technology-wise) and loads lumped at the 230 kV node.

Indonesia

Indonesia is composed of thousands of islands. Three of the largest islands are Java, Sumatra, and Kalimantan, which together form the main Indonesian grid system.

Perusahaan Listrik Negara (PLN), Indonesia's national power company, owns and operates generation and transmission systems in the three islands or subsystems. Java and Sumatra are part of the Southern subregion within the APG framework, while Kalimantan is part of the Eastern subregion.

Java has the largest grid in Indonesia, with an installed base of 66 GW. This mainly comprises coal-based generation as well as a sizeable proportion of gas, hydro, small VRE, bio, and geothermal. The highest transmission voltage is 500 kV.

Sumatra is another major grid in Indonesia, with an installed base of 12 GW and a peak load of 7.5 GW. Generation is dominated by coal, with some gas, hydro, very small VRE, and bio-based generation. Sumatra has a considerable amount of geothermal generation. The highest transmission voltage is 500 kV. The island is very rich in VRE resources and is expected to have a high percentage of VRE generation in the future.

Java and Sumatra are not connected to any other AMS. However, as part of the APG, Java and Sumatra will be connected via a HVDC link in the future. Sumatra will also be connected to Peninsular Malaysia and Singapore via HVDC.

Kalimantan has a smaller grid and consists of three subsystems: Barito, Khatulistiwa, and Mahakam. Collectively, Kalimantan has installed capacity of 4.8 GW and a peak load of 2.2 GW. The highest transmission voltage is 150 kV. Internally, the Barito and Mahakan grids are interconnected. The Khatulistiwa grid is connected to Sarawak. As part of the APG, in the future, Mahakam is planned to be connected with Sabah.

Malaysia

Malaysia's power transmission system consists of three subsystems operated by three companies: Tenaga Nasional Berhad in Peninsular Malaysia, Sabah Electricity Sdn Bhd in the Sabah region, and Sarawak Energy Berhad in the Sarawak region.

Peninsular Malaysia, Sabah, and Sarawak

Under the framework of the APG, Peninsular Malaysia is part of the Southern subregion, while Sabah and Sarawak are part of the Eastern subregion.

These three subsystems are not interconnected. Peninsular Malaysia forms the main part of the Malaysian power grid, with installed generation capacity of 26 GW. This is predominantly gas and coal-based generation, with a small proportion of hydro and VRE generation. The peak load is 18.8 GW, while the highest transmission voltage is 500 kV.

Currently, it is connected to Singapore via a 230 kV subsea cable and to Thailand via an HVDC connection. In April 2024, the establishment of Energy Exchange Malaysia for green electricity with neighbouring countries was announced.

Sarawak is a smaller grid, with an installed base of 7.4 GW and a peak load of 5.5 GW. Generation is mainly hydro and coal, with a small percentage of gas generation. The highest transmission voltage is 275 kV. Sarawak is connected to the West Kalimantan or Khatulistiwa grid. In the future, there is a possibility that Sarawak will be connected to Brunei and Sabah.

Sabah has installed capacity of 1.4 GW and a peak load of 1.0 GW. The generation is predominantly gas-based, with a small percentage of diesel, hydro, VRE, and bio. The highest transmission voltage is 275 kV. Sabah is not connected to any AMS, but it plans to be connected to Sarawak and Kalimantan as a part of the APG. As for Sarawak, the transmission will be upgraded to a 500 kV corridor between them in future scenarios.

West Sarawak is a major load centre, with dominant thermal generation, and is connected to the Kalimantan–Khatulistiwa grid through 275 kV lines. Central Sarawak has hydro potential, and East Sarawak will be connected to Brunei and Sabah in 2025.

5. Challenges of Regional Grid Connectivity

Regional grid connectivity between India and AMS presents a variety of challenges that must be addressed to ensure successful implementation and sustainability. These challenges can be categorised into technical, political, and regulatory, and economic and financial challenges. Addressing these challenges of regional grid connectivity requires coordinated efforts and strategic planning. Overcoming these challenges involves upgrading infrastructure, harmonising regulations, securing financing, and fostering international cooperation. By addressing these obstacles, India and AMS can realise the full potential of regional grid connectivity – enhancing energy security, promoting economic growth, and achieving sustainable development.

5.1 Technical Challenges

5.1.1. Infrastructure Development

- **Ageing infrastructure:** Existing infrastructure in some countries may be outdated and inadequate to support regional grid connectivity. Upgrading and modernising these systems can be a significant technical challenge.
- **Geographical barriers:** Diverse geographical terrain, such as mountains, forests, and rivers, complicate the construction and maintenance of cross-border transmission lines. It will be a challenge to add a submersible line (from Singapore to Sumatra, Kalimantan, Malaysia, Sabah, Sarawak, and Brunei to the Philippines).

5.1.2. Grid Compatibility and Integration

- **Grid standards and synchronisation:** Different countries may have varying grid standards, voltages, and frequencies. Harmonising these technical parameters is essential for seamless integration and efficient energy transfer.
- **Interoperability issues:** Ensuring interoperability between different grid systems, especially when incorporating renewable energy sources, requires advanced technologies and coordination.

5.1.3. Transmission Losses and Efficiency

- **High transmission losses:** Long-distance transmission can result in significant energy losses, reducing the efficiency and reliability of cross-border power transfer.

- **Power quality and stability:** Maintaining consistent power quality and stability across interconnected grids is crucial. Fluctuations in voltage and frequency can affect the performance and reliability of the grid.

5.1.4. Technological Advancements:

- **Adoption of advanced technologies:** Integrating advanced technologies such as smart grids, real-time monitoring systems, and energy storage solutions is necessary to enhance grid performance. However, the adoption and implementation of these technologies pose technical challenges.

5.2 Political and Regulatory Challenges

5.2.1. Sovereignty and National Security Concerns

- **Control and ownership:** Countries may be reluctant to cede control over their energy infrastructure to foreign entities, fearing national security risks and loss of sovereignty.
- **Political instability:** Political instability and changing governments can disrupt long-term energy cooperation agreements and infrastructure projects.

5.2.2. Regulatory Frameworks

- **Divergent regulations:** Different regulatory frameworks and policies across countries can hinder the implementation of regional grid connectivity projects. Harmonising these regulations is essential for smooth operation.
- **Licensing and permitting:** Obtaining the necessary licences and permits for cross-border projects can be a complex and time-consuming process, involving multiple stakeholders and regulatory bodies.

5.2.3. International Relations and Diplomacy

- **Geopolitical tensions:** Geopolitical tensions and historical conflicts between neighbouring countries can impact cooperation on energy projects and hinder progress.
- **Negotiation and coordination:** Effective negotiation and coordination amongst countries are crucial for resolving disputes, aligning interests, and achieving mutual benefits.

5.3 Economic and Financial Challenges

5.3.1. High Capital Costs

- **Initial investment:** Developing cross-border energy infrastructure requires significant initial capital investment, including the construction of transmission lines, substations, and renewable energy projects.
- **Financing difficulties:** Securing financing for large-scale energy projects can be challenging, particularly in countries with limited financial resources or high-risk profiles.

5.3.2. Cost-Sharing and Tariff Mechanisms

- **Equitable cost sharing:** Determining an equitable cost-sharing mechanism for joint projects is essential to ensure fairness and mutual benefits. Disagreements over cost allocation can delay or derail projects.
- **Tariff structures:** Establishing transparent and fair tariff structures for cross-border electricity trade is crucial. Differing tariff policies and pricing mechanisms can complicate trade agreements.

5.3.3. Economic Viability

- **Return on investment:** Ensuring a reasonable return on investment for stakeholders is necessary to attract private sector participation and maintain project sustainability.
- **Market demand and supply:** Balancing market demand and supply is critical to avoid oversupply or shortages of electricity, which can impact the economic viability of regional grid projects.

5.4. Risk Management

5.4.1. Financial risks: Currency fluctuations, inflation, and interest rate changes can affect the financial stability of energy projects. Effective risk management strategies are needed to mitigate these risks.

5.4.2. Insurance and guarantees: Providing adequate insurance and guarantee for cross-border projects is essential to protect investments and manage potential risks.

6. Policy Recommendations for Enhanced Power Trade and Grid Connectivity Between India and the ASEAN Region

Infrastructure development is key for the promotion of power trade, but India and the ASEAN region have inadequacy of grid infrastructure, lack of proper investment, disparities in tariffs, lack of adequate transfer of technology, and lack of harmonious policies. Furthermore, geopolitical issues hamper the power trade and grid connectivity in the region. Therefore, comprehensive strategies and policy are needed for accelerated power trade and grid connectivity.

6.1. Harmonisation of Regulatory Frameworks

- **Standardise regulations:** Establish common standards and regulatory frameworks for electricity trade and grid connectivity across India and AMS. This includes harmonising grid codes, safety standards, and technical specifications to ensure seamless integration and operation.
- **Streamline licensing and tariff mechanisms:** Develop consistent licensing procedures and transparent tariff structures to facilitate cross-border electricity trade. This will involve regulatory bodies working together to align policies and simplify approval processes.

6.2. Infrastructure Development and Modernisation

- **Invest in transmission infrastructure:** Prioritise investment in robust and high-capacity transmission lines to connect regional grids. This includes the construction of new interconnectors and the upgrading of existing infrastructure to handle increased power flows.
- **Smart grid technologies:** Implement advanced technologies like smart grids and energy management systems to improve the reliability, efficiency, and stability of cross-border electricity exchanges. These technologies can optimise load management, reduce losses, and enhance grid resilience.

6.3. Financial and Institutional Mechanisms

- **Create a regional energy fund:** Establish a dedicated fund to support infrastructure projects and capacity building initiatives. This fund can be sourced from member countries, international financial institutions, and private sector investments.

- **PPPs:** Encourage PPPs to leverage private sector expertise and capital. This approach can accelerate project implementation and ensure better risk management and innovation in infrastructure development.

6.4. Capacity Building and Technical Assistance

- **Training programmes:** Develop and implement training programmes for regulatory authorities, grid operators, and other stakeholders. These programmes should focus on best practices, technological advancements, and regulatory frameworks relevant to cross-border power trading.
- **Technical assistance:** Provide technical assistance to countries that need support in developing and implementing policies and infrastructure for cross-border electricity trade. This could include expert consultations, feasibility studies, and pilot projects.

6.5. Environmental and Social Safeguards

- **Promote renewable energy:** Prioritise the integration of renewable energy sources in regional power trade agreements. This would help reduce carbon emissions and contribute to climate goals while ensuring energy security.
- **Community engagement:** Involve local communities in the planning and implementation of cross-border projects to ensure that their interests and concerns are addressed. This includes assessing and mitigating the social and environmental impacts of infrastructure projects.

6.6. Strengthen Regional Cooperation and Dialogue

- **Bilateral and multilateral agreements:** Foster the development of bilateral and multilateral agreements that outline the terms and conditions of power trade, dispute resolution mechanisms, and collaborative projects.
- **Regional energy forum:** Establish a regional energy forum comprising representatives from India and AMS. This platform could facilitate regular dialogue, knowledge sharing, and coordinated action on energy policies and projects.

6.7. Research and Development

- **Joint R&D initiatives:** Promote joint research and development initiatives focused on innovative solutions for grid connectivity, energy storage, and renewable integration. Collaborative research and development (R&D) can lead to technological breakthroughs that benefit all member countries.

- **Data sharing and analysis:** Develop mechanisms for sharing data and conducting joint analyses of energy demand, supply, and infrastructure needs. Accurate data and collaborative research are essential for informed decision-making and strategic planning.

6.8. Risk Management and Security

- **Cybersecurity measures:** Implement stringent cybersecurity measures to protect the regional grid infrastructure from cyberthreats. This includes developing joint cybersecurity protocols and conducting regular security assessments.
- **Disaster preparedness:** Establish regional strategies for disaster preparedness and response to ensure grid resilience in the face of natural disasters and other emergencies. This includes creating backup systems and emergency support mechanisms.

By implementing these policy recommendations, India and AMS could significantly enhance power trade and grid connectivity, leading to improved energy security, economic growth, and regional stability. These strategic interventions would pave the way for a more integrated and prosperous energy future in the region.

7. Conclusion

In conclusion, the pursuit of power trading and regional grid connectivity between India and AMS presents a transformative opportunity to enhance energy security, foster economic growth, and strengthen regional stability. Despite the considerable challenges, such as regulatory disparities, infrastructure limitations, and geopolitical complexities, the potential benefits far outweigh these hurdles. Strategic interventions are required to harmonise regulatory frameworks, invest in advanced infrastructure, and foster diplomatic engagement. By addressing these challenges through collaborative efforts, India can take the lead by strengthening interconnections with Myanmar over land and establishing undersea cable links from the Andaman and Nicobar Islands to Indonesia, Thailand, and Singapore. This way, nations can unlock the full potential of regional energy cooperation. This will not only contribute to sustainable development and economic resilience but also pave the way for a more integrated and prosperous regional community.

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