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Brief Report
On
SARI/EI Delegation to the Second Meeting of SAARC Council of Experts of Energy Regulators (Electricity)

24th and 25th October, 2017
Hotel Marriott, Islamabad, Pakistan

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Brief Report

Based on the invitation received from SAARC Secretariat, Kathmandu, Nepal, SARI/EI Delegation comprising of Mr. V.K. Kharbanda, PD, SARI/EI/IRADe and Mr. Rajiv Ratna Panda, PC, SARI/EI/IRADe participated in the 2nd Meeting of Second Meeting of SAARC Council of Experts of Energy Regulators (Electricity) held on 24th and 25th October, 2017 at Hotel Marriott, Islamabad, Pakistan.

Mr. Kharbanda, made a detailed presentation on "Potential to enhance Power Trade in Western Part of South Asia: Techno Economic rational". In his presentation, he covered a) Experience and Lessons from Cross Border Electricity Trade (CBET) in South Asia and future perspective b) South Asian Power Sector Profile -India-Bangladesh, India-Bhutan and India-Nepal CBET c) Potential benefits of power trade d) Key findings of the study on "Potential for Power Trade in Western part of South Asia" d) Case for Pakistan-India Cross Border Interconnection – Techno-Economic options & potential benefits and e) Way forward. He said that for a pan South Asia regional grid, the interconnection between Pakistan and India is critical to connect the western part of south Asia region and augment the interconnections established on eastern side of south Asia region with the potential to bring about an integration in the power systems of Central Asian countries and South Asian countries. The detailed presentation is attached as Annexure-I.

Mr. Rajiv made a detailed presentation titled "Harmonization of grid codes, operating procedures and standards to facilitate/promote cross border electricity trade in the south Asia region" and presented the Key Findings of the study[1] focusing on Framework Grid Code Guidelines. In his presentation, he covered a) Grid Interconnection-Cross Border Electricity Trade (CBET) in South Asia: Current and Future Trading Scenarios b) Challenges for Harmonization of grid codes c) South Asia Power System- Technical Info-Gap Analysis d) Context, purpose, preamble of the Framework Grid Code Guidelines (FGCG) e) brief summary of the FGCG on Planning, connection, operation, metering, protection, scheduling & dispatch of interconnected regional power system in South Asia. He stressed that with High Level of Cross Border Interconnection being envisaged, it is of paramount importance that for safe, reliable and stable operation of the interconnected transmission system, the various technical aspects of grid codes (planning, connection, metering, Protection etc.), operating procedures and standards needs to be harmonized/coordinated. He also said that considering the technical complexity in farming regional grid code and associated harmonization and for integrated system planning and operation, this study has suggested to create a Regional Technical Institutions/Body such as South Asian Forum of Transmission Utility (SAFTU). SAFTU will provide technical support & inputs in farming regional grid code and harmonization. The detailed presentation is attached as Annexure-II.

Both the presentations were highly appreciated by the members. SARI/EI has been identified by the SAARC Council of Experts of Energy Regulators (Electricity) to provide technical support to "assess and review the suitability of a set of electricity regulations for implementation of the SAARC Framework agreement and for enhanced electricity trade in South Asia", in view the prevailing regulatory framework in the region and international experiences and best practices.

[1] http://www.irade.org/Harmonisation-of-grid-codes-operating-procedures-and-standards-to-facilitatepromote-cross-border-electricity-trade-in-the-south-Asia-region-Framework-grid-code-guidelines-Rajiv-LR-1.pdf

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Annexure-II

Harmonization of grid codes, operating procedures and standards to facilitate/promote Cross Border Electricity Trade (CBET) in the South Asia Region:

Framework Grid Code Guidelines

Rajiv Ratna Panda
SARI/EI/IRADe

2nd Meeting of SAARC Council of Experts of Energy Regulators
24th and 25th October, 2017
Hotel Marriott, Islamabad, Pakistan

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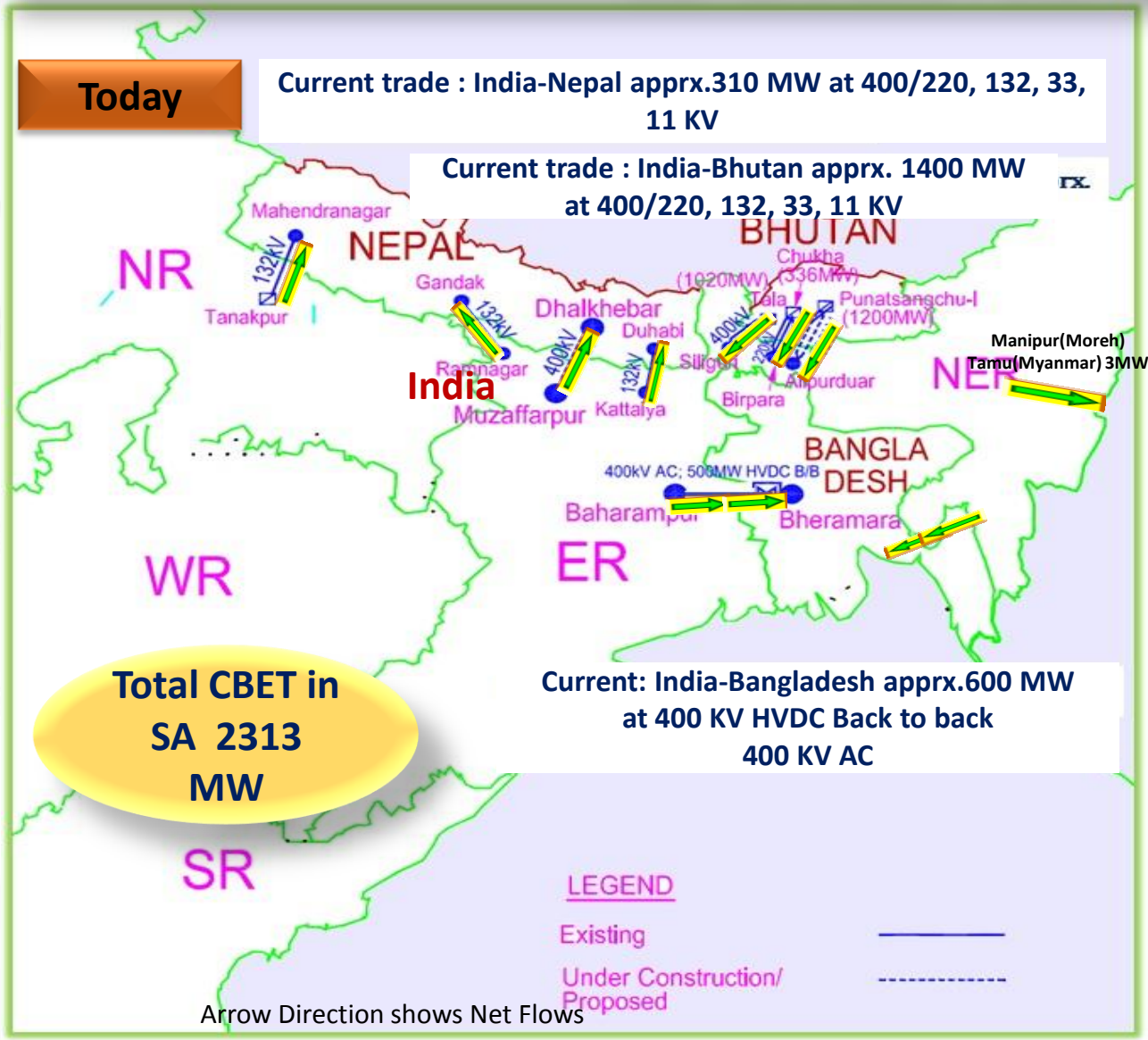
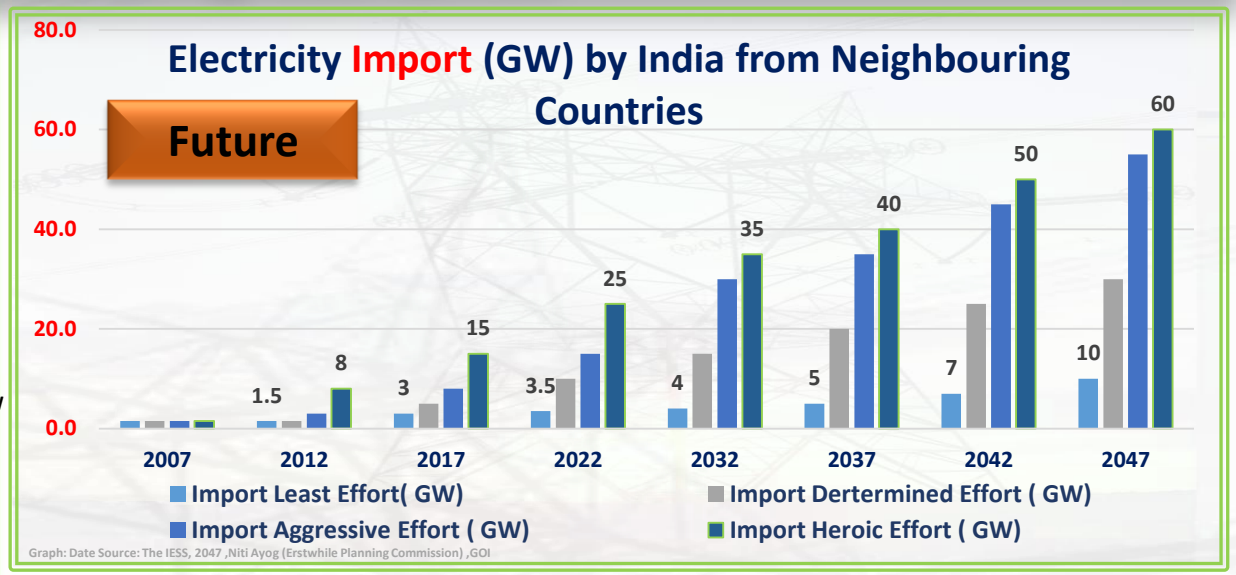
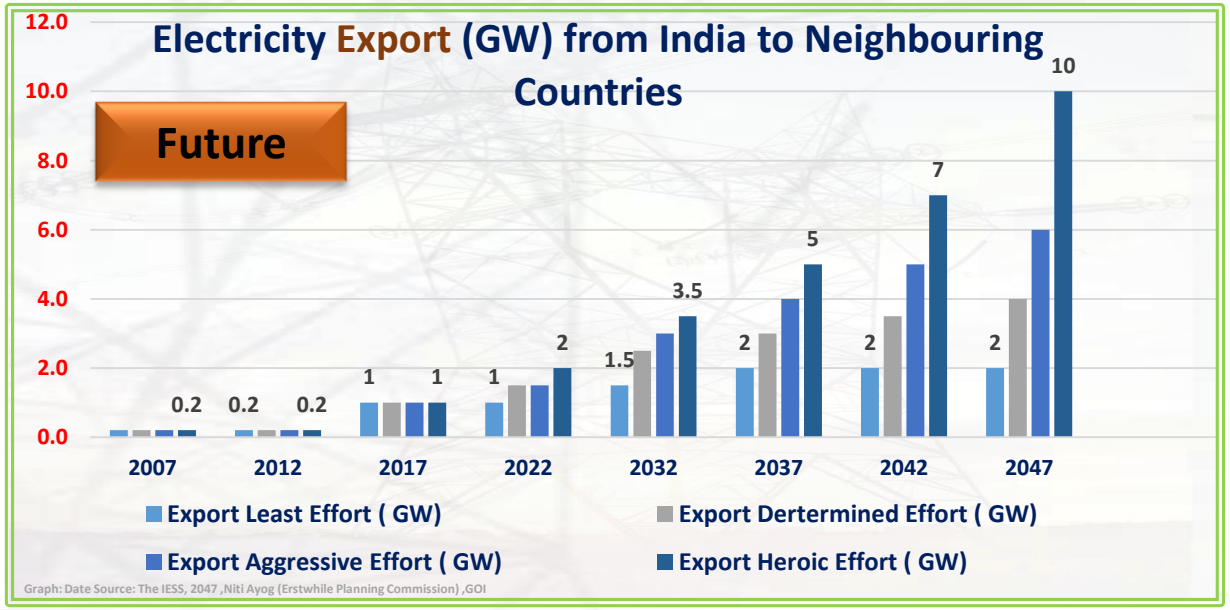
Content

Grid Interconnection-Cross Border Electricity Trade (CBET) in South Asia
Current and Future Trading Scenarios







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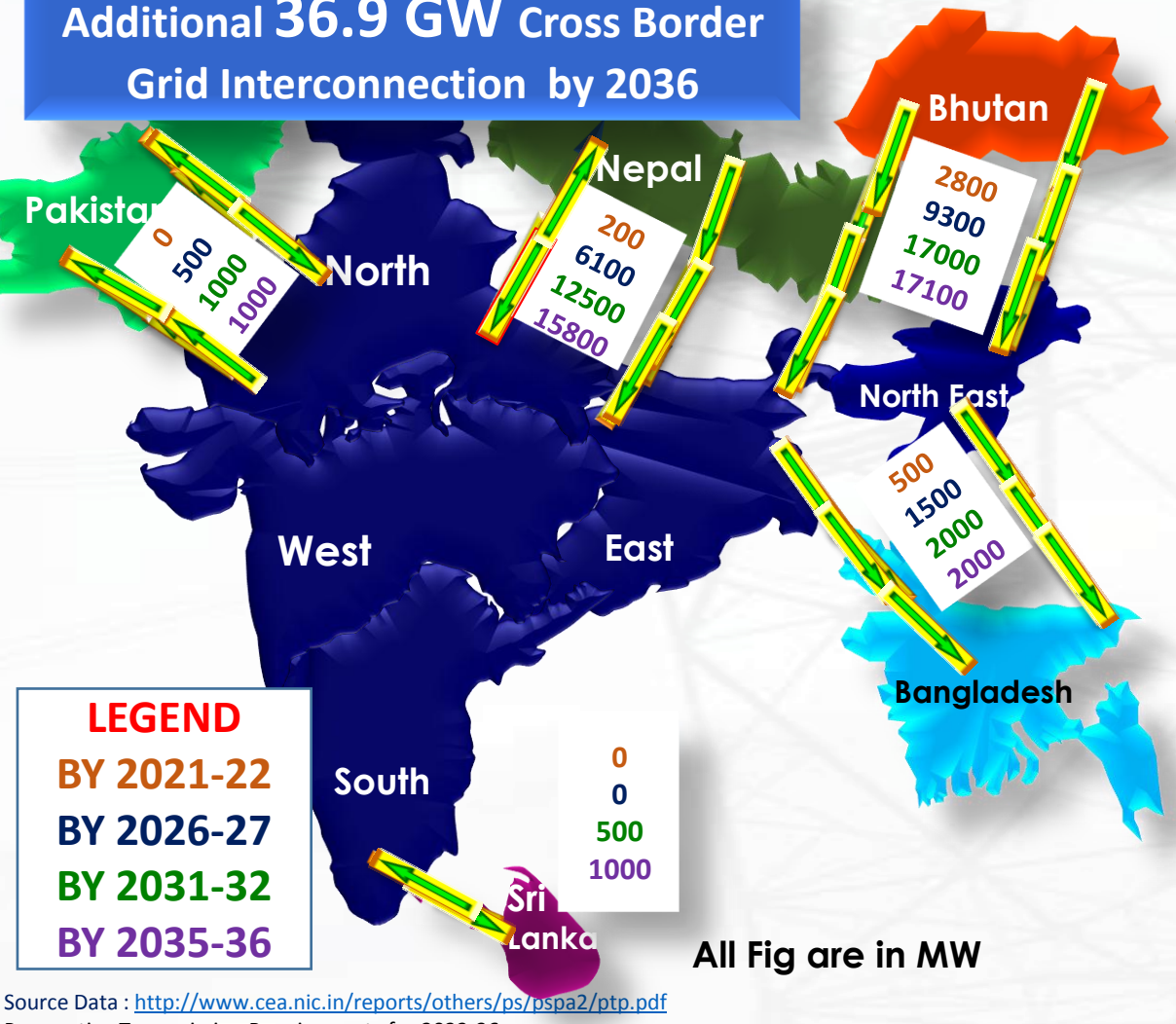
South Asia Regional Grid: Transmission Capacity by 2036/2040

Additional 36.9 GW Cross Border Grid Interconnection by 2036



LEGEND

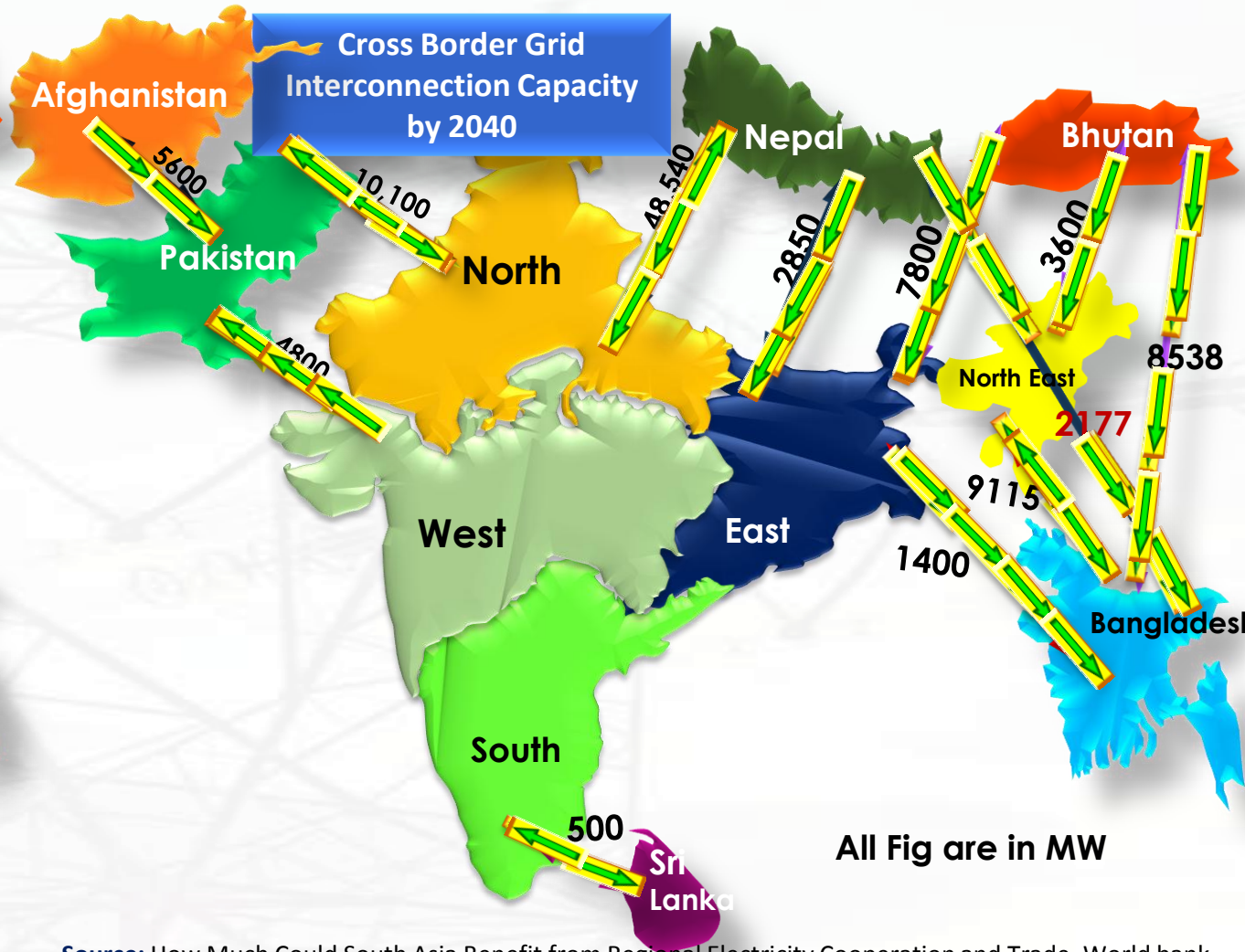
- BY 2021-22
- BY 2026-27
- BY 2031-32
- BY 2035-36

All Fig are in MW

Source Data : http://www.cea.nic.in/reports/others/ps/pspa2/ptp.pdf
Perspective Transmission Requirements for 2022-36

Bangladesh is in the process of Planning to Import around Apprx. 6000 MW by 2034 (PMSP 2015-JICA Presentation,4th June,2015)

Cross Border Grid Interconnection Capacity by 2040



All Fig are in MW

Source: How Much Could South Asia Benefit from Regional Electricity Cooperation and Trade, World bank

Why the Need for Harmonization of Grid Codes for Safe, Reliable and stable operation of the Interconnected Power system

With High Level of Cross Border Interconnection being envisaged, it is obvious that for safe, reliable and stable operation of the interconnected transmission system, the various technical aspects of grid codes, operating procedures and standards needs to be harmonized/coordinated.

Harmonization means to have procedures, schedules, specifications of systems to make them uniform or mutually compatible and manage the differences & inconsistencies among measurements, methods.

Compatibility has to be there depending on the type of interconnection.

In case of a synchronous interconnection, voltage, basic insulation strength, nominal frequency and protection scheme must match.

In case of asynchronous interconnection though may require less level of harmonization, the tripping of HVDC terminal would itself can constitute a disturbance in terms of loss of load or loss of supply at bigger level.

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Challenges for Harmonization of grid codes –Questions explored during the Study

How to secure the own power system while connecting with cross border regional power systems?

Can be the present Grid Code/guidelines serve the purpose for CBET? What are the Gaps

What are all the technical measures to be taken while connecting for cross border?

What are the challenges of integrating a small power system with a large power system

How the present dispatch scheduling mechanism will get effected with CBET?

How much import/export is required for future? How CBET will help the reliability of the power in country or Impact the reliability, security ?

Who is responsible for what in CBET operation?

How the frame work guidelines will help for bilateral and multilateral interconnections?

Is it required to modify the existing grid codes which focusing on domestic power system

How to implement the Cross Border Grid Code?

Background and Approach of the Study :Framework Grid Code Guidelines

Background- ***Framework Grid Code Guidelines (Volume –III) is one of the outcome of the TF-2 study on Harmonization of grid codes, operating procedures and standards to facilitate/promote cross border electricity trade in the south Asia region.***

Steps for the Study

1. **Review of Existing Studies/ Literature/ Reports**
2. **Detailed Review & Analysis of Grid Codes of SAC and Gap Analysis**
   - Summary of the Gaps Identified on Planning. Connection, Operation, Scheduling & Dispatch, Metering etc.
   - Current status in member countries w.r.t to key aspects of Grid Codes i.e. Planning. Connection, Operation, Scheduling & Dispatch, Metering etc.
3. **Review and Analysis of Grid Codes, Technical Standards & Regulations of relevant International Regional Power Systems/Pools. Identification of Best grid code practices wr.t CBET**
   - Critical Inference Drawn for South Asia based on analysis of International best practices in grid codes and impact analysis
   - Europe-ENTSOe, North America-NERC, Southern Africa- SAAP
4. **Impact Analysis based on International Experience Review and Gap Analysis**
5. **Framework Grid Code Guidelines**
6. **Implementation provision of Framework Grid Code Guidelines**
   - Recommend Institutional Mechanism for Implementation of Framework Grid Codes Guidelines SAC to promote CBET

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Study Volumes

Volume -I

It covers

1) Findings of the analysis of existing Grid Codes of South Asian countries

2) Findings of the Gap analysis.

3) recommendations for South Asia

Volume II

It covers

1) Findings of review and analysis of International regional power pools, international best practice and impact analysis

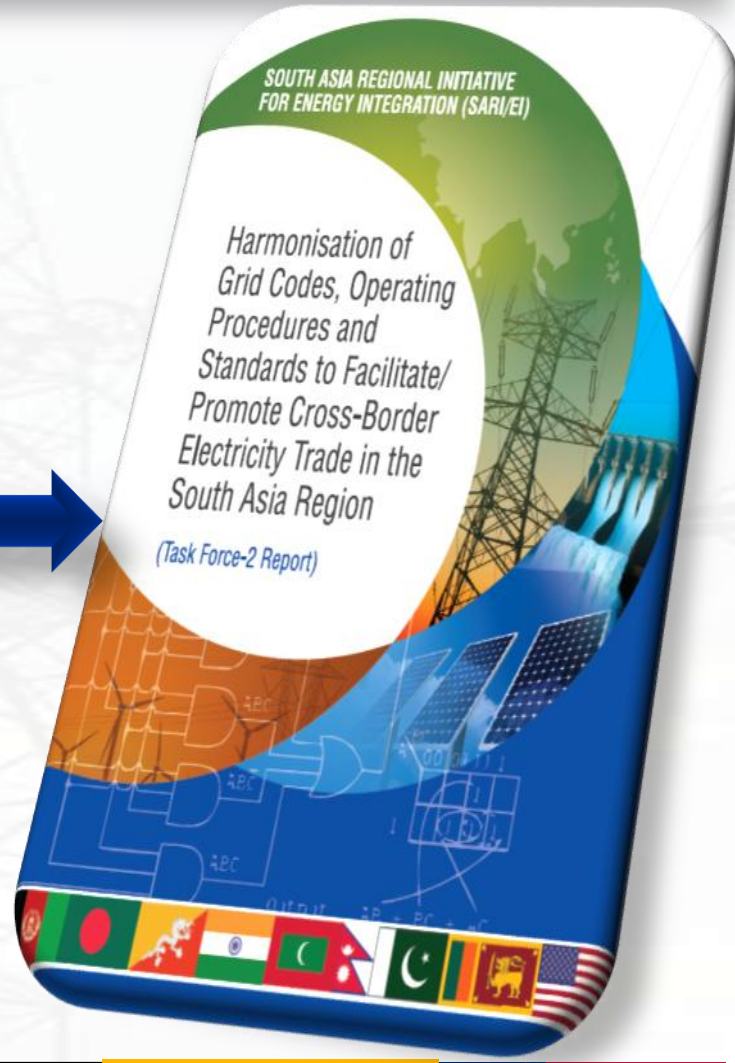
2.Recommedation for South Asia.

Volume III

1)Framework Grid Code Guidelines in the form draft codes

2) Implementation provisions.

3) Brief Summary of Gap analysis , international experience review.



Extensive Analysis through a Consultative Process over a period of two Years

2014 *Need for Grid Code Harmonization was deliberate in the 2nd meeting of Task Force 2 (TF-2) on 16th -17th April, 2014 at Kathmandu, Nepal*

2015 *Terms of Reference of the Study drafted and the same was deliberated and finalized by TF-2 members in the 3rd meeting of TF-2 on held on 25th-26th February 2015 at Colombo Sri Lanka.*

2015 *Study Awarded to PRDC on 17th 2015 through a competitive bidding process.*

2015 *Gap Analysis, Findings of the analysis of Grid codes of South Asian Countries , draft findings were presented and deliberated in the 4th Meeting TF-2 -5th-6th August,2015 at Delhi*

2015 *Findings of the Review and Analysis of Grid Codes, International Regional Power Systems/Pools ,Frame work Grid Code guidelines presented and deliberated in the 5th Meeting TF-2, 17th Sep 2015, Kolkata, India.*

2016 *Presentation of the key findings i.e. Draft Frame work Grid Code guidelines in 2nd Meeting of SAARC Energy Regulators on 8th -9th February 2016 - Colombo, Sri Lanka*

2016 *Stakeholder Consultation , SARI/EI Technical Delegation to SA countries to interact with planning agencies, system operators ,Regulators etc. in April, May,2017*

2016 *Presented and deliberated the Key findings in the* 6th Meeting of TF-2 , 20th April 2016, Dhaka, Bangladesh-Deliberated on the Findings

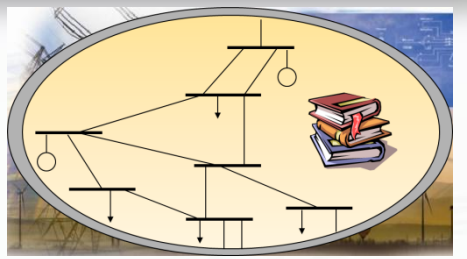
2016 *Presentation of the key findings i.e. Draft Frame work Grid Code guidelines in e 3rd Meeting of SAARC Energy Regulators on 21st -22nd,Sept. 2016, Pakistan*

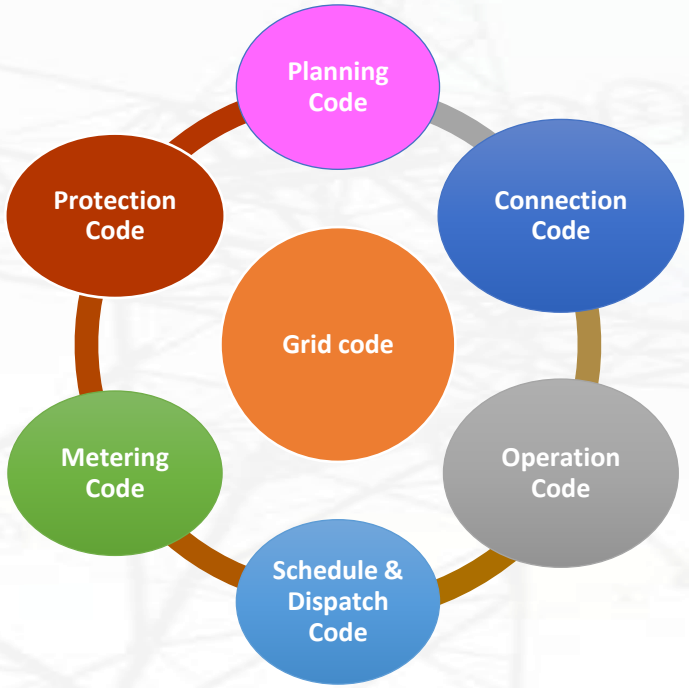
2016 *Finalization and Publishing of the Report in September 2016*

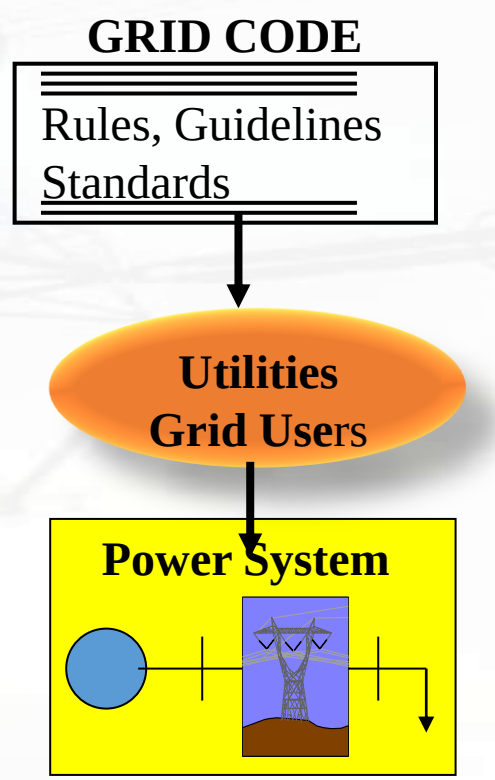
Grid Codes

A Set of rules, guidelines & standards

- To be followed by various persons and participants in the power system
- To plan, develop, maintain and operate the power system in the most secure, reliable, economic and efficient manner
- To facilitate healthy competition in the generation and supply of electricity.
- Grid codes are approved by a regulatory body or government in exercise of powers conferred to it under the relevant electricity act/legislation







South Asia Power System- Technical Info-Gap Analysis

	Voltage		Frequency	
	Normal	Emergency		
Bangladesh	Normal: ±5%	Emergency: ±10%	49 Hz to 51 Hz	
Bhutan	Normal: ±5%	Alert: ±10%	Normal: 49.5 Hz to 50.5 Hz	Alert: 49 Hz to 51Hz but above Normal range.
India	Normal: ±5% for 400 kV, 765 kV, ±10% for 220 kV & below.	±10% for 220 kV & below.	49.9 Hz to 50.05 Hz	
Nepal	Normal: ±5%	Emergency: ±10%	48.75 – 51.25 Hz	
Pakistan	Normal: 8% and -5% .	Emergency: ±10%	49.8 Hz to 50.2 Hz(Frequency sensitive mode)	49.5-50.5 (Tolerance Frequency band) 49.4-50.5(Load sheading threshold and contingency frequency band)
Sri Lanka	Normal: ±5% for 132 kV, ±10% for 220 kV.	Emergency: ±10%	49.5 Hz to 50.5 Hz	

Acceptable Voltage Deviations are similar but the permitted frequency deviation is different- Need to harmonize for synchronous interconnection

Except India, grid codes of all other SA nations specify the same voltage variation limits for both planning and operation stages.(For India :refer CEA's manual on transmission planning).
For (India) Planning studies +/-2% 765kV; +/-3% 400 kV; +/-5% to 7% for below 220 kV

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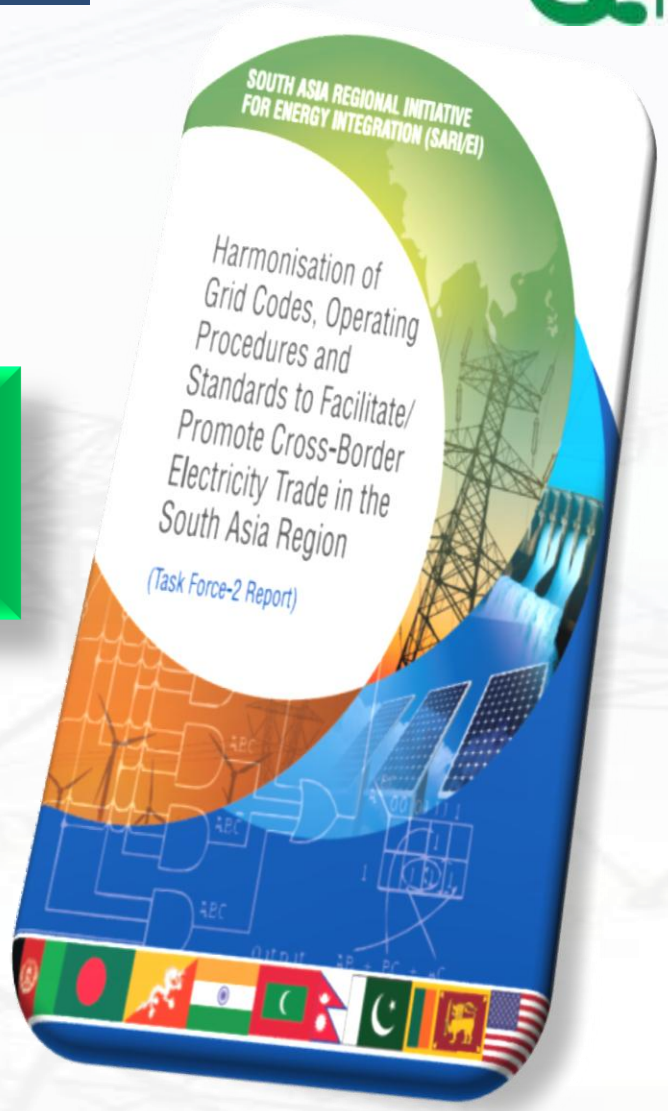
Framework Grid Code Guidelines (FGCG)



Context: Framework Grid Code Guidelines (FGCG)

Context of the Framework Grid Code Guidelines (FGCG)

- CBET in the region is set to change with **several new transmission interconnections being proposed** that will **enable greater integration of power systems** in South Asian member countries.
- With High Level of Cross Border Interconnection being envisaged, it is obvious that **for safe, reliable and stable operation** of the interconnected transmission system, the various **technical aspects of grid codes (planning, connection, metering, Protection etc.), operating procedures and standards needs to be harmonized/coordinated**.
- Harmonization means **to have procedures, schedules, specifications of systems to make them uniform or mutually compatible** and manage the differences & inconsistencies among measurements, methods.
- Compatibility has to be there depending on the type of interconnection. In case of a synchronous interconnection, **voltage, basic insulation strength, nominal frequency and protection scheme must match**.
- In case of asynchronous interconnection though may require less level of harmonization, the **tripping of HVDC terminal would itself can constitute a disturbance in terms of loss of load** or loss of supply at bigger level.

Existence of broader framework and consensus is evident from the IGFA

The **SAARC Inter-Governmental Framework Agreement (IGFA) for Energy Cooperation**, signed by Foreign Ministers of the eight member states **provides a strong basis for ensuring consistency in certain identified areas** of trade as follows:

- *Article 7 (Planning of Cross-border interconnections)*
- *Article11 (System Operation and Settlement Mechanism)*
- *Article 10 (Electricity Grid Protection System)*
- *Article 8 (Build, Operate and Maintain)*
- *Article 9 (Transmission Service Agreements)*
- *Article 12 (Transmission Access)*

FGCG in the form draft Codes are in line with IGFA

It is important to provide actionability to the Articles by defining them into operating rules and common grid code guidelines w.r.t CBET transactions through Grid Code Harmonization

The Framework Grid Code Guidelines (FGCG) in the form of Draft Codes are based on the Review & Analysis of Grid Codes of SAC, Gap Analysis, Review and Analysis of Grid Codes, Technical Standards & Regulations of relevant International Regional Power Systems/Pools and Impact Analysis.

Purpose : Framework Grid Code Guidelines (FGCG)

Purpose of the guidelines

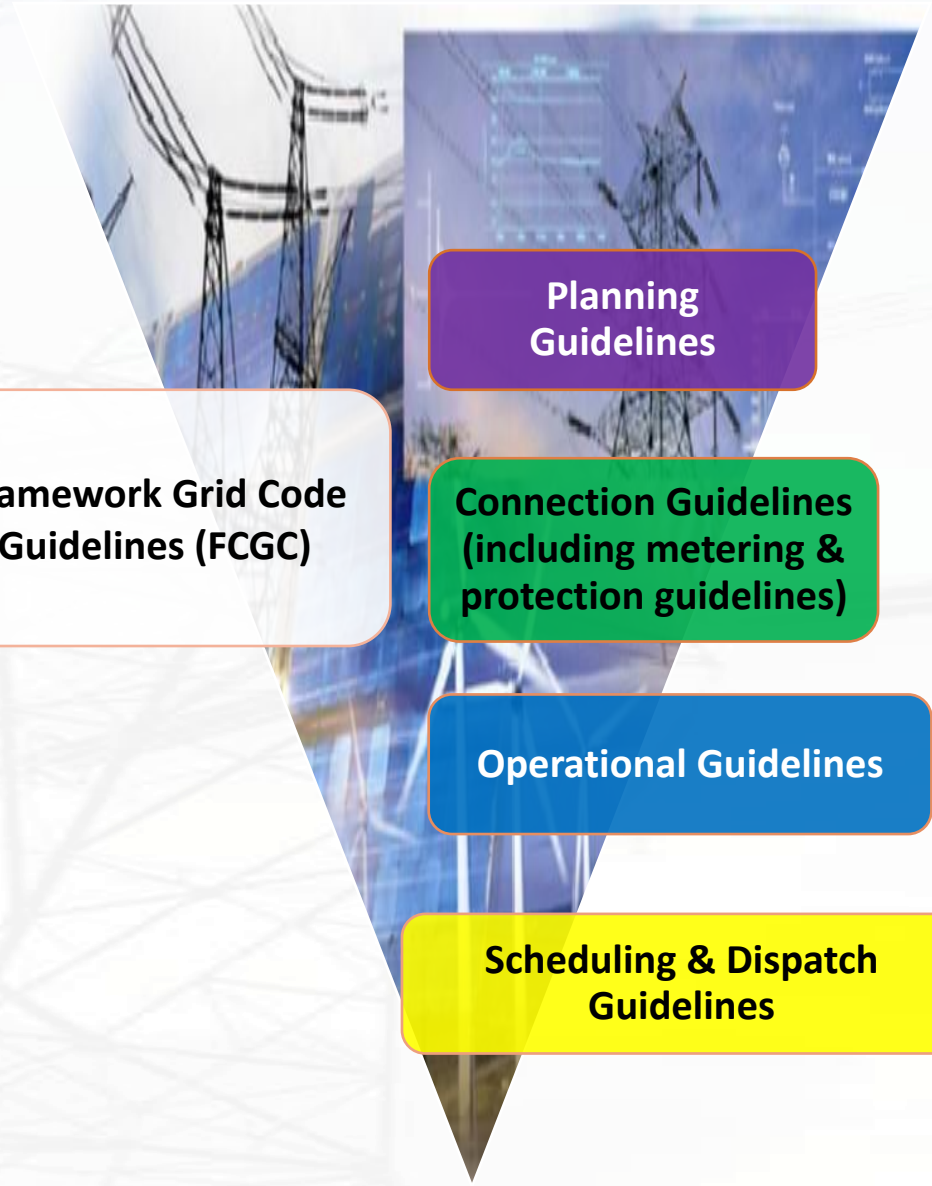
Framework Grid Code Guidelines (FGCG)

Establish clear technical framework and Grid code & related regulatory environment vis-à-vis a coordinated /harmonized cross border Grid Codes for smooth, reliable , secure Electricity trading

Provide roadmap for action and decision making for Relevant Authorities/Regulators through FGCG

Provides consistency across technical parameters ,grid codes, standards, operating procedures in CBET transactions and gives certainty certainty to grid users

The flexible nature of **Framework Grid Code Guidelines** and focus on specific aspects of CBET only, would permit both the **Framework Grid Code Guidelines** and the national regulatory framework and Grid codes to co-exist.



Preamble to the Framework Grid Code Guidelines

- These Framework Grid Code Guidelines **apply to CBET only** among the South Asian Countries.
- These Framework Grid Code Guidelines are **non-binding in nature** and are aimed to provide the national regulators of SAC with a consistent set of guidelines and grid codes applicable to CBET only.
- The guidelines deal only with **limited areas** where a need for such common guidelines and grid codes has been felt by the SAC and are not meant to be comprehensively dealing with all matters related to CBET. For all other purposes, the respective Grid Code guidelines shall apply.
- **SAFER*** shall be the institutional body working towards enabling the facilitation/adoption Framework Grid Code Guidelines & Draft Codes by the National Regulatory Authorities and facilitating the required changes to be made in the Grid Code framework.
- In countries where regulators do not exist, the responsibilities shall rest with the relevant ministry and/ or empowered entity for specific issues.
- Considering the technical complexity in farming grid code, harmonization and for integrated system planning and operation, this study has suggested to create a Regional Technical Institutions/Body such as **South Asian Forum of Transmission Utility (SAFTU). SAFTU** will provide technical support & inputs in farming grid code, harmonization to the SAFER.

***South Asia Forum of Electricity Regulators (SAFER) suggested by SARI/EI Task Force -1 Or any other appropriate Regional Regulatory Institutional Mechanism..**

Brief Summary of the Framework Guidelines – Planning

Planning Guidelines and Codes

1

The Planning Guidelines and Codes provides information and stipulates the various criteria to be adopted for planning and development studies. It covers codes on

- ✓ Planning Philosophy,Transmission Planning Criterion , Transmission Reliability Criteria, Planning Margins etc.
- ✓ Transmission system capability of withstanding loss of most severe single system infeed, Transient Stability Limit and Reactive Power planning.

2

The Planning Guidelines and Codes recommends :

✓Master Plan with a planning horizon of 10 years as the basis for planning. Can be for bi-lateral or multilateral.

✓Load-generation scenarios shall be worked out to reflect typical daily and seasonal variations in load demand/availability.

✓Voltage and Equipment Loading Margins. Short circuit ratio (SCR) at the converter terminals of HVDC installations shall be greater than 3.The LOLP of 0.2% or lower shall be considered in planning exercise while assessing cross border line flows.

3

The Planning Guidelines and Codes recommends –Planning Criterion:

✓Requirement of reactive power compensation (static and/or dynamic)

✓Voltage limits for planning studies (N-0 , N-1 contingencies)- ±3% voltage*. Thermal loading limits of lines & transformers- 15% margin.

4

The Planning Guidelines and Codes are in line with the overall objective of with article 7 of the SAARC framework agreement for energy cooperation (electricity) as regard to planning of cross border interconnections.

*±5 % voltage-Normal(Operational), ± 10% voltage-Emergency

The nominal frequency shall be 50 Hz. The steady state frequency limits shall be +0.05 Hz to -0.1 Hz, i.e. from 49.9 Hz to 50.05 Hz.. The instantaneous frequency limits shall be —0.8 Hz. *{The nominal frequency is that followed by all South Asian countries. The steady state frequency limits is that stated in Indian Grid Code. The instantaneous frequency limits is adopted from the European Grid Code.}*

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Brief Summary of the Framework Guidelines – Connection

Connection Guidelines and Codes

1

The Connection Guidelines and Codes specifies :

✓ A compliance of minimum of technical, design and operational plant criteria by the existing and prospective new users.

✓ It includes the meter placement, compliance of meters according to standards in terms of accuracy levels, accessibility of the meters, maintenance responsibility of meters ,meter placement, compliance of meters according to standards .

2

The Connection Guidelines and Codes recommends Technical Requirement for Connectivity :

✓Reactive power *, Frequency and voltage parameters, Short-circuit fault levels, Metering system.

✓Stipulated Guidelines and code for Protection Requirement, Protection devices, Simulation Models, Data & Communication, Cyber Security. Connection Agreement .

3

The Connection Guidelines and Codes recommends :

✓Equipment Standards: Frequency limits for Equipments: 47.5 – 48.5 Hz (90 min); 48.5– 49.0 Hz (not less than the period for 90 minutes); 49.0–51.0 Hz (Unlimited); 51.0 – 51.5 Hz (30 min).

✓At interconnection point , operating voltage for 400 kV and above is : ±5% and connected equipment shall withstand the voltage variation of ±10%.

✓Bi-directional meters shall be installed at the connection point by following IEC standards. Meter accuracy shall be 0.2% and the secondary burden shall be maintained between 25% and 100% of rated values.

4

Connection Guidelines & Codes In line with article 8, 9 & 10 of the SAARC framework agreement for energy cooperation (electricity)

* reactive power flow on the link shall be within lead/lag 0.97 power factor and operated within the grid code voltage level)

Brief Summary of the Framework Guidelines –Operation

Operation Guidelines and Codes

1

The Operation Guidelines and Codes specifies

✓All necessary aspects relevant to outage planning, operational security analysis, frequency control and handling of reserves

✓Operation code also covers operational security aspects pertaining to power system states; frequency control; voltage, reactive power, short circuit management; power flow management, contingency analysis and stability management.

✓Details for high level operational procedures, for example, demand control, operational planning and data provision.

2

The Operation Guidelines and Codes recommends :

✓No important element of the interconnected grid shall be deliberately opened or removed from service at any time, except certain emergency condition, safety of human life etc.

✓Adequate operating reserves (Primary/Secondary/Tertiary) shall be made available for CBET.

✓Stipulates Guidelines and codes for Demand Estimation for operation and Congestion Management, Outage

✓Planning, recovery procedure , Operation Liaison , exchange of information etc.

3

The Operation Guidelines and Codes recommends :

✓Frequency limits: Frequency – for synchronously interconnected system:

Nominal State: 50Hz, **Steady state limits:** +0.05Hz to -0.1Hz, Instantaneous limits: ± 0.8Hz

Alert: Exceeds steady state limits for upto 10 mins

Emergency: Exceeds steady state limits for >10 mins up to 20 mins

4

✓At interconnection, operating voltage for 400 kV and above is : Normal: ±5% , Alret: ±5% Emergency: ±10%.

Brief Summary of the Framework Guidelines–Scheduling & Dispatch

Scheduling & Dispatch Guidelines and Codes

1

✓**The Scheduling & Dispatch Guidelines and Codes specifies**

✓Procedures to be adopted for Scheduling and dispatch of generation and allocation of power drawl

✓Include procedure and Formula for calculation of TTC, ATC along with reliability margins and the regulations for mechanism for forward capacity allocation and congestion relieving mechanism, Deviation Settlement mechanism(Technical Part only)

2

The Scheduling & Dispatch Guidelines and Codes recommends

✓Standardized scheduling intervals.

✓Detail Guidelines for scheduling & dispatch procedures, the establishment of scheduling processes, provision of information to other country system operators, day ahead scheduling procedure, intra-day scheduling/revision procedure, sharing of information on schedules and standardized scheduling intervals for cross border trade.

✓Charges for Losses: Cross Border System Operator Compensation (CBSOC) Fund.

3

The Scheduling & Dispatch Guidelines and Codes recommends :

✓Each time block shall be for a duration of 15 minutes and a common time of Indian Standard Time (IST) can be adopted for uniformity.

✓The coordinating forum shall be responsible for computation of actual net injection/drawal of on the cross border link, 15 minute-wise.

4

The Scheduling & Dispatch and Codes Guidelines and Codes enable non-discriminatory access to the respective transmission grids for purpose of cross border trade in line with article 12 of SAARC framework agreement for energy cooperation (electricity)

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Implementation of Framework Grid Code Guidelines (FGCG): Implementation Provisions

Overall Approach for Grid Code Harmonization/Coordination in South Asia

Framework Grid Code Guidelines (FCGC)

Development of Framework guidelines on the identified Areas i.e. Planning, Operation, Connection , Scheduling & Dispatch and contains explanatory statement along with draft code for each of the above identified areas. (Done by this Study)

Cross Border Grid code (CBGC)

Development of codes based on Framework Grid Code Guidelines and Draft Codes by the relevant authorities of South Asian Countries. (Draft Codes developed by this Study will be the base document)

Agreement & Operationalization of Cross Border Grid code

Framework Grid Code Guidelines (FCGC) in the form Draft codes

- **Planning Guidelines**
- **Connection Guidelines (including metering & protection guidelines)**
- **Operational Guidelines**
- **Scheduling & Dispatch**

The draft code can be adopted/adapted fully or in parts by the relevant authorities and can form the basis for harmonising/Coordination of the existing national codes in the identified areas for CBET.

Implementation Philosophy–International Experience-Need of Institutional Mechanism

entsoe
Reliable Sustainable Connected

European Union
ENTSO-E's responsibilities in enhancing the cooperation between its 41 member TSOs across the EU to assist in the development of a pan-European electricity transmission network

- Developed the Network codes on on System operation, connection and capacity allocation etc.
- System Development Committee
- System Operation Committee.
- Market Committee
- 'Research Development Committee

SAPP

Southern African Power Pool
Aim to provide the least cost, environmentally friendly and affordable energy and increase accessibility to rural communities.
It is a Inter-Utility organisation established through Inter-Utility MOU

- *Operational Subcommittee*
- *Planning Subcommittee*
- *Environment Subcommittee*
- *Operating Guidelines*
- *DAM Book of Rules*
- *DAM legal Agreement*

pjm

PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia.

- *Operating Agreement*
- *Operating Committee (OC)*
- *Planning Committee (PC)*
- *Market Implementation Committee (MIC)*
- *Markets and Reliability Committee (MRC)*
- *Other sub committees and task forces.*
- *Transmission Owners Agreement*

West African Power Pool

West Africa Power Pool: Integrate the operations of national power systems into a unified regional electricity market. Inter Utility Organisation, WAPP Utility Members(26)

- Engineering and Operating Committee (EOC)
- Strategic Planning & Environmental Committee
- Operation manual-WAAP
- Regional Market Rules for the WAPP
- Transmission Tariff Methodology
- 2012-2015 WAPP Business Plan

Way Forward

- *For the first time grid codes has been studied and analyzed from perspective of CBET in South Asia and the report is first of its kind in South Asia.*

- *Harmonized Grid codes are important for*

1. *safe, stable, reliable and integrated operation of the regional power system*
2. *for development of Robust South Asia Regional Power Grid (SARPG).*
3. *To bring Sustainability of Energy Integration in South Asia*

- *Appropriate Institutional Mechanism and a strong institutional sponsor is required for facilitating and working towards enabling the* **Implementation of Framework Grid Code Guidelines (FGCG).**

- ***South Asia Countries needs to work together and strengthen their grid codes form the perspective of CBET and SARPG.***

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Thank You

Contact
rajivratnapanda@irade.org
rajivratnapanda@gmail.com

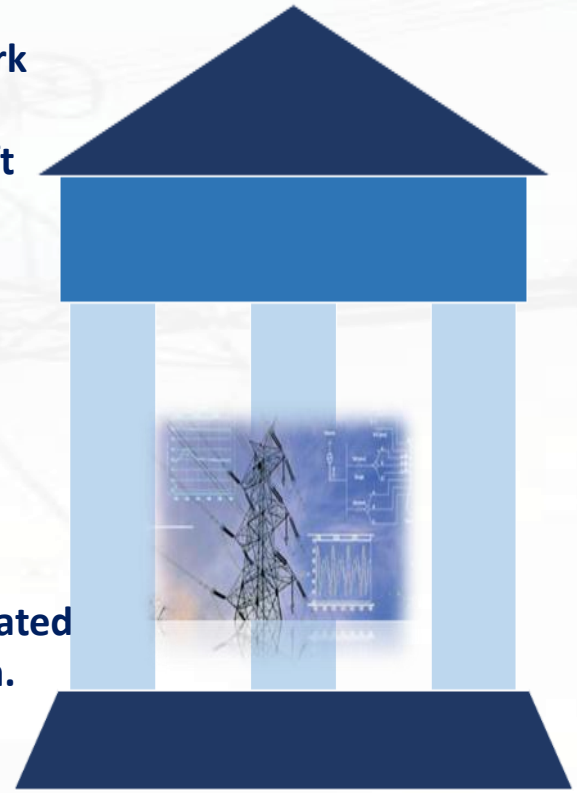
Framework Grid Code Guidelines Implementtion: Institutional Mechanism

Institutionalize the Process

South Asian Forum of Transmission Utility **(SAFTU)**

For Implementation Framework Grid Code Guidelines and for integrated system planning and operation , Study Recommended to create a Regional Technical Institutional Mechanism i.e. South Asia Forum of Transmission Utilities (SAFTU)

- Facilitate regional system planning and coordinated operation of the interconnected transmission network
- Facilitate and lead the work towards the adoption and implementation of framework guidelines and draft codes by the national regulatory agencies and provide technical support & assistance to SAFER* on the framework guidelines and draft codes. Development of Codes ,Technical Standards, Technical Guidelines.
- Act as a Secretariat to the various technical Groups/ Standing Committees formed under SAFTU.
- Come up with various white papers, discussion papers on various technical issues related regional power system planning, operation, maintenance etc.
- To act as a platform for cross-cutting deliberations on technical, standard, system operation, planning related issues for advancing CBET in South Asia and for development of an integrated and regional power system.
- To facilitate technical capacity building among members at both national and regional levels through information sharing and skills training.



*** Any other appropriate Regional Regulatory Institutional Mechanism.**

Implementation Framework Grid Code Guidelines (FGCG)

The Framework Grid Code Guidelines (FGCG) shall be implemented in a phased manner

Stage 1:
Endorsement of Framework Grid Code Guidelines (FGCG) and Draft Codes by National Regulators

FGCG and Draft Codes will be in the **form of a non-binding framework guiding CBET**. Gradually a **legal status will be accorded** to the Guidelines.

Proposed Guidelines are **flexible in nature with limited focus only on specific aspects of CBET**

Stage 2:
Identification of changes/ amendments in National Grid Codes and Regulation for adoption of Framework Grid Code Guidelines (FGCG) and Draft Codes

National Regulators/ Empowered entities shall identify changes required to be in the national Grid codes and related regulations

Changes to be identified based on FGCG and Draft Codes. Draft codes developed as a part of FCGC can be adopted in toto or in parts as appropriate by the relevant authorities and can form the basis for harmonising/coordination of the existing national grid codes from the perspective of CBET.

Stage 3:
Notification of new orders and changes/ amendment in grid codes and related Regulations w.r.t CBET

National Grid Code/ Related Regulations or **Framework Grid Code Guidelines (FGCG) and Draft Codes will be updated or modified to ensure consistency**

Framework Grid Code Guidelines (FGCG) and Draft Codes will be updated **basis on other technical, reliability, stability studies undertaken in the due course.**

Stage 4:
Framework Grid Code Guidelines (FGCG) and Draft Codes updated and adopted for CBET as Cross Border Grid Codes

Regular updation and improvement in **Framework Grid Code Guidelines (FGCG), Draft Codes and Cross Border Grid Codes**

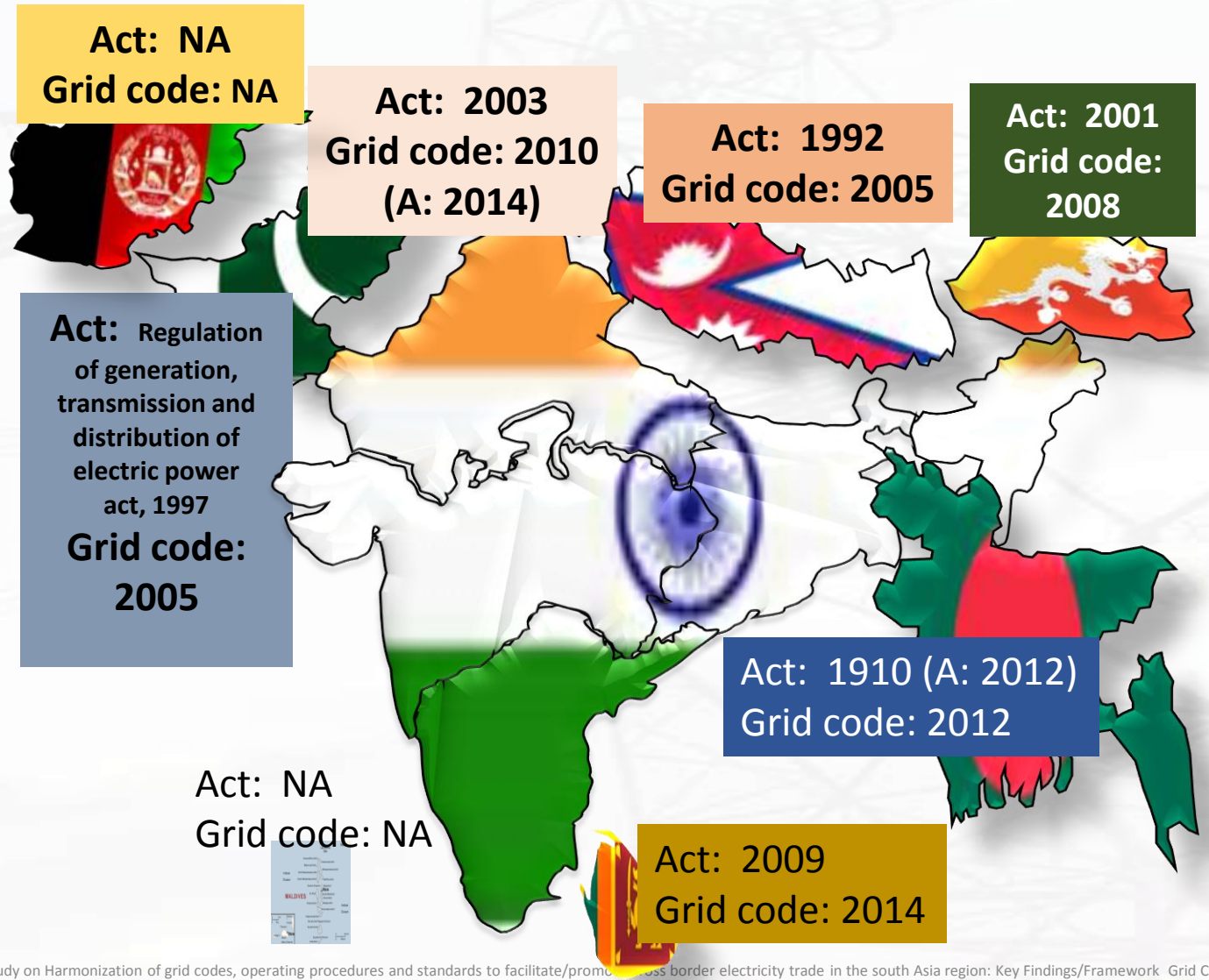
Adoption by **National Governments giving a Legal status**

Becomes binding on all CBET transactions

The above steps will require consensus building and hence will need to be facilitated through a strong sponsor. The Task Force-1 study has proposed South Asian Forum of Electricity Regulators (SAFER) or another appropriate Regional Regulatory Institutional Mechanism to manage such process.

Considering the technical complexity involved with respect to farming grid code regulations and harmonization of grid codes and for integrated system planning and operation , this study has suggested to create a Regional Technical Institutions/Body such as South Asian Forum of Transmission Utility (SAFTU). SAFTU will provide technical support & inputs to the SAFER (or any other regulatory regional regulatory institutional mechanism in South Asia).

Legal and Regulatory Framework Reviewed : South Asia Grid Codes



Country	Apex legal Document	Grid code document
Afghanistan	Not Available (NA)	NA
Bangladesh	Electricity Act, 1910 (AMENDMENT 2012)	Grid Code, 2012
Bhutan	Electricity Act of Bhutan, 2001	Grid Code 2008 (Reprint 2011)
India	Electricity Act, 2003	Grid code 2010 (Amendment 2014)
Maldives	NA	NA
Nepal	Electricity Act 1992	NA Grid code 2005
Pakistan	Regulation of generation, transmission and distribution of electric power act, 1997	Grid Code, 2005
Sri Lanka	Electricity Act 2009	Grid Code, 2014

Note : This study has considered Grid codes, Laws ,regulations as exist as of July,2016 has been reviewed and analysed only .

Technical Info

Country	Permissible Frequency Band (Hz)
Afghanistan	NA
Bangladesh	49.0 – 51.0 Hz
Bhutan	49.5 – 50.5 Hz
India	49.9 – 50.05 Hz
Maldives	49.5 – 50.5 Hz
Nepal	48.75 – 51.25 Hz
Pakistan	49.5 – 50.5 Hz
Sri Lanka	49.5 – 50.5 Hz

Country	Transmission Voltage Levels (kV)	Permissible Deviation
Afghanistan	220, 110	NA
Bangladesh	400, 230	+/- 5%
Bhutan	400, 220	+/- 5%
India	765, 400 220, 132	+/- 5%; +/-10%;
Maldives	33, 11	+/- 10%
Nepal	220, 132,	+/- 10%
Pakistan	500, 220	+/- 10%
Sri Lanka	220, 132	+/- 5%; +/- 10%

Acceptable Voltage Deviations are similar but the permitted frequency deviation is different- Need to harmonize for synchronous interconnection

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Implementation Provisions: Coordination Groups/Standing Committees Under SAFTU

Operation and Maintenance Coordination Group


- The Operation and Maintenance Coordination Group needs to be constituted for smooth operation and maintenance of the interconnecting project after its commissioning. The scope would also include maintenance of associated communication facilities, coordination of protective devices, maintenance coordination etc.
  - Operation and Protection Coordination Group
  - Commercial Coordination Group

Project Monitoring Group


- The project monitoring group would monitor different milestones of the project after completion of DPR. The detailed activities need to be monitored include tendering activities, forest and environmental clearances, acquisition of land for substation, construction of the project, commissioning of the project etc.

Design Coordination Group


- The Design Coordination Group would prepare the Detailed Project Report on the basis of various activities like detailed survey of the routes of transmission lines, assessment of size & location of substation land, finalization of the details of design parameters of the substations and transmission lines etc.

Power System Planning Committee

- ❑ Power System Planning Committee under SAFTU will lead in preparation of the Regional Master Plan.
- ❑ Master Plan shall formulate the plan for next 10 years, considering necessary system up gradations, both proposed and commissioned.
- ❑ Master Plan must be reviewed annually and must ensure adequacy for all scenarios that could be possible in the next 10 years, by forecasting both demand and generation considering necessary factors.

Framework Grid Code Guidelines (FGCG) and Codes- Brief Summary

Brief Summary of the Framework Guidelines

Planning Guidelines

- In line with article 7 of the SAARC framework agreement for energy cooperation (electricity) as regard to planning of cross border interconnections, the preparation of master plan is recommended for each of the cross border links between the countries.
- The master plan can be for bi-lateral transaction or multilateral transactions but shall eventually cover the entire region. However, it is intended that the master plan shall cover a horizon of next 10 to 20 years.
- The Guidelines aim to provide for the supply of information and stipulates the various criteria to be adopted for planning and development studies

Connection Guidelines

- The connectivity guidelines in line with article 8, article 9 and article 10 of the SAARC framework agreement for energy cooperation (electricity) detail the connection of generator, deal with network connectivity and protection issues in detail and elaborate on the communication framework and exchange of data among the countries.
- The technical requirements covered in the connectivity code include but are not limited to frequency and voltage requirements, short circuit current requirements, reactive power requirements, responsibility & owner ship, protection & control and metering requirements.
- It specifies a minimum of technical, design and operational plant criteria to be compiled with by the existing and prospective users.
- It includes the meter placement, compliance of meters according to standards in terms of accuracy levels, accessibility of the meters, maintenance responsibility of meters etc.,

Brief Summary of the Framework Guidelines

Operation Guidelines

- In order to enable secure and reliable operation of the interconnected grid, the operational guidelines is intended to cover all necessary aspects relevant to outage planning, operational security analysis, frequency control and handling of reserves and the emergency operational procedures.
- In addition to above, the operation code also covers operational security aspects pertaining to power system states, frequency control management, voltage & reactive power management, short circuit management, power flow management, contingency analysis and stability management.
- It contains details for high level operational procedures, for example, demand control, operational planning and data provision.

Schedule and despatch Guidelines

- While making guidelines for scheduling & dispatch procedures, the establishment of scheduling processes, provision of information to other country system operators, day ahead scheduling procedure, intra-day scheduling/revision procedure, sharing of information on schedules with other trading countries and standardized scheduling intervals for cross border trade play a vital role.
- These Guidelines enable non-discriminatory access to the respective transmission grids for purpose of cross border trade in line with article 12 of SAARC framework agreement for energy cooperation (electricity) and include procedure for calculation of TTC, ATC along with reliability margins and the regulations for mechanism for forward capacity allocation and congestion relieving mechanism.
- It describes the procedures to be adopted for Scheduling and despatch of generation and allocation of power drawl

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Brief Summary of the Framework Guidelines

Planning

Master Plan with a planning horizon of 10 years has been suggested as the basis for planning the interconnected network among member countries and reviewed every alternative year.

Load-generation scenarios shall be worked out so as to reflect in a pragmatic manner due to typical daily and seasonal variations in load demand and generation availability

Voltage and Equipment Loading Margins

Short circuit ratio (SCR) at the converter terminals of HVDC installations shall be greater than 3.

N-0, N-1 transmission contingency criteria

Requirement of reactive power compensation (static and/or dynamic)

Connection

Connection Requirements: Reactive power, Frequency and voltage parameters, Short-circuit fault levels, Metering system, Protection devices, Simulation Models, Data & Communication, Cyber Security.

Frequency limits: 47.5 – 48.5 Hz (90 min); 48.5– 49.0 Hz (not less than the period for 90 minutes); 49.0 – 51.0 Hz (Unlimited); 51.0 – 51.5 Hz (30 min).

At interconnection, operating voltage for 400 kV and above is : ±5% and connected equipment shall withstand the voltage variation of ±10%.

Bi-directional meters shall be installed at the connection point by following IEC standards for meter accuracy

Energy Accounting and Audit functions shall be carried out by coordinating agency.

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Brief Summary of the Framework Guidelines

Operational

No important element of the interconnected grid shall be deliberately opened or removed from service at any time, except

The exchange of information over a common platform and include sufficient information on who is responsible for exchange of what data, containing how much detail, at what frequency and in what format along with the need for time stamping.

Adequate operating reserves (Primary/Secondary/Tertiary) shall be made available for CBT.

Voltage and Frequency limits for various states (Normal/Alert/Emergency)

Demand Estimation for operation

Congestion Management

Scheduling

Computation of the Available Transfer Capability (ATC)

Each time block shall be for a duration of 15 minutes and a common time of Indian Standard Time (IST) can be adopted for uniformity.

Control on its generation and / or load to maintain its interchange schedule with other member countries whenever required and contribute to frequency regulation of the synchronously operating system.

The coordinating forum shall be responsible for computation of actual net injection/drawal of on the cross border link, 15 minute-wise, based on the above meter readings.

Deviation Settlement mechanism

Charges for Losses

Framework Grid Code Guidelines (FGCG) and Draft Codes-Planning

Planning Guidelines: Planning Philosophy

Master Plan with a planning horizon of 10 years has been suggested as the basis for planning the interconnected network among member countries and reviewed every alternative year.

As the cross-border interconnection is expected to cater for the long term requirements of member countries, sufficient forecasting of demand and generation planning shall be carried out. All the stakeholders shall furnish the desired planning data from time to time to enable to formulate and finalize plan.

From practical considerations the load variations over the year shall be considered as under:

- **Annual Peak Load**
- **Seasonal variation in Peak Loads for Winter, Summer and Monsoon**
- **Seasonal Light Load or Off-peak load (for Light Load scenario, motor load of pumped storage plants shall be considered)**

The load-generation scenarios shall be worked out so as to reflect in a pragmatic manner due to typical daily and seasonal variations in load demand and generation availability which impact the cross border power flow along with the impact of RE i.e., wind & solar.

Planning Guidelines: Planning Philosophy

Master Plan Planning horizon of 10 years with revision for every alternative year: Both Active & Reactive power

Long term Load Forecasting

Generation Adequacy/Planning

Transmission Planning for CBT

Load-generation Scenarios

- Annual peak Load
- Seasonal Peak variations
- Seasonal Off-peak variations

The temporary over voltage (peak phase voltage) limits

- 1.4 p.u. for a 765 kV system
- 1.5 p.u. for a 400 kV & 500 kV system

The switching over voltage (peak phase voltage) limits

- 1.9 p.u. for a 765 kV system
- 2.5 p.u. for a 400 kV & 500 kV system

Short circuit ratio (SCR) at the converter terminals of HVDC installations shall be greater than 3.

Planned maximum sub-transient short circuit fault levels shall not be greater than 80% of equipment ratings.

Line to earth voltage during single line to earth faults should not rise above 80% of the rated line to line voltage.

Planning Guidelines: Transmission Reliability Criteria

Criteria for system with no contingency ('N-0')

- For the planning purpose all the equipment's shall remain within their normal thermal loadings and voltage ratings.
- The angular separation between adjacent buses shall not exceed 30 degree
- Voltage step resulting from capacitor/reactor switching shall not exceed 3.0%.

Criteria for single contingency ('N-1')

- All the equipment's in the transmission system shall remain within their normal thermal and voltage ratings after a disturbance involving loss of any one of the following elements , but without load shedding / rescheduling of generation:
  - Outage of a 400 kV single circuit,
  - Outage of a 400 kV single circuit with fixed series capacitor (FSC),
  - Outage of an Inter-Connecting Transformer (ICT),
  - Outage of a 765 kV single circuit,
  - Outage of one pole of HVDC bi-pole
- The angular separation between adjacent buses under ('N-1') conditions shall be permitted up to 30 degree
- The system shall be capable of withstanding the loss of most severe single system infeed without loss of stability.

Planning Guidelines: Planning Margins

Thermal loading limits of lines and transformers	15% margin
Voltage limits for planning studies (N-0 7 N-1 contingencies)	±3%
765 kV system	Max: 788 kV; Min: 742 kV
500 kV system	Max: 515kV; Min: 485 kV
400 kV system	Max: 412 kV; Min: 388 kV
Generation Units	
Thermal	Qmax = 40% of Pmax, and Qmin = (-) 10% of Pmax
Nuclear	Qmax = 40% of Pmax, and Qmin = (-) 0% of Pmax
Hydro	Qmax = 50% of Pmax, and Qmin = (-) 20% of Pmax

Planning Guidelines: Transmission Planning Criterion

Nominal Frequency	50 Hz
Steady State Operational Frequency Limits	+ 0.05 Hz to - 0.1 Hz
Instantaneous Frequency Limits	± 0.8 Hz

The temporary over voltage (peak phase voltage) limits due to sudden load rejection shall be:

- 1.4 p.u. for a 765 kV system
- 1.5 p.u. for a 400 kV & 500 kV system

The switching over voltage (peak phase voltage) limits shall be:

- 1.9 p.u. for a 765 kV system
- 2.5 p.u. for a 400 kV & 500 kV system

Short circuit ratio (SCR) at the converter terminals of HVDC installations shall be greater than 3.

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  - Outage of a 400 kV single circuit with fixed series capacitor (FSC),
  - Outage of an Inter-Connecting Transformer (ICT),
  - Outage of a 765 kV single circuit,
  - Outage of one pole of HVDC bi-pole
- The angular separation between adjacent buses under ('N-1') conditions shall be permitted up to 30 degree
- The system shall be capable of withstanding the loss of most severe single system infeed without loss of stability.

Reactive power compensation Studies

- Requirement of reactive power compensation (static and/or dynamic) shall be assessed through appropriate studies for cross border transactions. This compensation shall be provided by the respective entities within a country and import of reactive power shall be avoided to the extent possible.

Planning Guidelines: Planning Margins

The new transmission additions required for cross-border transmission may be planned keeping a margin of 15% in the thermal loading limits of lines and transformers.

At the planning stage, a margin of about ±3% may be kept in the voltage limits and thus the voltages under load flow studies (for 'N-0' and 'N-1' steady-state conditions only) may be maintained within the limits given below:

- For 765 kV level, a maximum of 788 kV and a minimum of 742 kV
- For 500 kV level, a maximum of 515 kV and a minimum of 485 kV
- For 400 kV level, a maximum of 412 kV and a minimum of 388 kV

In planning studies all the transformers may be kept at nominal taps and On Load Tap Changer (OLTC) may not be considered. The effect of the taps shall be kept as operational margin

For the purpose of load flow studies at planning stage, the nuclear generating units shall normally not run at leading power factor. To keep some margin at planning stage, the reactive power limits (Qmax and Qmin) for generator buses may be taken as:

- Thermal Units: Qmax = 40% of Pmax, and Qmin = (-) 10% of Pmax
- Nuclear Units: Qmax = 40% of Pmax, and Qmin = (-) 0% of Pmax
- Hydro Units: Qmax = 50% of Pmax, and Qmin = (-) 20% of Pmax

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Framework Grid Code Guidelines (FGCG) and Draft Codes-Connection

Connection Guidelines: Technical Requirements

The Connection Agreement shall be mandatory between the applicant and the national transmission utility of the member country at the synchronous connection point.

To comply with the connection code(s), the user shall be capable to meet the minimum standard requirement at the inter connection point which is defined by:

- Reactive power requirements
- Frequency and voltage parameters
- Short-circuit fault levels
- Metering system
- Protection devices
- Simulation Models
- Data and Communication Facilities & Event Recording Instruments including real time data gathering with time stamping
- Cyber Security
- Schedule of cross border assets of member country grid

Reactive Power Requirements

- Respective country's power authority need to ensure that reactive power requirements are kept at bare minimum (within lead/lag 0.97 power factor and operated within the grid code voltage level) at connection point.
- In case of HVDC link or asynchronous link, the voltage is to be maintained within the limits by the respective transmission agencies to prevent mal-operation of the HVDC links.

Connection Guidelines: Connection Guidelines

Frequency

- **User shall be capable of staying connected to the network and operating within the Frequency ranges and time periods which is specified by the system operator or automatically disconnect at specified frequencies if required by the operator.**
- **Recommended frequency band of operation shall be within 49.9 Hz to 50.05 Hz to maintain security of the total interconnected system. However all the connecting equipments shall withstand the frequency profile.**

Frequency	Time period for operation
47.5– 48.5 Hz	90 minutes
48.5– 49.0 Hz	To be defined by each system operator, but not less than the period for 90 minutes
49.0 – 51.0 Hz	Unlimited
51.0 – 51.5 Hz	30 minutes

Voltage

- At the point of Interconnection, acceptable range of operating voltages shall be ±5% for 400 kV and above transmission voltage levels but all the connected equipment shall withstand the voltage variation of ±10%.

Short-Circuit Fault Levels

- The coordination forum or the planning committee shall provide minimum and maximum short circuit level of the interconnecting substation of cross-border link for various possible scenarios

Connection Guidelines: Protection Requirements

Protection schemes relevant for the power generating module and the network shall be coordinated and agreed between the relevant network operator and the power generating facility owners.

Protection scheme for Generation Facilities

External and internal short circuit	Inter-area oscillations	Rate of change of frequency
Over-/under-excitation	Inrush current	Neutral voltage displacement
Stator and rotor overload	Asynchronous operation (pole slip)	Inverse power
Asymmetric load (-ve phase sequence)	Power generating module line protection	Over fluxing (U/f)
Over-/under-voltage at the connection point	Protection against inadmissible shaft torsions (for example, sub-synchronous resonance)	Backup schemes against protection and switchgear malfunction
Over-/under-voltage at the alternator terminals	Unit transformer protection	

Protection Scheme Devices Of Demand Facilities Shall Cover -

- External and internal short circuit;
- Over- and under-voltage at the connection point;
- Over- and under-frequency;
- Demand circuit protection;
- Unit transformer protection; and
- Backup schemes against protection and switchgear malfunction.

Fault Recorders at Generator And Transmission facilities shall -

- Exist at all transmission lines, autotransformers or phase-shifters connected to busses; shunt capacitors, shunt reactors, Individual generator line interconnections, Dynamic VAR devices and HVDC terminals
- Record duration shall be a minimum of one (1) second
- Have a minimum recording rate of 16 samples per cycle

Connection Guidelines: Metering Requirements

Bi-directional meters shall be installed at the connection point between the transmission connected grid of the participating countries, between the transmission grid & the generator and between the transmission connected grid & the distributor who are part of cross country power flow

- Minimum standard of accuracy of meters shall comply with the latest IEC standards - Main and Check Meters: The minimum standard of accuracy of Meters shall be 0.1%
- For the voltage and current transformers, accuracy shall be 0.2% and the secondary burden shall be maintained between 25% and 100% of rated values.
- The metering shall record : Bus voltage; Frequency; Active Power, Energy; Reactive Power; Current; Any other facilities as agreed in the connection agreement.

It is recommended that Energy Accounting and Audit functions shall be carried out by coordinating forum or the planning committee (as per planning guidelines) or separate agency as required.

All Main energy meters for interconnection shall be owned by Government designated Transmission Licensee in whose premises the meter is located and the check meters shall be owned by the other member country Licensee.

Location of Meters			
Stages	Main Meter	Check Meter	Standby Meter
Generating station not directly connected to the Transmission system	On all outgoing feeders	On all outgoing feeders	H.V side of the Generator Transformers H.V side of all station auxiliary Transformers
Transmission connected	At both ends of the Interconnected Transmission line. Meters at both ends shall be considered as main meters for respective licensees.	-	There shall be no separate standby meter. Meter installed at other end of the line in case of two different licensees shall work as standby meter.

Operational Guidelines: System Security Aspects

The list of important grid elements that impacts the CBET shall be prepared and published in advance.

No important element of the interconnected grid shall be deliberately opened or removed from service at any time, except

- Under an emergency, and conditions in which such isolation would prevent a total grid collapse and/or would enable early restoration of power supply
- For safety of human life
- When serious damage to costly equipment is imminent then isolate the equipment by suitable disconnection without endangering security of the system
- Such isolation is to be specifically instructed after mutual agreement of the System Operators of the two countries through specific messages exchanged to this effect.

Any prolonged outage of power system elements, which is causing or likely to cause danger to the grid or sub-optimal operation of the grid, the same shall be regularly monitored by the respective regional heads and be reported

The exchange of information shall happen over a common platform and include sufficient information on who is responsible for exchange of what data, containing how much detail, at what frequency and in what format along with the need for time stamping.

Operators shall exchange the protection set-points of the lines, reliability entities of relay or equipment failures, revised fault analysis study, letters of agreement on settings, notifications of changes, or other equivalent evidence that will be used to confirm that there was coordination of new protective systems or changes in the transmission systems.

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Framework Grid Code Guidelines (FGCG) and Draft Codes-Operation

Operational Guidelines: System Security Aspects

All thermal and hydro generating units shall follow their respective Grid codes and shall have AVRs & Governors in operation with tuned PSS for effective damping of oscillations.

Adequate operating reserves (Primary/Secondary/Tertiary) shall be made available. The cross border links shall facilitate in the primary reserve process. However, it is desirable that the adequate control is established to restore the power flow to the scheduled level within a block period.

System Security Limits			
	Normal	Alert	Emergency
Voltage (400, 500 & 765 kV)	± 5%	± 5%	± 10%
Frequency – for synchronously interconnected system	Nominal: 50Hz Steady state limits: +0.05Hz to -0.1Hz Instantaneous limits: ± 0.8Hz	Exceeds steady state limits for upto 10 mins	Exceeds steady state limits for >10 mins up to 20 mins
Equipment loading	Within Limits	Within Limits	Exceeds limits of short term overload

Special protection system (SPS) to prevent cascading with the outages Wind and solar generation shall be treated as a must-run station, unless instructed otherwise by respective operators on consideration of grid security.

The protection strategy and concepts shall be reviewed every five years.

Protective relay settings shall not limit transmission loadability nor interfere with system operators' ability to take remedial action to protect system reliability and shall be set to reliably detect all fault conditions and protect the electrical network from these faults.

Operational Guidelines: Demand Estimation for Operational purposes

The existing demand estimation procedure as per the grid code of the respective member country can continue for daily/ weekly/ monthly/ yearly basis for current year for load - generation balance planning. The present guidelines is for information purpose only

Each region shall carry out its own demand estimation from the historical data and weather forecast data from time to time. All necessary data and information shall be provided by relevant entities as required for demand estimate. The monthly estimated demand shall be shared with the operation planning authorities.

Based on the demand estimation for operational purposes on a daily/weekly/monthly basis, mechanisms and facilities shall be created at the earliest to facilitate on-line estimation of cross border power flow for each 15 minutes block.

Operational Guidelines: Congestion Management

Commercial principles for congestion management need to be developed in order to facilitate cross border transactions. Transmission agencies shall be responsible to continuously monitor and adopt curative measures, when necessary.

- For long term commitments, re-dispatch and counter flow measures may be followed.
- For medium and short term commitments, load curtailment shall be the last resort.
- The respective member country utilities shall also implement automatic demand management like rotational load shedding, demand response.

The frequency thresholds of 49.5 Hz can be defined for automatic shedding of loads and is recommended and the loads should be classified in four groups,

- loads for scheduled power cuts / load shedding,
- loads for unscheduled load shedding,
- loads to be shed through under frequency relays & df/dt relays
- loads to be shed under any Special Protection Scheme.

All manual load shedding shall be coordinated between operators and demand facilities which shall be maintained by the respective country authorities without affecting the grid security

Operation- Coordination Between System Operators

Each operator shall provide the following information for the purposes of system defence plan procedures and restoration plan procedures:

- To neighboring operators
- To the regional head
- To Transmission connected distribution systems

Reporting procedures in respect of all events in the system to all users and all verbal notifications may be backed up with appropriate written reports.

To facilitate smooth operation, different coordination forums are formed which is given below and this groups shall recommended to meet once every calendar quarter

- Operation and Protection Coordination Group
- The Commercial Coordination Group

In addition to the above coordination forums, the transmission system owners of the respective countries may coordinate with each other for various aspects pertaining to the O&M of the transmission assets in their respective jurisdiction.

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Framework Grid Code Guidelines (FGCG) and Draft Codes- Scheduling & Dispatch

Scheduling & Dispatch Guidelines: Introduction

Computation of the Available Transfer Capability (ATC) is suggested. System operator shall consider the technical limit imposed by the system components, the thermal line limits, bus voltage limits and stability limit.

Each time block shall be for a duration of 15 minutes and a common time of Indian Standard Time (IST) can be adopted for uniformity.

Transmission Losses will be apportioned between two countries based on a mutually agreed methodology.

- **Transmission System Losses would be borne in kind by the utilities as per the quantum declared for the respective area of jurisdiction in the interim.**

The (firm) power traded would normally be treated as a 'must-run' and thus would not be subject to revision / curtailment except under conditions which pose a threat to the System Security of either of the participating countries.

Control on its generation and / or load to maintain its interchange schedule with other member countries whenever required and contribute to frequency regulation of the synchronously operating system.

Take the responsibility of coordinating the scheduling of a generating station, within the country area, real-time monitoring of the station's operation in its availability declaration, or in any other way revision of availability declaration and injection schedule, switching instructions, metering and energy accounting, outage planning, etc.

Scheduling & Dispatch Guidelines: Demarcation of Responsibilities

Operated as power pools with their own scheduling and dispatch process, in which the respective system operators shall have the total responsibility for

- Scheduling/dispatching of their own generation.
- Regulating the demand of its control area.
- Scheduling their drawal.
- Regulating the net drawal of their control area.

The member country entities shall ensure

- there is no over drawl when frequency is 49.5 Hz or below.
- When frequency is higher than 50.2 Hz, the actual net injection shall not exceed the scheduled dispatch for that time block.

The generating stations and sellers shall be responsible for their power generation/power injection as per daily schedules

The coordinating member may direct the system operator to increase/decrease their drawal/ generation in case of contingencies e.g. overloading of lines/transformers, abnormal voltages, threat to system security. Such directions shall immediately be acted upon.

The coordinating forum shall be responsible for computation of actual net injection/drawal of on the cross border link, 15 minute-wise, based on the above meter readings.

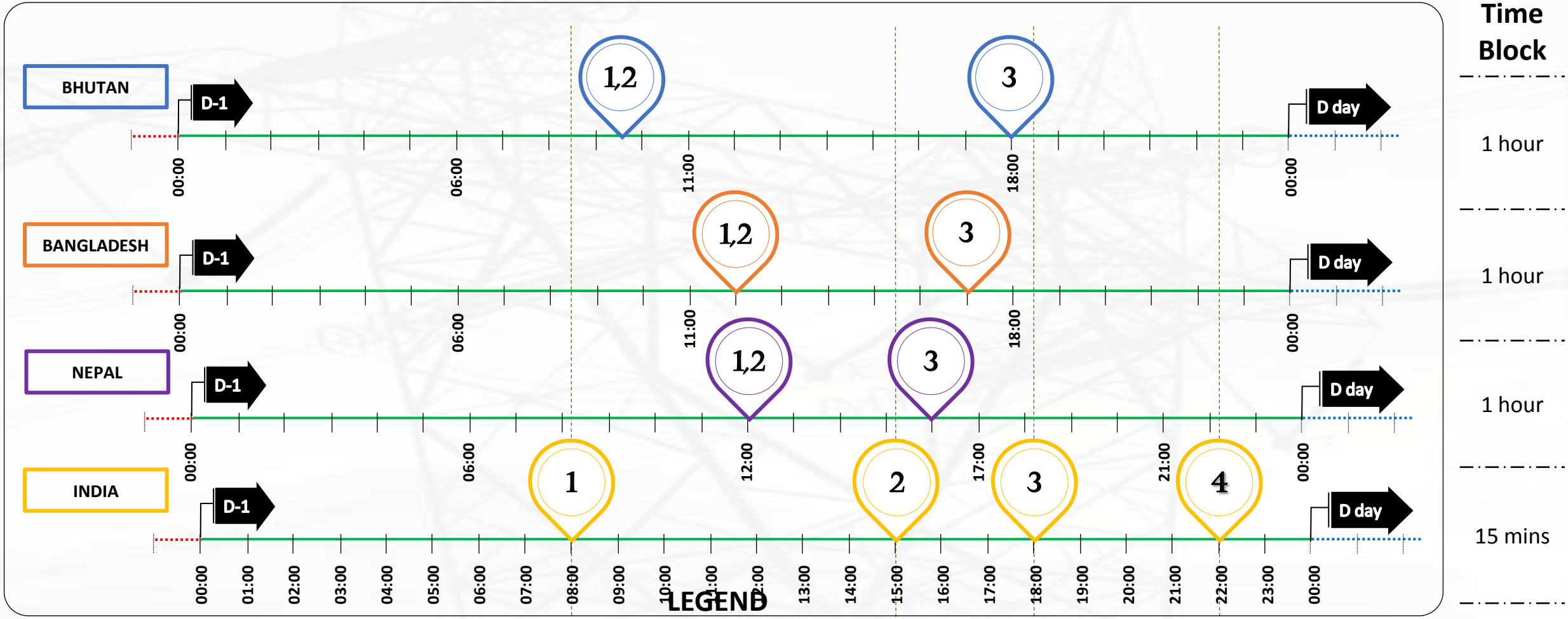
Scheduling & Dispatch Guidelines: Timeline

Time	Activity
0800 hrs	Member country Load Dispatch Centres shall compile their foreseen MW and MWh generation capabilities for the next day and submit the cross-border power transfer, i.e., from 0000 hrs to 2400 hrs of the following day to the coordinator heads.
1500 hrs	Member country Load Dispatch Centres shall compile their foreseen load pattern for the next day and submit revised cross-border power transfer to the coordinator heads.
1800 hrs	All coordinator heads together or a scheduling authority decides the best dispatch and drawal schedule for cross border interconnection and each coordinator head conveys the net dispatch schedule and the net drawal schedule through cross border interconnection to each member country load dispatch centres under its control.
2200 hrs	Any modifications in load or generation shall be brought to the notice of the coordinator head by the member country dispatch centre.

Each time block shall be for a duration of 15 minutes and a common time of Indian Standard Time (IST) can be adopted for uniformity.

The priority of scheduling of power over the cross border link would be long-term contracts, medium term contracts and short term bilateral contracts (up to 3 months) in that order.

Scheduling & Dispatch Guidelines: Timeline



1: Capability Declaration 2: Drawal Declaration 3: Drawl and Dispatch Schedule Finalization & Declaration 4: Last Call for Modifications

Scheduling & Dispatch Guidelines: Deviation Settlement

Special energy meters at all interconnections between the countries for recording the actual net import / export MWh and MVArh on a 15-minute basis . Deviation from schedule on the Cross Border Link will be calculated for each 15 minute time interval.

Energy accounting is on weekly basis.

Transmission charges for wheeling of power up to the international interconnection for the international trade would be borne by both the buyer and the seller as per the prevailing methodology in the respective country.

Transmission charges for the international interconnection would be payable by the market participants as per the charges mutually agreed between the participating member countries.

Operation charges, taxes, levies and other statutory duties / levies would be payable to the system operators by the participants as per the prevailing laws of the land.

A suitable payment security mechanism for transmission charges, system operation charges and charges of imbalance would be put in place by the participating member countries.

The member states shall put into place through mutual agreement a mechanism for dispute resolution.

Scheduling & Dispatch Guidelines: Charges for Losses

Transmission system operators shall be compensated for energy losses based on an estimate of what losses would have been incurred in the absence of transits of electricity.

An agency shall be established comprising of representatives of all participating countries for the long term, a fund shall be established to compensate energy losses incurred. The fund may be referred to as Cross Border System Operator Compensation (CBSOC) Fund.

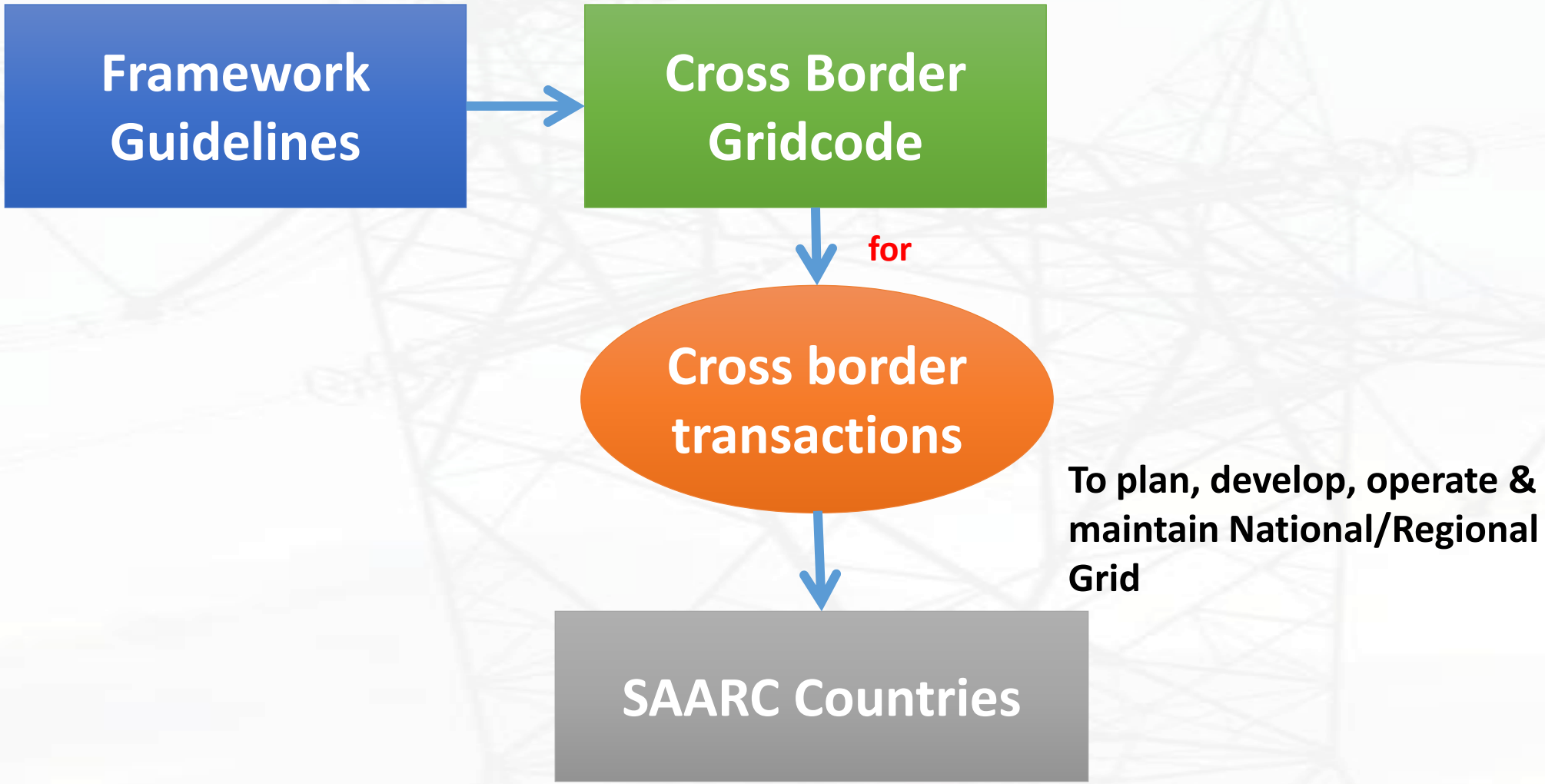
All contributions and payments shall be made as per the agreements in place and the agency shall be made responsible for relating to the CBSOC Fund as follows

- To establish the arrangements for the collection and disbursement of all payments
- To determine the timing of payments.
- To publish report annually on the implementation of the mechanism(normally on 15 minutes time block) and the management of the fund.
- To carry out the loss calculation and shall publish this calculation and its method in an appropriate format.

The amount of losses incurred on a transmission system shall be established by calculating the difference between

- The amount of losses actually incurred on the transmission system during the relevant period.
- The estimated amount of losses on the transmission system which would have been incurred on the system during the relevant period if no transits of electricity had occurred.

Overall Flow



GAP Analysis - South Asia Country Grid codes

Planning

1. Inconsistency in planning period of Master plan which varies from 1 year to 10 or 20 years.
2. Less importance for generation Planning.
3. Voltage margin during planning studies varies for each country
4. Various approaches used for planning studies
5. Less or no priority for reactive power assessment
6. No guidelines for Identification of network modeling while determining CBT potential
7. Absent of Accurate Long term load forecasting for various countries
8. Limited Guidelines for renewable generation and its penetration impacts on CBT
9. Guidelines for HVDC connections for Asynchronous CBT connections

Connection

1. Guidelines of reactive power at interconnecting CB transactions
2. Various operating frequencies and voltage limits for all SA countries
4. Different guidelines for sharing the operational data between countries through SCADA
6. Definition of standard criteria to obtain the cross border trade connection.
7. IEC standards can be followed for meters for all countries instead of various procedures
8. The designated transmission agency of the country shall be responsible to carry out the operation and maintenance activities including meter reading.

GAP Analysis - South Asia Country Grid codes

Operational

1. For most of the counties, operating states (like Normal/Alert/Emergency) are not defined.
2. Various guidelines for generators to control power through AVR and PSS
3. Missing of guidelines for operational reserves
4. Standard the guidelines for short load forecast
5. Operational liaison is briefed only in India, Pakistan and Bhutan grid codes. However, it is preferable to follow European process for CBT.
6. The load shedding can be adopted on frequency dependent for CBT instead country specific process.
7. Specific guidelines for outage management are required CBT
8. A Restoration Plan must be during a black-out condition, this plan must be followed till the CBT grid reaches a stable state.

Scheduling

1. Generators are responsible to provide their capability for the day-ahead schedules
2. In India, Pakistan and Sri Lanka, current day revisions are also allowed
3. Day ahead scheduling procedure is recommended for the cross border links. A common time of Indian Standard Time (IST) can be adopted for uniformity.
4. Till the development of secure cross border scheduling mechanism, the Indian scheduling and Dispatch procedure may be followed

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Brief Summary of the Framework Guidelines

Planning

Master Plan with a planning horizon of 10 years has been suggested as the basis for planning the interconnected network among member countries and reviewed every alternative year.

Load-generation scenarios shall be worked out so as to reflect in a pragmatic manner due to typical daily and seasonal variations in load demand and generation availability

Voltage and Equipment Loading Margins

Short circuit ratio (SCR) at the converter terminals of HVDC installations shall be greater than 3.

N-0, N-1 transmission contingency criteria

Requirement of reactive power compensation (static and/or dynamic)

Connection

Connection Requirements: Reactive power, Frequency and voltage parameters, Short-circuit fault levels, Metering system, Protection devices, Simulation Models, Data & Communication, Cyber Security.

Frequency limits: 47.5 – 48.5 Hz (90 min); 48.5– 49.0 Hz (not less than the period for 90 minutes); 49.0 – 51.0 Hz (Unlimited); 51.0 – 51.5 Hz (30 min).

At interconnection, operating voltage for 400 kV and above is : ±5% and connected equipment shall withstand the voltage variation of ±10%.

Bi-directional meters shall be installed at the connection point by following IEC standards for meter accuracy

Energy Accounting and Audit functions shall be carried out by coordinating agency.

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Brief Summary of the Framework Guidelines

Operational

No important element of the interconnected grid shall be deliberately opened or removed from service at any time, except

The exchange of information over a common platform and include sufficient information on who is responsible for exchange of what data, containing how much detail, at what frequency and in what format along with the need for time stamping.

Adequate operating reserves (Primary/Secondary/Tertiary) shall be made available for CBT.

Voltage and Frequency limits for various states (Normal/Alert/Emergency)

Demand Estimation for operation

Congestion Management

Scheduling

Computation of the Available Transfer Capability (ATC)

Each time block shall be for a duration of 15 minutes and a common time of Indian Standard Time (IST) can be adopted for uniformity.

Control on its generation and / or load to maintain its interchange schedule with other member countries whenever required and contribute to frequency regulation of the synchronously operating system.

The coordinating forum shall be responsible for computation of actual net injection/drawal of on the cross border link, 15 minute-wise, based on the above meter readings.

Deviation Settlement mechanism

Charges for Losses

Planning Guidelines: Planning Philosophy

Master Plan Planning horizon of 10 years with revision for every alternative year: Both Active & Reactive power

Long term Load Forecasting

Generation Adequacy/Planning

Transmission Planning for CBT

Load-generation Scenarios

- Annual peak Load
- Seasonal Peak variations
- Seasonal Off-peak variations

The temporary over voltage (peak phase voltage) limits

- 1.4 p.u. for a 765 kV system
- 1.5 p.u. for a 400 kV & 500 kV system

The switching over voltage (peak phase voltage) limits

- 1.9 p.u. for a 765 kV system
- 2.5 p.u. for a 400 kV & 500 kV system

Short circuit ratio (SCR) at the converter terminals of HVDC installations shall be greater than 3.

Planned maximum sub-transient short circuit fault levels shall not be greater than 80% of equipment ratings.

Line to earth voltage during single line to earth faults should not rise above 80% of the rated line to line voltage.

Planning Guidelines: Transmission Reliability Criteria

Criteria for system with no contingency ('N-0')

- For the planning purpose all the equipment's shall remain within their normal thermal loadings and voltage ratings.
- The angular separation between adjacent buses shall not exceed 30 degree
- Voltage step resulting from capacitor/reactor switching shall not exceed 3.0%.

Criteria for single contingency ('N-1')

- All the equipment's in the transmission system shall remain within their normal thermal and voltage ratings after a disturbance involving loss of any one of the following elements , but without load shedding / rescheduling of generation:
  - Outage of a 400 kV single circuit,
  - Outage of a 400 kV single circuit with fixed series capacitor (FSC),
  - Outage of an Inter-Connecting Transformer (ICT),
  - Outage of a 765 kV single circuit,
  - Outage of one pole of HVDC bi-pole
- The angular separation between adjacent buses under ('N-1') conditions shall be permitted up to 30 degree
- The system shall be capable of withstanding the loss of most severe single system infeed without loss of stability.

Planning Guidelines: Planning Margins

Thermal loading limits of lines and transformers	15% margin
Voltage limits for planning studies (N-0 7 N-1 contingencies)	±3%
765 kV system	Max: 788 kV; Min: 742 kV
500 kV system	Max: 515kV; Min: 485 kV
400 kV system	Max: 412 kV; Min: 388 kV
Generation Units	
Thermal	Qmax = 40% of Pmax, and Qmin = (-) 10% of Pmax
Nuclear	Qmax = 40% of Pmax, and Qmin = (-) 0% of Pmax
Hydro	Qmax = 50% of Pmax, and Qmin = (-) 20% of Pmax

Connection Guidelines: Connection Procedure

Applicant contacts relevant system operator or designated agency.

Applicant obtains & fills installation document

INSTALLATION DOCUMENT

- ✓ **Location**
- ✓ **Date**
- ✓ **Maximum capacity**
- ✓ **Type of energy source**
- ✓ **Type of generator**
- ✓ **Technical specifications**
- ✓ **Steady state & Dynamic studies**
- ✓ **Contact details and attestations of owner & installer**
- ✓ **OEM certificates for all equipments.**

The application is submitted back to system operator or designated agency.

A joint planning committee comprising of CTUs of member countries shall be authorized to provide clearance

Operational Guidelines: Outage Management

Formation outage coordination region

Identification of relevant assets

Identification of critical assets

Preparation of year ahead draft coordination plan

Resolution of all incompatibilities by iterative reassessment

- **Status**
- **Reason for unavailability**
- **Conditions to make asset unavailable**
- **Restoration time**

Finalization of outage plan for implementation in the next financial year

Review and adjustment on quarterly and monthly basis

Submission and Publishing of quarterly and monthly reports

Preparation of week ahead plan & Exchange of plan over weekly teleconference

For any deviation, procurement of prior permission

During emergencies, reassess before executing planned outage

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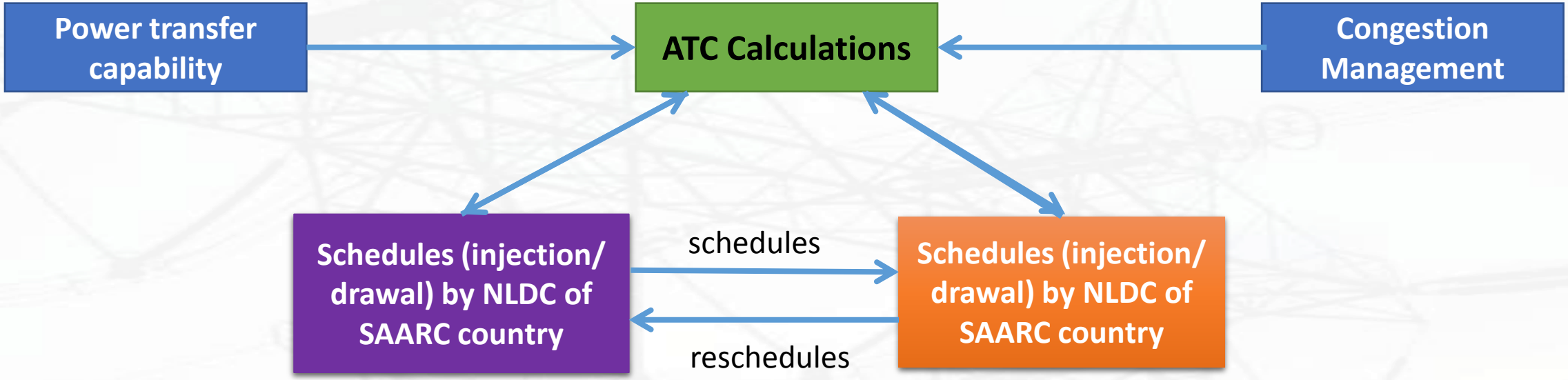
Scheduling & Dispatch Guidelines: Day-ahead & current cross border market



Responsibilities of trade countries

1. f<49.5 Hz; no over drawals
2. f<49.5 Hz; over injection is allowed
3. f>50.2 Hz; over drawals are allowed
4. f>50.2 Hz; no over injection
5. Deviation settlement
6. Loss consideration

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Scheduling & Dispatch Guidelines: Timeline

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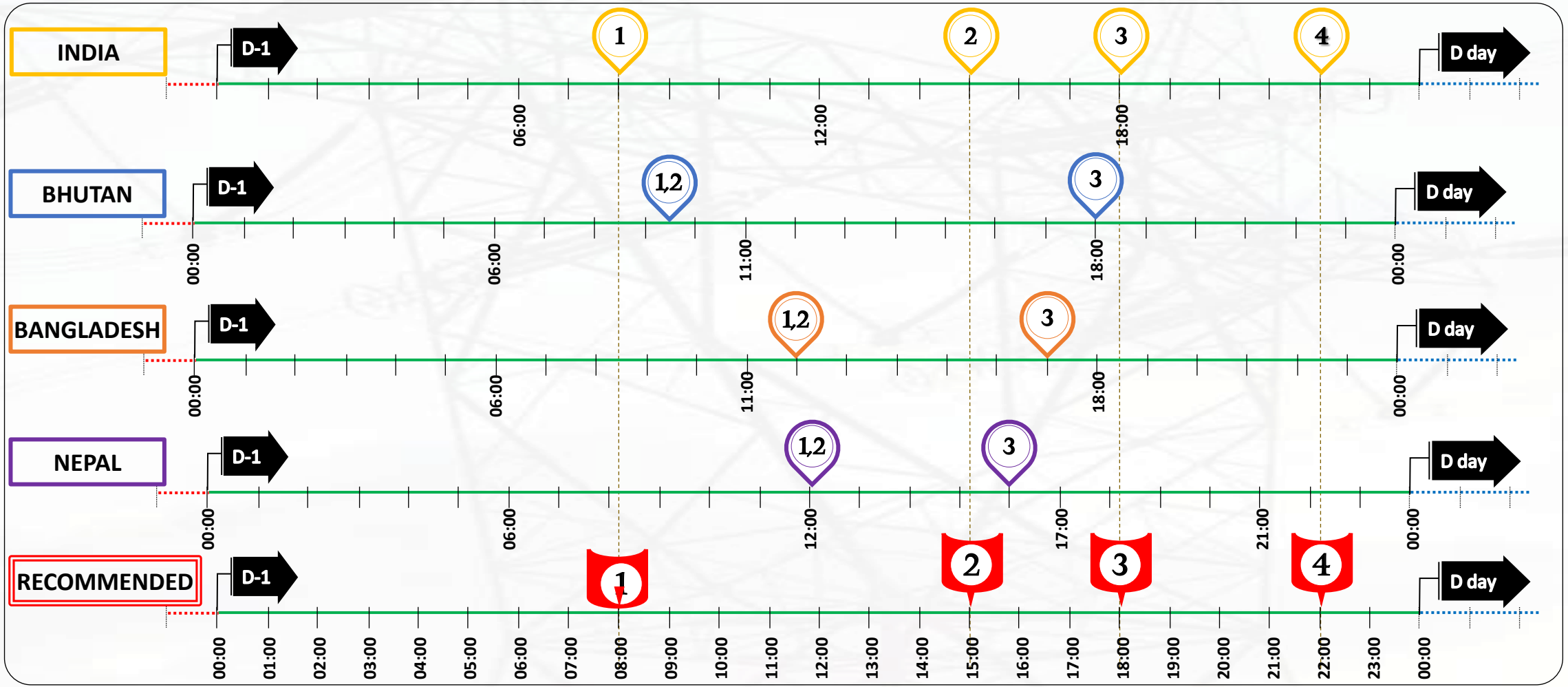
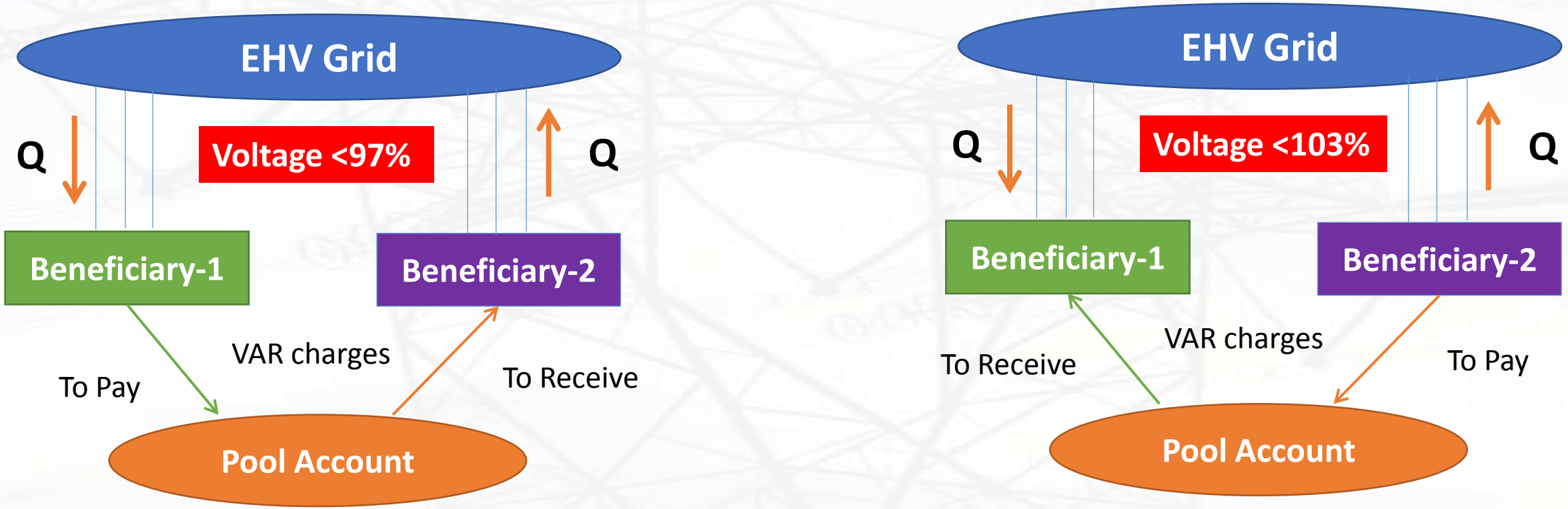


Time Block
15 mins
1 hour
1 hour
1 hour
15 mins

Scheduling & Dispatch Guidelines: Deviation Settlement

Reactive Power & Voltage Control



Scheduling & Dispatch Guidelines: Charges for Losses

Tentative establishment of an inter-transmission system operator compensation mechanism

In the long term, establishment of Cross Border System Operator Compensation (CBSOC) Fund

Establishment of an Agency to schedule, enable and document timely collection and disbursement of CBSOC related funds

Contribution from system operators in proportion to the net flows onto and from their transmission system as a share of the sum of the net flows onto and from all transmission systems.

CBSOC Fund

Compensation to system operators based on an estimate of losses in the absence of transits of electricity

Transit of electricity shall be calculated on 15 minutes time block

The agency shall be responsible for carrying out the loss calculation

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Gap Analysis of South Asian Grid Codes
&
Impact Analysis of International Cross-Border Codes

GAP Analysis - South Asia Country Grid codes

Planning

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2. Less importance for generation Planning.
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Review of Grid Codes -Gap analysis : Key Findings (Planning Code)

Except India, grid codes of all other SA nations specify the same voltage variation limits for both planning and operation stages. (For India: refer CEA's manual on transmission planning).

Country	Voltage – Normal		Voltage - Emergency conditions
	Planning Studies	Operational conditions	
Nepal,Bhutan,Bangladesh	+/- 5%	+/- 5%	+/- 10%
Sri Lanka	+/- 5% for 132 kV, +/-10% for 220 kV	+/- 5% for 132 kV, +/-10% for 220 kV	+/- 10% for 132 kV, +/-10% for 220 kV
Pakistan	+/- 5% for 500 kV, 220 kV	+/- 5% for 500 kV, 220 kV	+/- 10% for 500 kV, 220 kV
India	+/- 2%→ 765 kV; +/- 3% → 400 kV; +/- 5% to 7% for below 220 kV	+/- 5% for 400 kV, 765 kV; +/- 10% for below 220 kV	+/- 5% for 400 kV, 765 kV; +/- 10% for below 220 kV

Voltage Deviations shall be in the same range for interconnection

For EHV (above 400kV) +/-5%

Gap Analysis of SA countries : Operation Code

Operating States:

- Only Bhutan grid code specifies the criteria for classifying an operating state as either Normal/Alert/Emergency.
- Pakistan grid code specifies 'N-1' contingency as emergency state.
- Other SA nations specify different security limits for Normal & Emergency conditions but they don't define the criteria for classifying "Emergency conditions".
- Indian grid code does not specify security limits for emergency conditions

	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Voltage Variation	Normal: ±5% Emergency: ±10%	Normal: ±5% Alert: ±10%	Normal: ±5% for 400 kV, 765 kV ±10% for 220 kV & below.	Normal: ±5% Emergency: ±10%	Normal: 8% and -5% . Emergency: ±10%	Normal: ±5% for 132 kV, ±10% for 220 kV. Emergency: ±10%
Operating Frequency Variation	49 Hz to 51 Hz	Normal: 49.5 Hz to 50.5 Hz Alert: 49 Hz to 51Hz but above Normal range.	49.9 Hz to 50.05 Hz	48.75 – 51.25 Hz	49.8 Hz to 50.2 Hz(Frequency sensitive mode) 49.5-50.5 (Tolerance Frequency band) 49.4-50.5(Load sheading threshold and contingency frequency band)	49.5 Hz to 50.5 Hz

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Review of South Asian Grid Codes - Gap analysis

Review of South Asian Grid Codes - Gap analysis : Key Summary on Planning Code (as an example)

Review of Grid Codes -Gap analysis : Key Summary on Planning Code

Planning code specifies

- The data information to be provided by all entities and various criteria to be adopted for Grid Planning
- Planning responsibilities of various entities in electricity sector.

Activity	Responsibility Authority	Country
Transmission planning activities	Transmission Licensee	Bhutan (BPC), Bangladesh (PGCB), India-(CEA/CTU/STU), Pakistan (NTDC), Sri Lanka (CEB)
	Grid owner	Nepal
Generation and Transmission Perspective Plan	Transmission Licensee	Pakistan, Sri Lanka, Nepal
	System Planner & transmission licensee	Bangladesh
	Ministry & System Operator (Dept. of hydro power & power system)	Bhutan
	CEA	India
Information Confidentiality	India: Nodal agencies shall provide the information to the public through various means of communications including internet. Other SA countries : Confidentiality of the user information made available to licensee shall be maintained.	

System master plan for each Cross border link– Decadal Plan with phased implementation.

For CBET Planning : Respective Transmission Agencies plan /coordinated transmission planning/Planning Committee

Information confidentiality or available on Public Domain.

Review of Grid Codes -Gap analysis : Key Summary on Planning Code

Criteria	Country	Remarks
'N-1' contingency criteria for AC lines	All SA countries	In India, outage of single circuit at 400 kV and 765 kV levels and outage of double circuit at 132 kV and 220 kV levels is considered as 'N-1' outage whereas in other grid codes, at all transmission voltage levels, outage of single circuit is considered. N-2 criterion is applied to important load centres.
'N-1' contingency criteria for HVDC	India	**HVDC Back-to-Back Station or HVDC Bi-Pole line**
Dynamic Stability	All SA countries	**Among other SA nations, Bangladesh, India and Pakistan specify that system shall survive a permanent three phase to ground fault on EHV lines with a fault clearance time of 100 ms. India grid code specifies many other disturbances also in detail for system stability.**
Generator loss	India and Sri Lanka	**System shall survive the loss the largest/critical generating unit.**

Contingency criteria : In the synchronous interconnection, the criteria of N-1 or N-1-1 contingency shall be defined and adopted

Review of Grid Codes -Gap analysis : Key Summary on Planning Code

Except India, grid codes of all other SA nations specify the same voltage variation limits for both planning and operation stages. (For India: refer CEA's manual on transmission planning).

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Pakistan	+/- 5% for 500 kV, 220 kV	+/- 5% for 500 kV, 220 kV	+/- 10% for 500 kV, 220 kV
India	+/- 2%→ 765 kV; +/- 3% → 400 kV; +/- 5% to 7% for below 220 kV	+/- 5% for 400 kV, 765 kV; +/- 10% for below 220 kV	+/- 5% for 400 kV, 765 kV; +/- 10% for below 220 kV

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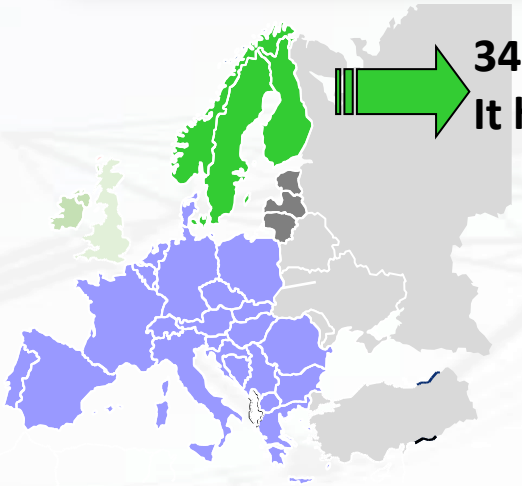
For EHV (above 400kV) +/-5%

International Experience Review and Impact Analysis

International Experience Review and Impact Analysis

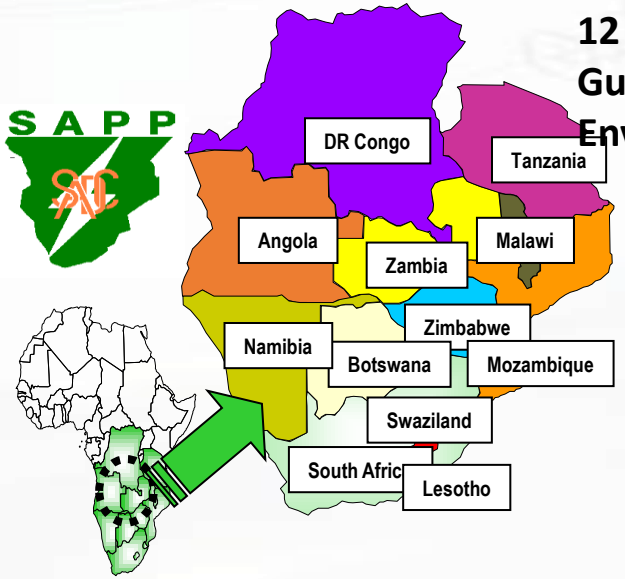


34 European Countries : ENTSOe

network codes

It has Framework Guidelines(FG) and Based on FG Network codes across key areas:

Connection, Operational (Operational Security , Planning ,Scheduling ,L/F Control & Reserve),Market Codes(CA and Congestion Management, Electricity Balancing)



12 Countries:
Guidelines on Operation ,Planning and Environment

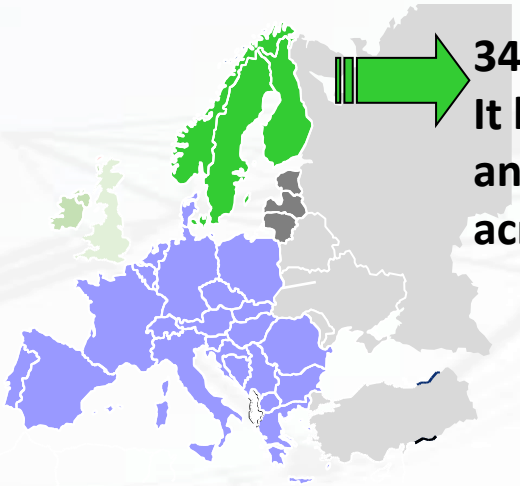
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico.

Various Standards related to Reliability Operation

International experience Review and Impact Analysis was carried out across a) Planning Code b) Connection Code c) Operation Code d) Metering Code

International Experience Review and Impact Analysis



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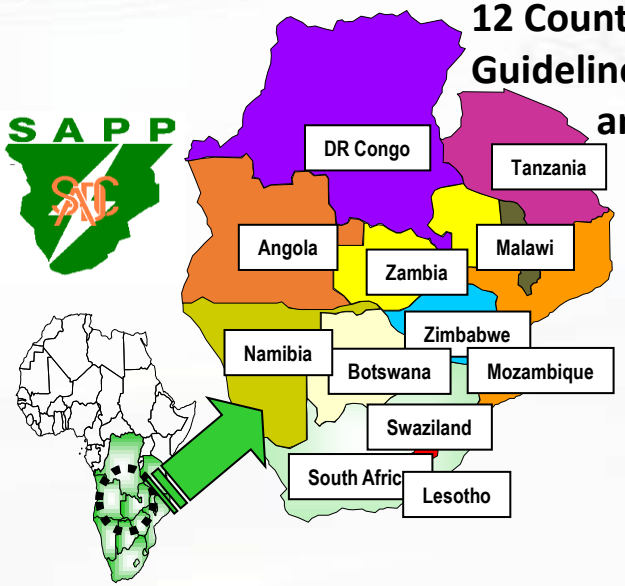

12 Countries:
Guidelines on Operation ,Planning and Environment

International experience Review and Impact Analysis was carried out across a) Planning Code b) Connection Code (includes metering & protection) c) Operation Code d) Scheduling & Dispatch Code

IMPACT ANALYSIS ON PLANNING CODE

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Transmission Planning Process and Criteria

European Grid Code/ENTSOe.

- TSO is responsible for planning,Upto 30 years ahead planning term categorized as mid, long & very long term.
- Contingencies listed and classified as Normal, Exceptional and Out Of Range.
- All TSOs are obligated to serve under an 'N-1' principle which is developed with the goal of preventing propagation of an incident.

NERC-Regulations/Standards

- Planning coordinator performs resource adequacy analysis.
- Apart from following year, studies carried out for up to 10 years, categorized as near and long term.
- Contingencies are classified as Normal, events resulting in single element loss, events resulting in multiple elements loss, extreme events resulting in single element removal or cascading outage.

SAPP Rules/Criteria, Grid Code

- Utility publishes the 5 year ahead Transmission System.
- Normal and N-1 contingency studies performed to assess reliability.
- Individual members develop criteria ensuring system security and reactive compensation.

South Asian Countries' Grid Code

- Either a planning authority or the operator prepares the plan.
- Different time horizon followed by different countries ranging from 1 to 20 years.
- Normal and N-1 contingencies are applicable. N-1-1 also included in India. LFA, SCS, TRS studies are used for planning.

Recommendations:

1. It is critical to have a coordinating institutional mechanism.
2. Road map with Master Plan covering the next 10 years .
3. System modelling and running studies for security assessment and Contingency studies for both Asynchronous and Synchronous connections

System Modeling and *Generation & Load Modeling Requirements*

European Grid Code

- **Demarcation of observability area to account for influence of neighbour.**
- **Individual Grid Models merged to form the Common Grid Model.**
- ***Large scale DGs are modeled in detailed but not accounted in transfer capacity calculations and dispatch.***

SAPP Grid Code

- **No Relevant Information Found**
- ***No Relevant Information Found***

NERC Grid Code

- **A detailed list of parameters required for accurate system modeling of each equipment is established.**
- ***The best model available for modeling the variable generators shall be used.***
- ***The accuracy of the detailed dynamic model shall comply with the standards.***

South Asian Countries' Grid Code

- **System modeled down to 220 kV.**
- **Base case constitutes upto 5-year ahead scenarios.**
- **Modeling requirements established for accurate system modeling.**
- The Indian planning code provides elaborate list of requirements for conventional generators and loads.
- High wind/solar generation injections are studied in combination with suitable conventional dispatch scenarios

- Defining Observability area is critical .
- Necessary parameters of all relevant equipments must be considered for accurate modeling of the system.
- With the increasing penetration of variable generation (wind & solar), it would be required to adequately model the impact of these generation on the system

Permissible Normal and Emergency Limits

European Grid Code

- Aspects covered-

  Thermal limits, voltage limits, maximum loss of load / generation, short circuit limits, stability limits and voltage collapse criteria.

NERC Grid Code

- Aspects covered-

  Steady state, post contingency and transient voltage limits, power limits, secure operation in all foreseen planning events.

SAPP Grid Code

- Aspects covered-

  Voltage limits during steady state and during switching, frequency limits, loading limits, fault level and stability criteria.

South Asian Countries' Grid Code

- Aspects covered-

  Steady state voltage and loading limits, reactive power limits, fault level, transient stability for contingency criteria and planning margins.

- Steady state & stability limits and fault levels already defined can be adopted
- Apart from the above mentioned limits, the criteria for HVDC connection, Reactive compensation, substation planning must be established.

Remedial Actions

European Grid Code

- Preventive and curative remedial actions are prepared and published.
- Primarily address power flow constraints and voltage constraints.

NERC Grid Code

- Corrective action plans are prepared for planning events wherever necessary.
- System deficiencies and corresponding actions are listed.

SAPP Grid Code

- SAPP code considers corrective measures for maintaining voltage limits

South Asian Countries' Grid Code

- To ensure security of the grid, the extreme/rare but credible contingencies are identified periodically and suitable defense mechanism, are worked out.

- Contingencies shall be evaluated and remedial and corrective action shall be listed.
- If corrective action requires new elements, remedial action shall be used in interim.
- Remedial actions shall be established for normal, severe and rare contingencies.

Available Transfer Capacity Calculation

European Grid Code

- Two approaches:
  i. Net Transfer Capacity Approach
  ii. Flow Based Approach (for day-ahead and Intraday)

NERC Grid Code

- Two approaches:
  i. Area Interchange Method
  ii. Flow Gate Approach (for day-ahead and Intraday)

South Asian Countries' Grid Code

- Single Approach:
  i. Available Transfer Capability Approach

- Till development of a matured market in the South Asian region, calculations carried out by India can be adopted
- In the long term, it would be necessary to adopt a sound principle based on European / North American practice

Congestion Management

European Grid Code

- Two approaches:
  i. Net Transfer Capacity Approach
  ii. Flow Based Approach (for day-ahead and Intraday)

NERC Grid Code

- Two approaches:
  i. Area Interchange Method
  ii. Flow Gate Approach (for day-ahead and Intraday)

South Asian Countries' Grid Code

- Single Approach:
  i. Available Transfer Capability Approach

- To develop commercial principles wherein it is the responsibility of transmission agencies.
- Till the establishment of congestion reliving mechanism:
  i. Honor long term commitment by re-dispatching or counter flow.
  ii. For medium or short term transactions, curtailment as a last resort

International Review & IMPACT Analysis ON Connection Code

Applicability of Regulation

European Grid Code

- All existing and new users including:
  i. Transmission System Operator
  ii. Power Generating Modules
  iii. Demand Facility Owner
  iv. Distribution Network Operator

NERC Grid Code

- All users seeking to integrate facilities, including:
  i. Generator Owner
  ii. Transmission Owner
  iii. Distribution Provider
  iv. Load-Serving Entity

South Asian Countries' Grid Code

- All existing and new users

- Shall be applicable to the authorised transmission agencies for cross border links and the associated sub-stations.
- For other links within the country, the respective countries connection code would be applicable

Connection Agreement

European Grid Code

- The connection agreement, which includes relevant site and technical specifications, needs to be signed between the relevant network operator and the user.

NERC Grid Code

- The connection agreement needs to be signed by the applicant in accordance with the NERC Reliability Standards.

South Asian Countries' Grid Code

- The connection agreement shall be signed by the designated transmission companies of the member countries and shall be facilitated by respective country regulatory commissions.

The connection agreement shall be mandatory between the designated transmission companies of member countries for the cross-border link.

Reactive Power Requirements

European Grid Code

- User should maintain reactive power within limits at PCC.
- Demand facilities, pf > 0.9
- Demand facilities with onsite generation must be able to export no reactive power when active power is < 25% of Max. import capability

NERC Grid Code

- Operate close to unity power factor to minimize the reactive power burden

South Asian Countries' Grid Code

- It is recommended and even strictly followed in most countries that the interconnection is not depended on reactive support.

- Participating generators must comply with respective country's regulation.
- Reactive power flow through cross border AC links shall be limited to 0.97 lead/lag at PCC.
- As for HVDC links, voltage shall remain within limits.

Frequency Requirements

European Grid Code

- Normal operating frequency is 50 Hz.
- Permissible frequency deviation is 49 – 51 Hz
- Wider ranges can be agreed upon among the TSOs.

NERC Grid Code

- Operating frequency is 60 Hz.
- Permissible variation is ±0.05 Hz.

South Asian Countries' Grid Code

- Operating Frequency is 50 Hz.

	Frequency Band (Hz)
Bangladesh	49.0 – 51.0
Bhutan	49.5 – 50.5
India	49.90 – 50.05
Maldives	49.5 – 50.5
Nepal	48.75 – 51.25
Pakistan	49.5 – 50.5
Sri Lanka	49.5 – 50.5

- Recommended Frequency band of operation of synchronised interconnection shall be within 49.9 Hz to 50.05 Hz
- All the connecting equipment shall withstand the 49 to 51 Hz and for limited duration beyond the specified limits

Voltage Requirements

European Grid Code

- Wide range of operating voltage is agreed between the user and system operator at the connection point
- A voltage range is defined for all equipments connected at 110 kV & above

NERC Grid Code

- The typical voltage range on the transmission system is from 90% to 105% of the nominal transmission voltages.

South Asian Countries' Grid Code

- The permissible deviations for all countries is observed to be ±5 to ±10% depending on voltage levels.

- At the point of Interconnection, acceptable range of operating voltages shall be ± 5% for 400 kV and above transmission voltage levels
- All the connected equipment shall withstand the voltage variation of ±10%

Protection & Control Schemes

European Grid Code

- The Relevant Network Operator shall define the schemes and settings necessary to protect the network, considering the characteristics of the Power Generating Module and Transmission connected distribution network

NERC Grid Code

- The Applicant connecting to the transmission system is responsible for proper protective equipment such that it coordinates with Transmission relays and meets all applicable standards.

South Asian Countries' Grid Code

- In India, all generators above 100 MW shall have two independent sets of main protection schemes and a backup protection scheme.
- Other nations specify one main & one back up protection scheme.

- At the connection point, respective agency shall be vested to prepare and review protection schemes according to the adopted standards in line with Article 10 of SAARC Framework Agreement for Energy Cooperation (Electricity)

Information Exchange

European Grid Code

All users shall be equipped as per the standards specified by the system operator to transfer the information within the defined time stamping.

NERC Grid Code

- Transmission system is responsible to gather real time information through Energy Management System.
- The EMS also acts as an accounting and detailed calculation platform to refine and store data.

South Asian Countries' Grid Code

- Transmission licensee is responsible for data communication through SCADA in Bhutan, Bangladesh, Pakistan and Sri Lanka.
- Grid Owner and RLDC are responsible in case of Nepal and India respectively.

- At the connection point, respective agency shall be vested to prepare and review protection schemes according to the adopted standards in line with Article 10 of SAARC Framework Agreement for Energy Cooperation (Electricity)

Connectivity Standards Applicable to Wind and other Generators using Inverters

European Grid Code

- Power quality of wind turbines and for the measurement of the related quantities shall follow IEC 61400-21 [IEC, 2008].
- The relevant parameters are active and reactive power, flicker, number of switching operations and harmonic related quantities

NERC Grid Code

- Design considerations include IEEE Standards 142, 519, 1100, 1159, and ANSI C84.1
- Forms of power quality degradation include voltage regulation & unbalance, harmonic distortion, flicker, voltage sags & transients

South Asian Countries' Grid Code

- Except India and Sri Lanka, grid codes of other SAARC member nations do not specify the connectivity standards/requirements to be complied with by Wind and other generating stations using inverters.

The renewable energy generators (including wind and solar) shall follow the respective country code in which it is connected.

International Review and IMPACT Analysis ON Operation CODE

Operating States

European Grid Code

- For each element in its transmission system, the European grid code mandates each TSO define operational security limits.
- TSO must classify current operating condition under one of the five states in real time.

NERC Grid Code

- The NERC grid code doesn't mention any hard-set limits for the classification of the operating state of a system.

South Asian Countries' Grid Code

- Bhutan specifies the criteria for classifying an operating state as Normal/ Alert/ Emergency.
- Pakistan specifies 'N-1' contingency as emergency.
- Other nations specify different limits for Normal & Emergency conditions

- It is recommended to have the 5 classifications of the operating states, i.e. Normal, Alert, Emergency, Blackout and Restoration.
- The operating limits must be maintained at all interconnections and interconnecting substations.

Requirements of Generators

European Grid Code

- The Power Generating Modules are categorized as type A, B, C or D based on the capacity and voltage ratings.
- For each category, the requirements including frequency response, voltage stability and islanding mode are elaborated.

NERC Grid Code

For 98% of all operating hours, Generator and Transmission Operators shall have AVR in service and in automatic voltage control mode for synchronous generators or synchronous condensers and PSS in service for synchronous generators with PSS.

South Asian Countries' Grid Code

- According to the Grid codes of India, Bhutan, Bangladesh and Sri Lanka, all generating units shall have AVR in service.
- Indian Grid code also specifies that a properly tuned PSS should be in service

- The generators must follow the grid code guidelines of the respective country of their location.
- With synchronised interconnection, it may be required that all the generators be equipped with tuned PSS.

Generator Reserves

European Grid Code

- The European TSOs have the possibility to access Reserve Capacity connected to another Synchronous Area, to comply with the amount of required reserves resulting from their own reserve dimensioning process of Frequency Containment Reserve, Frequency Restoration Reserve or Replacement Reserves.

NERC Grid Code

- Each Balancing Authority & Reserve Sharing Group shall maintain a minimum amount of Contingency Reserve.
- At least half of the minimum amount of Contingency Reserve shall be reserved as Operating Spinning Reserve that can respond within ten minutes.

South Asian Countries' Grid Code

- Grid codes of all SA nations except India specify that adequate operating reserves (Spinning/ Contingency/ Stand-by) shall be made available for use.
- India mentions the requirements of Instantaneous pick-up.

- The cross border links shall facilitate in the primary reserve process.
- However, it is desirable that the adequate control be established to restore the power flow to the scheduled level within a block period (15 minutes).

Short Term Demand Estimation

European Grid Code

All TSOs perform annual, summer and winter generation adequacy assessments by forecasting the weekly peak demand for each period of study for both normal and severe conditions.

NERC Grid Code

The Transmission Operator performs seasonal, next-day, and current-day Bulk Electric System studies to determine loading levels.

South Asian Countries' Grid Code

- Demand estimation for daily/ weekly/ monthly/ yearly basis is carried out.

- Short term demand forecast must be made mandatory to the extent to specify the scheduled power transfer through the cross-border links.
- This demand must be managed by respective authority without affecting grid security.

Operational Liaison

European Grid Code

An elaborate chapter is provided in one of the European Network Codes detailing of the necessary data exchange between relevant significant grid users

NERC Grid Code

Each Reliability Coordinator, Transmission Operator and Balancing Authority shall provide adequate and reliable telecommunications facilities for the exchange of Interconnection and operating information

South Asian Countries' Grid Code

- Operational liaison is briefed only in India, Pakistan and Bhutan grid codes.
- Before carrying out any operation, the system operator must notify and give details to all grid users whose system operation may get affected.

- The liaising procedure shall be adopted from the European Grid Code.
- All necessary communication and data sharing must happen over a common platform

Load Shedding Schemes

European Grid Code

- Frequency thresholds, not less than 49 Hz, are defined for load shedding by each TSO.
- Load shedding should be established in stages to minimize the further risk.

NERC Grid Code

- Each Transmission Operator shall establish plans for automatic load shedding for undervoltage conditions if the Transmission Operator, Planner(s) or Coordinator(s) determine that an under-voltage load shedding scheme is required

South Asian Countries' Grid Code

- All countries have a frequency dependent load shedding scheme in place.
- Indian Grid code of India specifies that load shedding shall be carried out to prevent over drawl when frequency is 49.5 Hz and below.

- The frequency thresholds of 49.5 Hz can be defined for automatic shedding of loads for the synchronous cross-border links.
- The loads should be classified as recommended in the Indian Grid Code and similar shedding rules may be adopted.

Outage Coordination

European Grid Code

- An outage coordination region is formed by grouping responsibility areas based on the extent of interconnection.
- A set of Power system assets are identified as relevant assets.
- Of these, few assets are listed as critical assets.
- The outage coordination planning takes all relevant assets into account

NERC Grid Code

- Each Generator Operator provides outage information to Transmission Operator daily for scheduled outages planned for next day.
- Transmission Operator establishes the outage reporting requirements and provides outage information daily to affected entities.

South Asian Countries' Grid Code

- In Sri Lanka, the transmission licensee shall establish a transmission outage program with a three year window.
- All other countries annually establish the outage plan for the following year,.

The process of selection of those important cross-border assets which have a considerable impact on the security of cross-border power flow shall be adopted from European Code.

Recovery Procedures

European Grid Code

- Each TSO prepares in advance and updates regularly a restoration plan.
- TSOs have to know the status of components of their power system after a blackout before starting the restoration process.

NERC Grid Code

Each Transmission Operator and Balancing Authority have emergency plans that enable it to mitigate operating emergencies which include communication protocols, controlling actions, coordinated tasks and the staffing levels for the emergency.

South Asian Countries' Grid Code

The relevant entities are authorized during the restoration process following a black out, to operate with reduced security standards for voltage and frequency, as necessary, in order to achieve the fastest possible recovery of the grid.

A Restoration Plan must be prepared and fixed by each region well in advance and during a black-out condition, this plan must be followed till the grid reaches a stable state

Schedule and Dispatch

European Grid Code

Scheduling agents are responsible for the transmission of their cross border schedule nominations to the responsible control area operator.

NERC Grid Code

Each Purchasing-Selling Entity that secures energy to serve Load via a Dynamic Schedule must submit a Request for Interchange as a non-time Arranged Interchange to the Balancing Authority.

South Asian Countries' Grid Code

- Generators are responsible to provide their capability for the day-ahead schedules.
- In India, Pakistan and Sri Lanka, current day revisions are also allowed.

- Day ahead scheduling procedure is recommended for the cross border links.
- A common time of Indian Standard Time (IST) can be adopted for uniformity.
- Till the development of secure cross border scheduling mechanism, the Indian scheduling and Dispatch procedure may be followed.
- The scheduling duration prevalent in India including the time block for the cross border transaction can be adopted as agreed in the TF 2 meetings

Charges for Losses

European Grid Code

- The Regulation established an ITC fund to compensate TSOs for the costs incurred in hosting cross-border flows.
- The fund aims to cover the cost of transmission losses and making infrastructure available, for cross-border flows.

NERC Grid Code

Settlement of losses shall be either handled as financial or as payment in-kind in accordance with the Transmission Service Provider tariff.

South Asian Countries' Grid Code

- The energy losses in the transmission system shall be compensated by the customers with additional injection at the injection point(s).

- In order to encourage the cross border energy exchange, it may be necessary to follow the mechanism similar to European practice wherein a scheduled fund can be created and the losses be compensated through this fund.
- The transmission agencies need to procure additional energy to compensate for the losses.

International Review and IMPACT ANALYSIS ON Metering CODE

Applicability

NERC Grid Code

- The code is applicable to Generator owners, Balancing Authority and Transmission Operator in accordance with reliability standards

South Asian Countries' Grid Code

- In India and Nepal, metering code applies to all the generating companies and licensees.
- In Sri Lanka, it is applicable to all licensees who are authorized to carry out distribution / transmission activities.
- For other countries, the same is not explicitly mentioned in their grid codes.

Metering code shall be applicable for Generators specified for cross-country transaction, Transmission system operators and distribution system/ Balancing Authority.

Standards Followed

NERC Grid Code

- The Metering equipment shall act in accordance with American National Standards Institute (ANSI) standards.

South Asian Countries' Grid Code

- The meters in India shall comply with BIS.
- Pakistan, Sri Lanka, Nepal and Bangladesh follow IEC standards.
- Bhutan and Bangladesh follows their own country specific meter standards.

IEC Standards shall be followed for the Metering.

Ownership

NERC Grid Code

- Transmission operator is responsible for properly maintaining its metering equipment.
- . Meter information is automatically and electronically communicated to Transmission operator

South Asian Countries' Grid Code

- In all the countries the meters placed in transmission system are owned and maintained by Transmission licensees.
- In all countries, billing is processed by system operators.

- All meters for interconnection shall be owned by Government designated Transmission Licensee.
- Energy Accounting and Audit functions shall be carried out by coordinating forum or the planning committee or separate agency.

Meter Location

NERC Grid Code

- For all Transformers connected through transmission, metering points are provided at the secondary side of all through-transmission transformers.
- Generators and transformers that are not through transmission but are tapped directly on the EHV system are provided with interchange metering on the primary side of the step-up, station service or radial transformer

South Asian Countries' Grid Code

In all countries the meters shall be located at outgoing feeders of generation substation

It is recommended that energy meters shall be provided at both sides of the connection point.

Operation and Maintenance

NERC Grid Code

- The owner for that meter shall take responsibility for operation and maintenance. The relevant Transmission operator maintains a metering database for auditing purposes.

South Asian Countries' Grid Code

- In Bangladesh, India and Pakistan, maintenance works of meters is carried out by the generating company or the licensee or distribution licensee.
- In Sri Lanka, Nepal and Bhutan, meter maintenance is by Transmission Licensee.

The designated transmission agency of the country shall be responsible to carry out the operation and maintenance activities.

Meter Reading & Recording

NERC Grid Code

- Meter readings shall be transmitted to the System Operator for Billing.
- Any generation unit participating in the Energy Market is required to have independent metering devices.
- Backup meters of sufficient accuracy to serve as a replacement for the primary metering system.

South Asian Countries' Grid Code

- All countries have the provision to transfer the meter readings which are connected at transmission connection point to remote location through data communication channels.
- In India, Nepal, Sri Lanka, Bhutan and Bangladesh, in case of meter failure, the data is taken from backup meters.

Meter reading and recording functions shall be carried out by coordinating forum or the planning committee or a separate agency

Access to Meters

NERC Grid Code

The Equipment owner of the premises where the meter is installed shall provide access to the transmission system operators for installation, testing, commissioning, reading and recording and maintenance of meters.

South Asian Countries' Grid Code

The owner of the premises where the meter is installed shall provide access to the authorized representative(s) of the licensee for installation, testing, commissioning, reading and recording and maintenance of meters.

The designated transmission agency shall give permission for the relevant system operator to install, testing commissioning, reading and recording and maintenance of meters.

Matrix -Salient Features of Various International Cross Border Grid Codes

	South Asian Countries' Respective Grid Codes	European Grid Code (ENTSOe)	NERC Regulations / Standards	SAPP Grid Code and Regulations
Transmission Planning Process	Either a planning authority or the operator prepares the plan. Different time horizon followed by different countries ranging from 1 to 20 years.	The TSO is responsible for planning. Planning is done for upto 30 years ahead and categorized as mid, long & very long term.	Planning coordinator performs resource adequacy analysis. Apart from following year, studies carried out for up to 10 years, categorized as near and long term.	Utility publishes the 5 year ahead Transmission System Development Plan on an annual basis.
System Observability	System modeled down to 220kV. Base case constitutes up to 5-year ahead scenarios. Modeling requirements established for accurate system modeling.	Demarcation of observability area to account for influence of neighbor for planning studies. Individual Grid Models merged to form the Common Grid Model.	Detailed lists of parameters are required for accurate system modeling of each equipment.	No Relevant Information Found
Voltage Requirements	The permissible deviations for all countries are observed to be $\pm$ 5 to $\pm$ 10% depending on voltage levels.	Wide range of operating voltage at the connection point A voltage range is defined for all equipment's connected at 110 kV & above	The typical voltage range on the transmission system is from 90% to 105% of the nominal transmission voltages.	No Relevant Information Found
Reactive Power Requirements	Reactive power flow on interconnection is strictly not mandated. Reactive power charges applicable for transfer of reactive power based on voltage profile	User should maintain reactive power within limits at PCC. Demand facilities pf> 0.9 Demand facilities with onsite generation must be able to avoid export of reactive power when active power < 25% of Max. import Capability	Operate close to unity power factor to minimize the reactive power burden	No Relevant Information Found

Matrix -Salient Features of Various International Cross Border Grid Codes

	South Asian Countries' Respective Grid Codes	European Grid Code (ENTSOe)	NERC Regulations / Standards	SAPP Grid Code and Regulations
Contingency Criteria	Normal and N-1 contingencies are applicable. N-1-1 also included in India. LFA, SCS, TRS studies are carried out for planning.	Contingencies listed and classified as Normal, Exceptional and Out Of Range. 'Network Stress Tests' performed to assess system health. All TSOs are obligated to serve under an 'N-1' principle	Contingencies are classified as Normal, events resulting in single element loss, events resulting in multiple elements loss, extreme events resulting in single element removal or cascading outage.	Normal and N-1 contingency studies performed to assess reliability.
Available Transfer Capacity Calculation	Single Approach : Available Transfer Capability Approach followed only in India	Two approaches: i) Net Transfer Capacity Approach ii) Flow Based Approach (for day-ahead and Intraday)	Two approaches: i) Area Interchange Method ii) Flow Gate Approach (for day-ahead and Intraday)	No Relevant Information Found
Connection Agreement	Not mandated except in India where connection agreement shall be signed by the designated transmission companies with CTU	The connection agreement, which includes relevant site and technical specifications, needs to be signed between the relevant network operator and the user.	The connection agreement needs to be signed by the applicant in accordance with the NERC Reliability Standards.	No Relevant Information Found
Protection and Control Schemes	In India, all generators above 100 MW shall have two independent sets of main protection schemes and a backup protection scheme. Other nations specify one main & one back up scheme.	The Relevant Network Operator shall define the schemes and settings necessary to protect the network, considering the characteristics of the Power Generating Module and Transmission connected distribution network	The Applicant connecting to the transmission system is responsible for proper protective equipment such that it coordinates with Transmission relays and meets all applicable standards.	No Relevant Information Found

Matrix -Salient Features of Various International Cross Border Grid Codes

	South Asian Countries' Respective Grid Codes	European Grid Code (ENTSOe)	NERC Regulations / Standards	SAPP Grid Code and Regulations
Standards for Wind and Other Generators Using Inverters	**Except India and Sri Lanka, grid codes of other SAARC member nations do not specify the connectivity standards/requirements to be complied with by Wind and other generating stations using inverters.**	**Power quality of wind turbines and for the measurement of the related quantities shall follow IEC 61400-21.** **The relevant parameters are active and reactive power, flicker, number of switching operations and harmonic related quantities**	**Design considerations include IEEE Standards 142, 519, 1100, 1159, and ANSI C84.1** **Forms of power quality degradation include voltage regulation & unbalance, harmonic distortion, flicker, voltage sags & transients**	**No Relevant Information Found**
Ownership of Meters	In all the countries the meters placed in transmission system are owned and maintained by Transmission licensees. In all countries, billing is processed by system operators.	No Relevant Information Found	Transmission operator is responsible for properly maintaining its metering equipment. Meter information is automatically and electronically communicated to Transmission operator	No Relevant Information Found
Location of Meters	In all countries the meters shall be located at outgoing feeders of generation substation	No Relevant Information Found	metering points are provided • at the secondary side of all Transformers connected through transmission. • primary side of the step-up, station service or radial transformer for Generators and transformers that are not through transmission but are tapped directly on the EHV system	No Relevant Information Found

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Annexure-I

South Asia Regional initiative for Energy Integration

Potential for Power Trade in western part of South Asia: Techno-Economic Rationale

2nd meeting SAARC Council of experts of Energy Regulators
24th -25th October 2017 , Islamabad ,Pakistan

V.K Kharbanda
Project Director,SARI/EI/IRADe

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Content

- **Experience and Lessons from Cross Border Electricity Trade (CBET) in South Asia and future perspective**
  - South Asian Power Sector Profile
  - India-Bangladesh, India-Bhutan and India-Nepal CBET
  - Potential benefits of power trade
- **Key findings of the study on "Potential for Power Trade in Western part of South Asia"**
  - Pakistan, India and Afghanistan Power sector Profile
  - Pakistan – Afghanistan CBET Link
  - Case for Pakistan-India Cross Border Interconnection – Techno-Economic options & potential benefits
- **Way forward**

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Experience and Lessons from Cross Border Electricity Trade in South Asia and future perspectives

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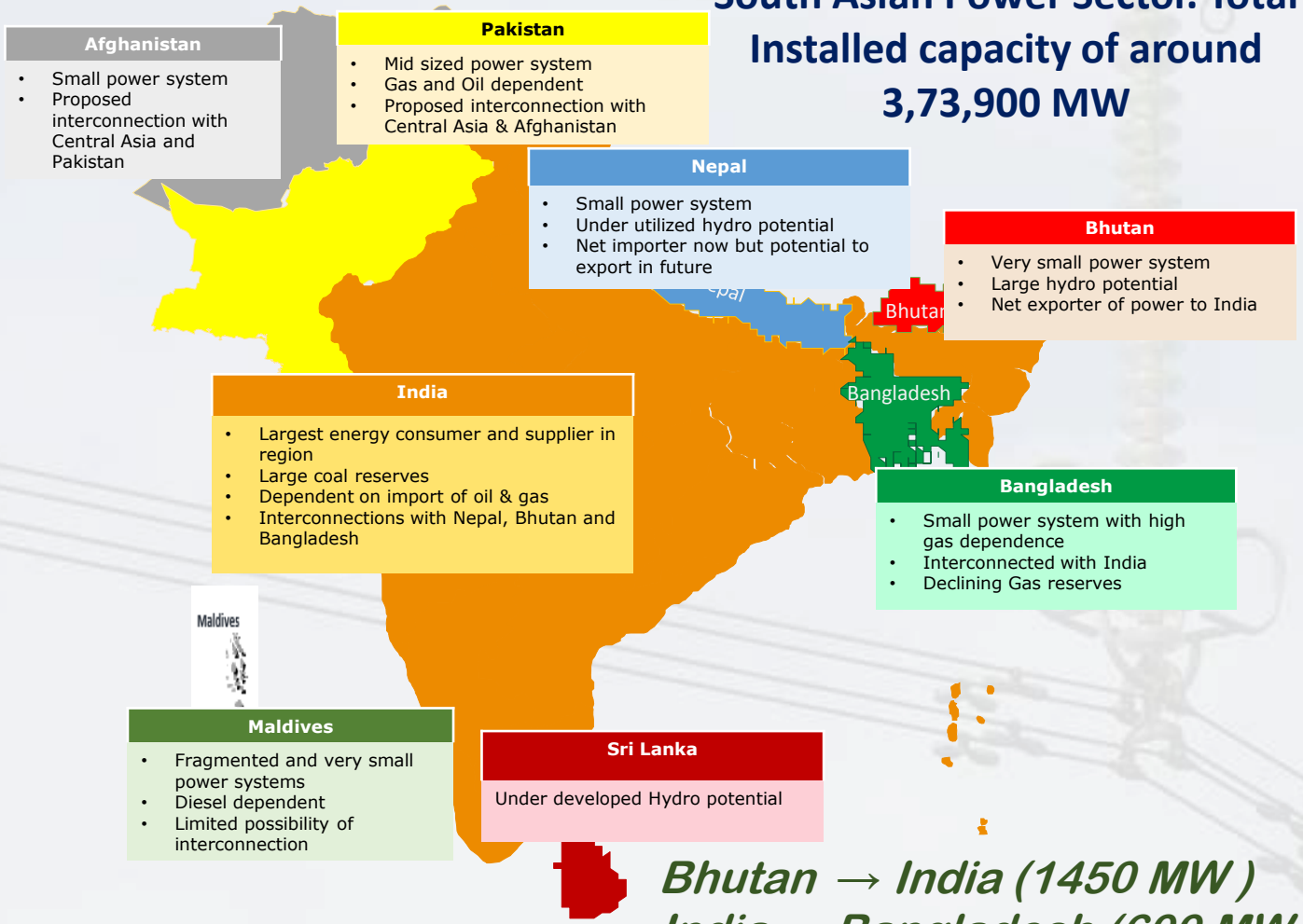
South Asian Power Sector Profile



South Asian Power Sector. Total Installed capacity of around 3,73,900 MW

Country	Installed Capacity (MW)
Afghanistan	1341
Bhutan	1,614
Bangladesh	12,071
India	329230
Nepal	765
Sri Lanka	4050
Pakistan	24,829
Total	373900

Source : Compiled form various sources PGCB, DGPC,CEA,Annual Report NEA, Status of Industry Report NEPRA, Task Force 1 Report IRADe Report on CBET in South Asia: Challenges and investment oppoutinuties, etc.

Bhutan → India (1450 MW)

India → Bangladesh (600 MW)

India → Nepal (300 MW)

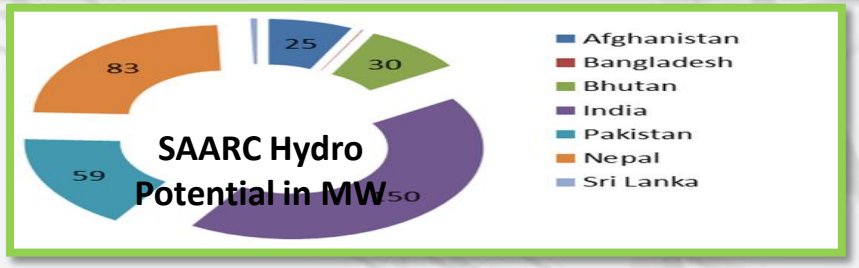
Resource Potential: Hydro Potential :350 GW !

- ✓ Vast potential of hydro power:350 GW
- ✓ Bhutan, Nepal, Pakistan, India: 30,83, 59, 150 GW respectively.
- ✓ Nepal and Bhutan can build export oriented hydro power plants
- ✓ Significant Coal deposits in India and Pakistan.
- ✓ Coal deposits in Bangladesh yet to be exploited.
- ✓ In addition to the conventional energy resources, there is huge renewable energy resources like solar and wind.

Country	Coal (million tons)	Oil (million barrels)	Natural Gas (trillion cubic feet)	Biomass (million tons)	Hydro (GW)
Afghanistan	440	NA	15	18–27	25
Bhutan	2	0	0	26.6	30
Bangladesh	884	12	8	0.08	0.33
India	90,085	5,700	39	139	150
Maldives	0	0	0	0.06	0
Nepal	NA	0	0	27.04	83
Pakistan	17,550	324	33	NA	59
Sri Lanka	NA	150	0	12	2
Total	108,961	5,906	95	223	349.33

Source: SAARC Secretariat (2010) for Bangladesh, Bhutan, India, Nepal, Sri Lanka; CWC (2005) for Indian States and WAPDA (2011) for Pakistan

Renewables	Bangladesh	India	Nepal	Bhutan	Pakistan	Sri Lanka
Solar Power (Kwh/sq. m per day)	3.8 - 6.5	4 - 7	3.6 - 6.2	2.5 - 5	5.3	NA
Wind (MW)	Very limited potential	151,918	3,000	4,825	24,000	25,000MW



India – Bangladesh Cross Border Electricity Trade (CBET) existing and proposed interconnections

CBET opportunities between India and Bangladesh have increased over last 3 years with development of interconnections

- 500 MW capacity through 400 KV back-to-back HVDC link on western side (with West Bengal) commissioned in Oct 2013
- 100 MW power transfer from Tripura (India) to Comilla (Bangladesh) on the eastern side in radial mode from Feb 2016
- Discussions for new interconnections under discussion in the Joint Working Group
- Additional 500 MW capacity on the existing transmission link with West Bengal by 2018
- Supply of 1600 MW by Adani from Jharkhand TPP through dedicated transmission Link

Interconnection	Estimated Cost (USD Million)
India Bangladesh HVDC Block –I • 125 km of 400 kV double circuit (D/C) T/L between substations at Baharampur (India) and Bheramara (Bangladesh), • 400kV switching station at Baharampur • 500 MW back to back HVDC sub-station at Bheramara	USD 193 Million (excludes Indian side transmission line cost)*
India-Bangladesh HVDC Block-II • 500 MW back to back HVDC sub-station	USD 144 Million in 2015

** Revised cost estimates 2015*

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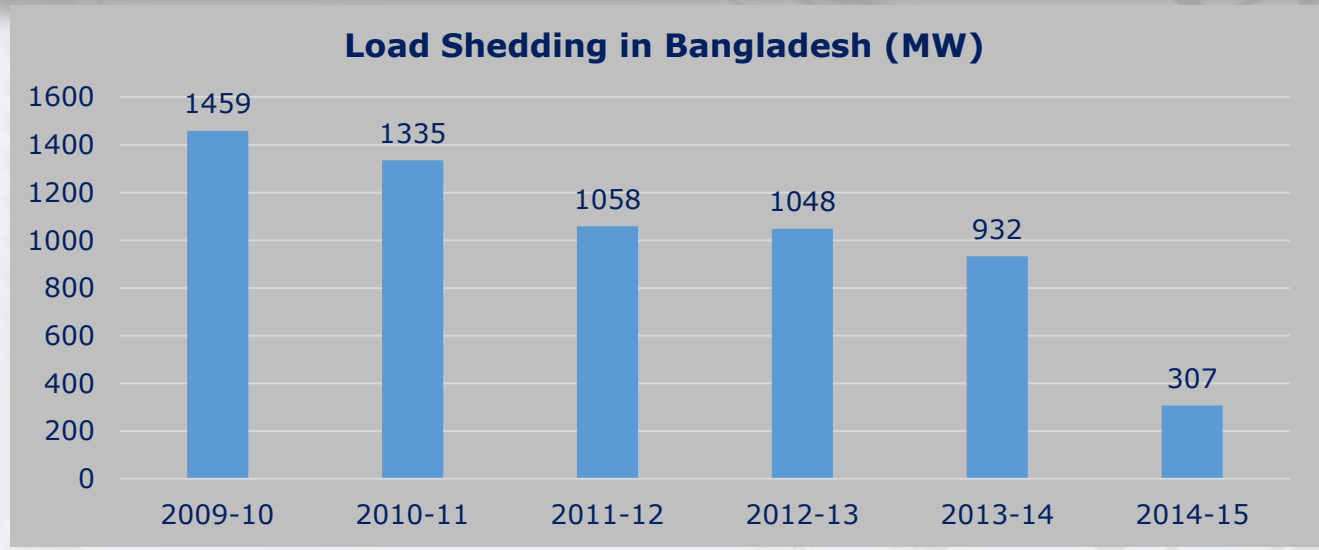
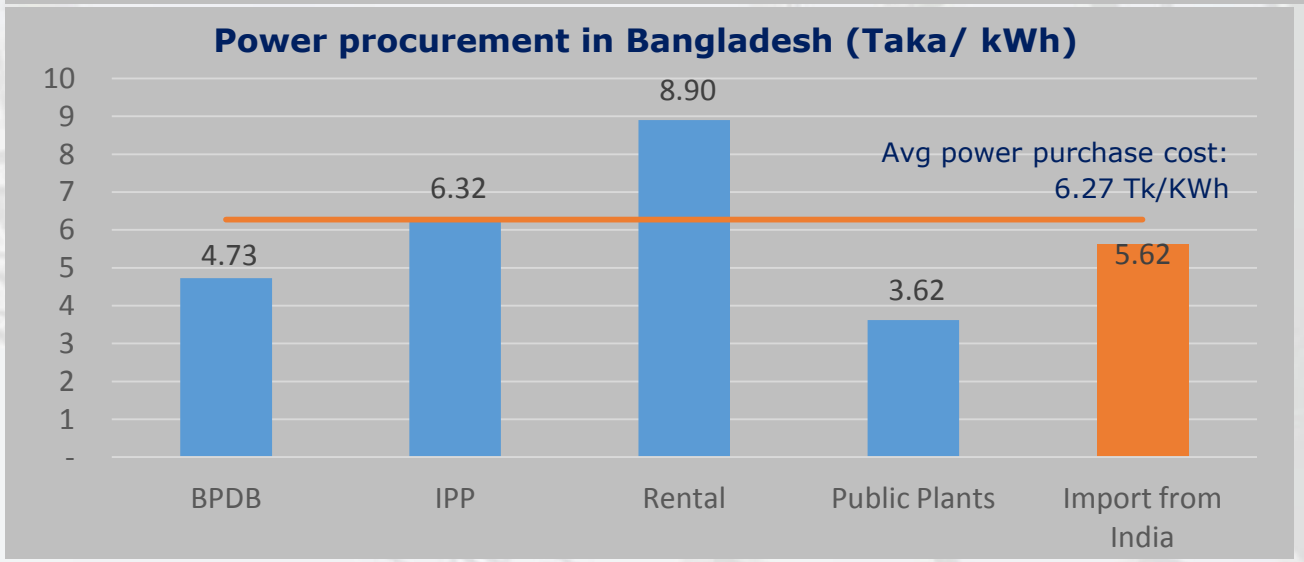
India-Bangladesh CBET Benefits

CBET has immensely benefited Bangladesh

- Reduced load shedding since import from India started in 2013.
- Reduction in power purchase cost leading to substantial savings due to cheaper tariff from India
- Future possibility to have access to cheaper and clean hydropower from Bhutan and Nepal



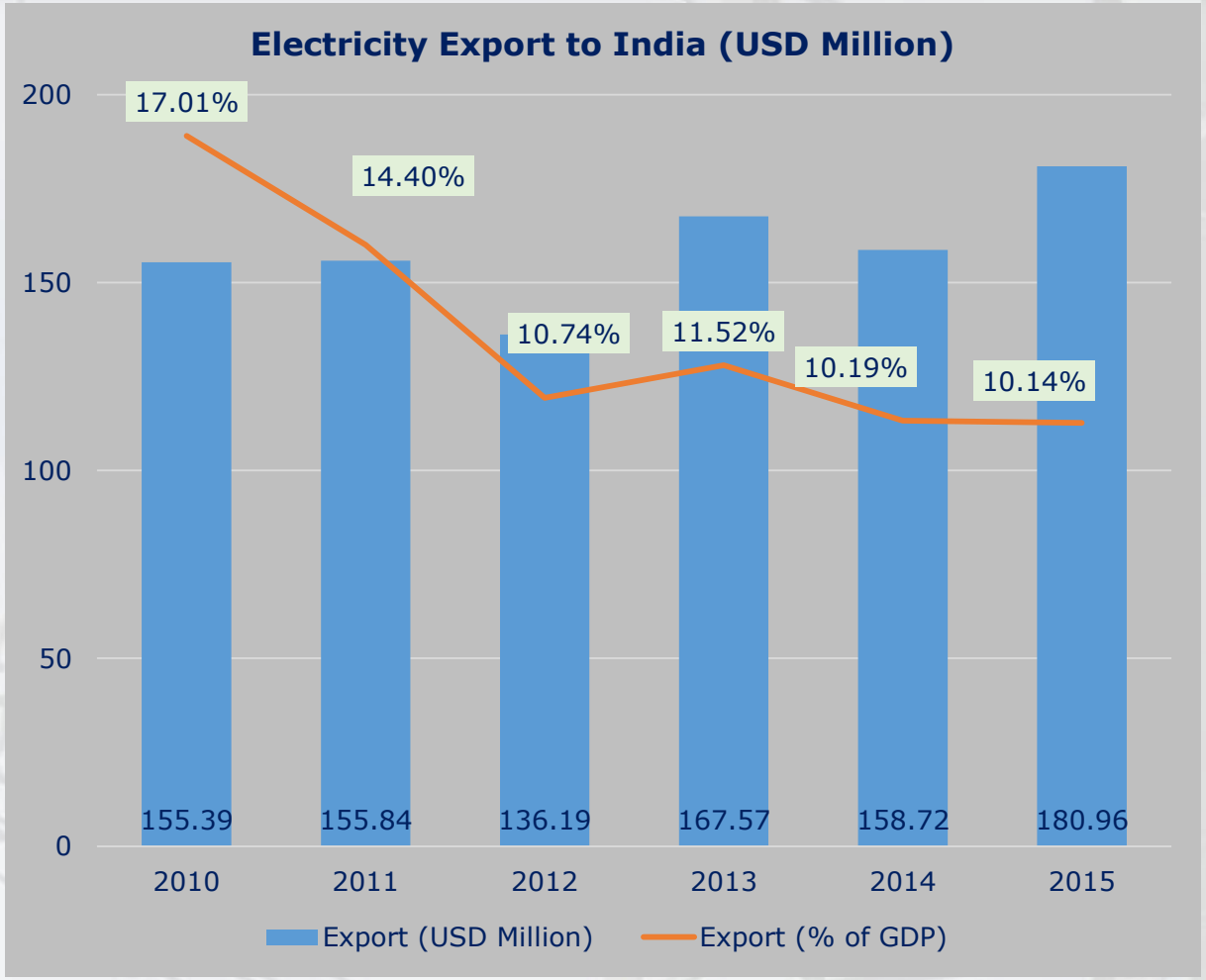


Source: BPDB Annual Report, 2015

India – Bhutan CBET Benefits

India has supported in the development of hydropower in Bhutan

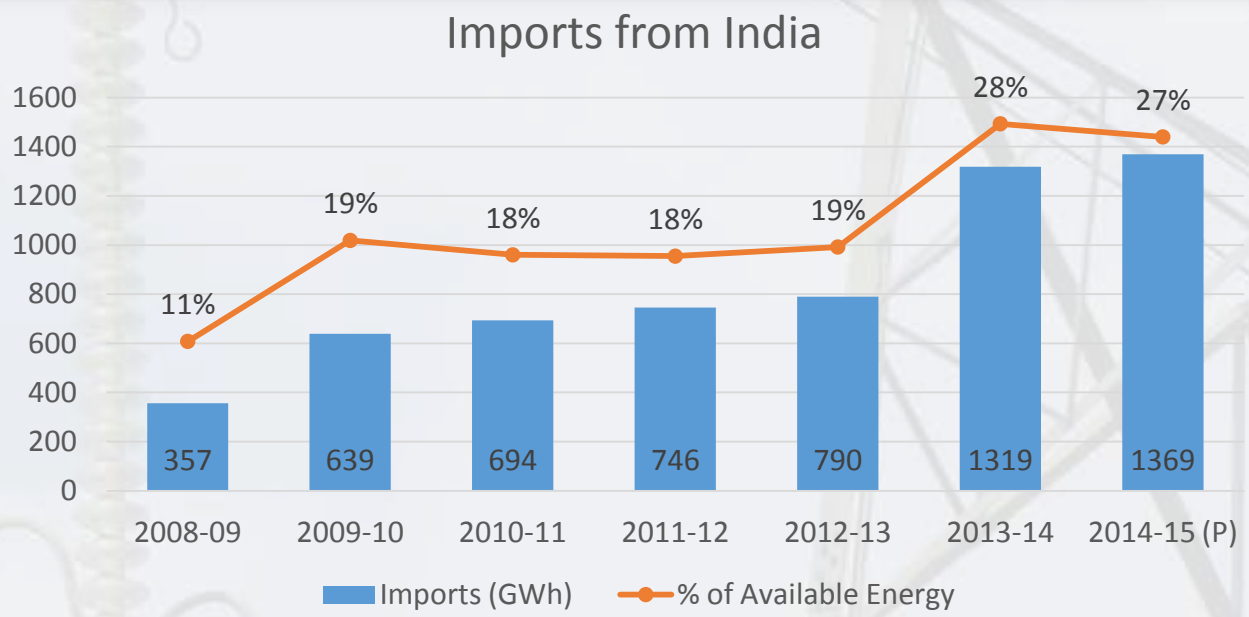
- Under Inter-governmental framework of India-Bhutan Agreement developed 1,416 MW HPPs (Tala-1020 MW, Chukka -336 MW , Kurichu -60 MW)
- Inter-Governmental Framework – Ongoing 2940 MW (Punatsangchhu-I (1200MW), Punatsangchhu-II (1020MW) and Mangdechhu (720 MW))
- Punatsangchhu-I (1200MW), Punatsangchhu-II (1020MW) Likely to be commissioned by 2020-21
- Transmission Link 400 kV AC ,Future HVDC Link
- Revenue from Exports of power have contributed Bhutan's GDP in the range of 11%-21% during the period 2003-2012.
- Per Capita Consumption -2600 kwh per capita, world average ~ 3000 kwh/per capita
- Development of Hydro Power has led to development of Industry such as Cement, Steel, Iron etc.



** Revised cost estimates 2015*

India-Nepal CBET

- Indo-Nepal power exchange began in 1971 with exchange of 5 MW of power to cater to isolated pockets on either side of the border
- The power exchange has been around 150 MW on radial mode at 11kV-132 kV levels between NEA and utilities on the Indian side
- Imports from India has been rising due to delays in domestic capacity additions in Nepal
- Dhalkebar (Nepal) – Muzaffarpur (India) 400 kV (132 kV) transmission line commissioned in Feb 2016 has added around 80 MW of import from India.
- The capacity will be enhanced to 1000 MW



Nepal will continue to be a net importer of energy in the short term, specifically during the dry season (winter months).
The power trading opportunities and option to sell to India will improve with the commissioning of domestic hydropower projects in Nepal

Source: NEA Annual Report

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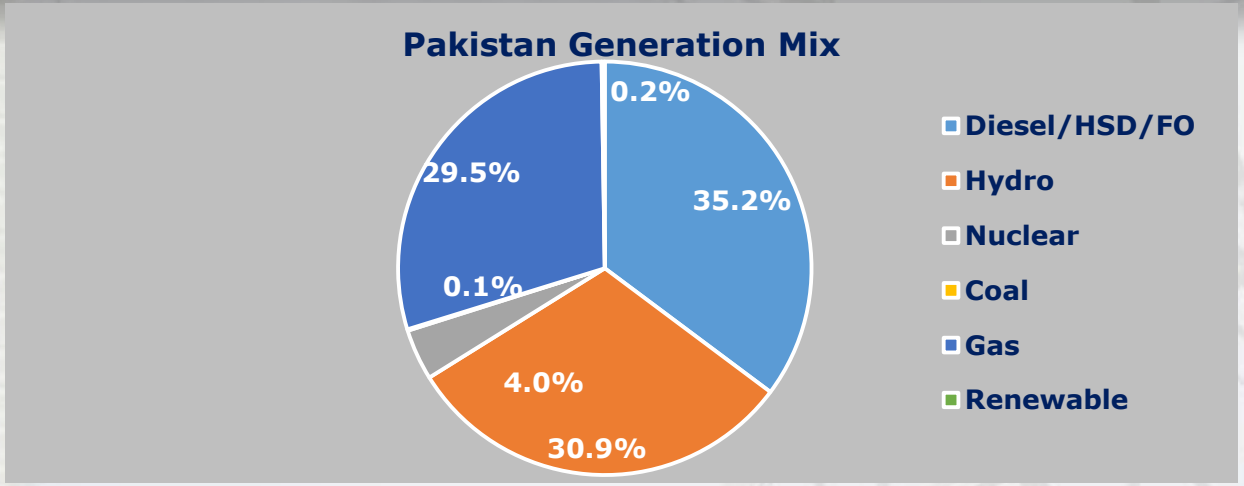
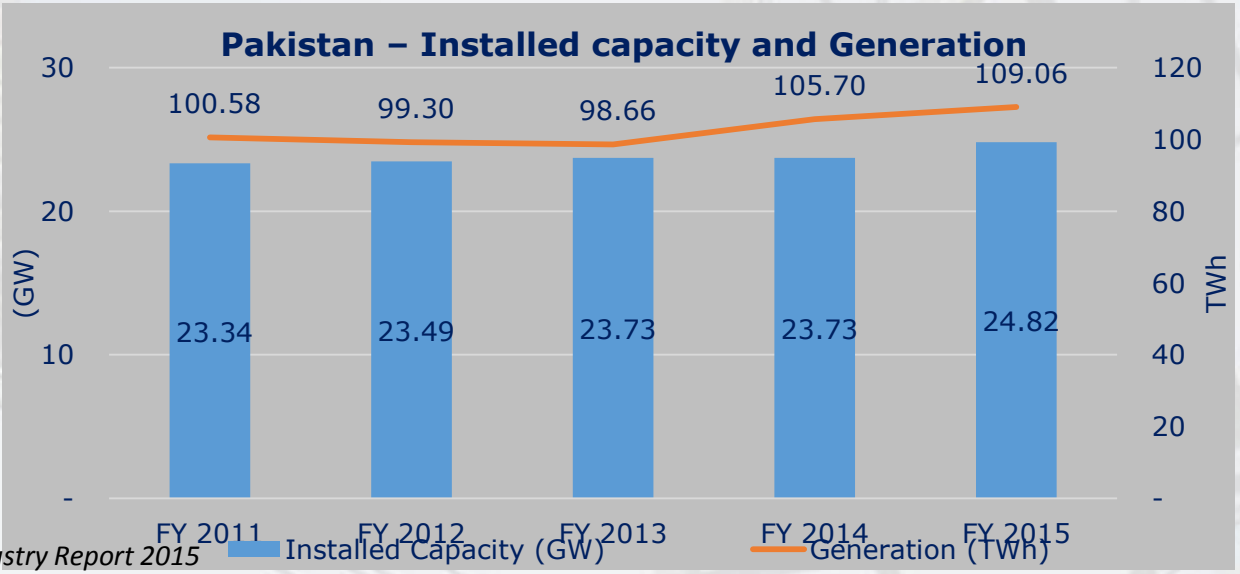
Key findings of the study on "Potential for Power Trade in Western part of South Asia"

Power Sector in Pakistan – Overview

- Installed capacity 25 GW
- Dominated by Hydro, Gas and Oil
- The capacity addition has been slow with around 1.5 GW added in 2011-2015
- The high dependence on oil (diesel, HSD, FO) has led to high power generation cost and volatility in prices
- Import from Iran has increased to 100MW from Feb'2017





Source: State of Industry Report 2015

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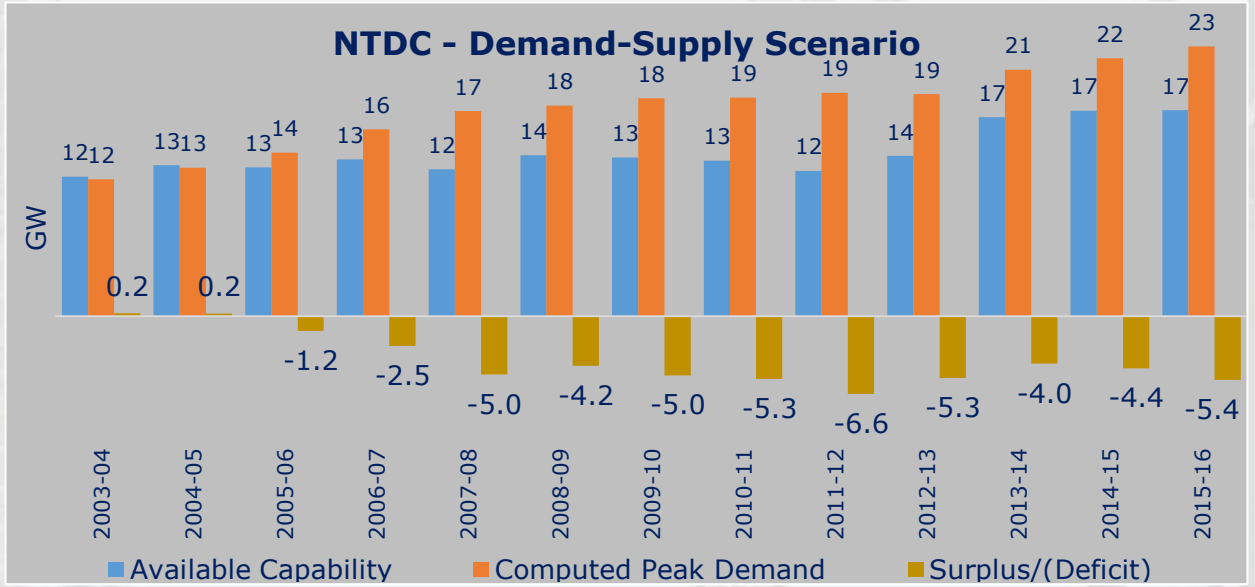
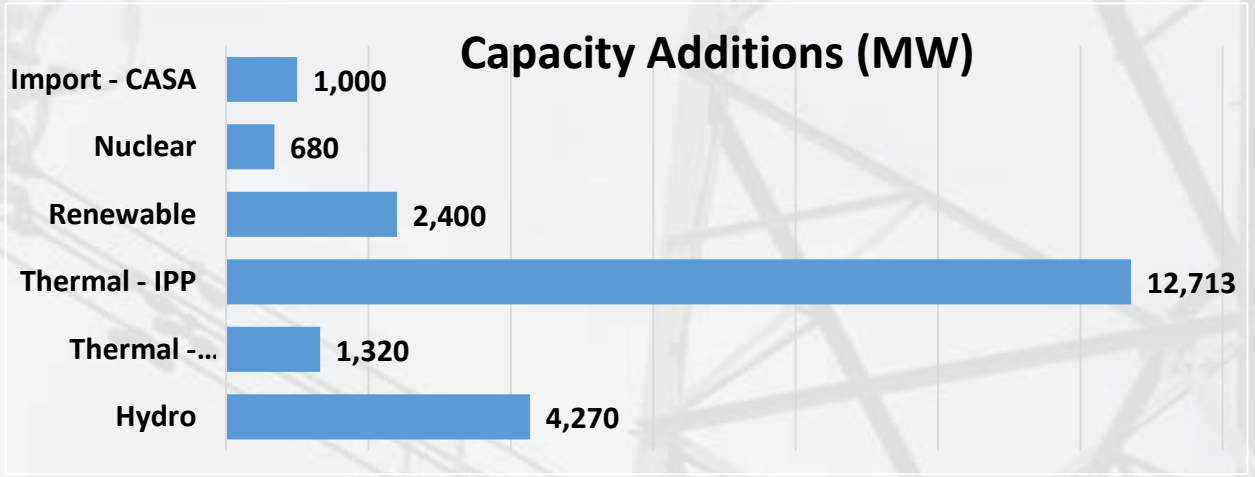
Power Sector in Pakistan – Demand Supply Scenario

- Power deficit over last 8 years with the peak demand deficit increasing to 5.4 GW
- Power shortages have led to power supply disruptions and also led to high dependence on the oil based generation
- Pakistan has set a target of adding 22.83 GW of power generation by FY 2020
- Short to medium term solution to meet its high demand is to import energy.
- In the long term, Pakistan may emerge as power surplus in the long run and may export power to nearby country

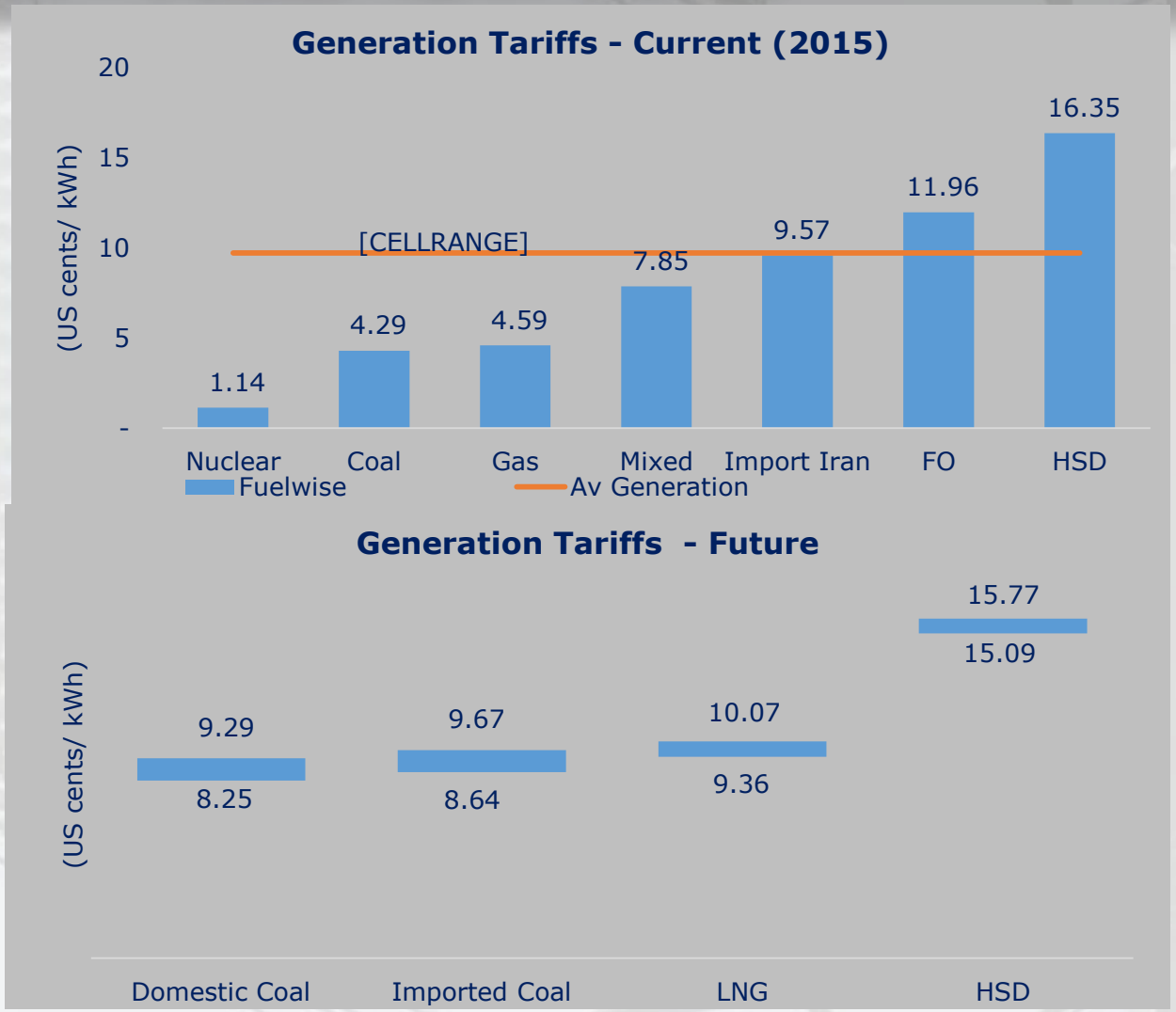




Source: NTDC Reports and presentation SAARC Workshop

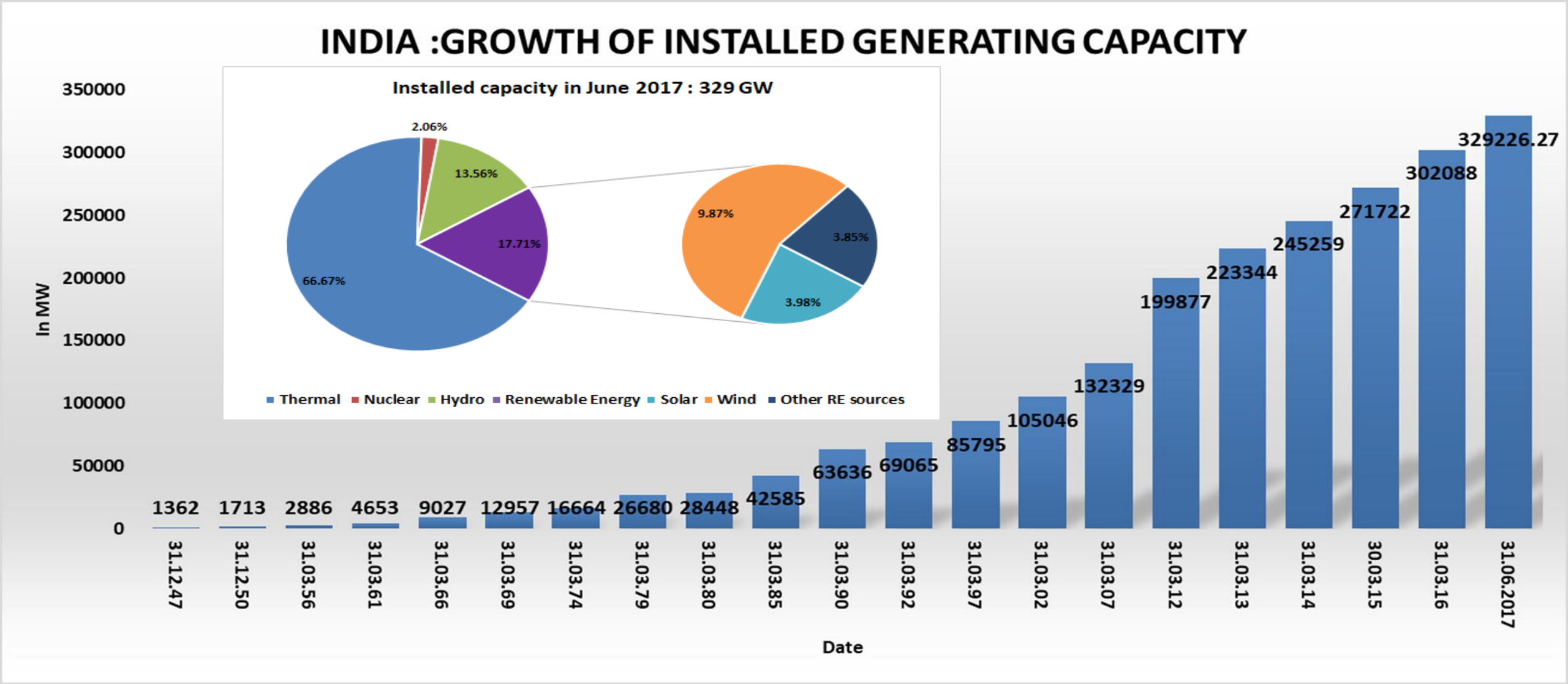
Power Sector in Pakistan – Power Tariff trends

- The average generation tariff in Pakistan is around 9.7 US cents/ kWh
- Power Tariffs remain high for HSD and FO based plants in FY 2015 even after decline in oil prices
- The tariffs are likely to be in the range of 15-16 US cents/ kWh in future as per NEPRA orders
- The generation tariffs from imported and domestic coal based plants would be in 8-10 US cents/ kWh range



Source: State of Industry Report 2015; NEPRA Orders

Power Sector in India – Overview



Source: CEA

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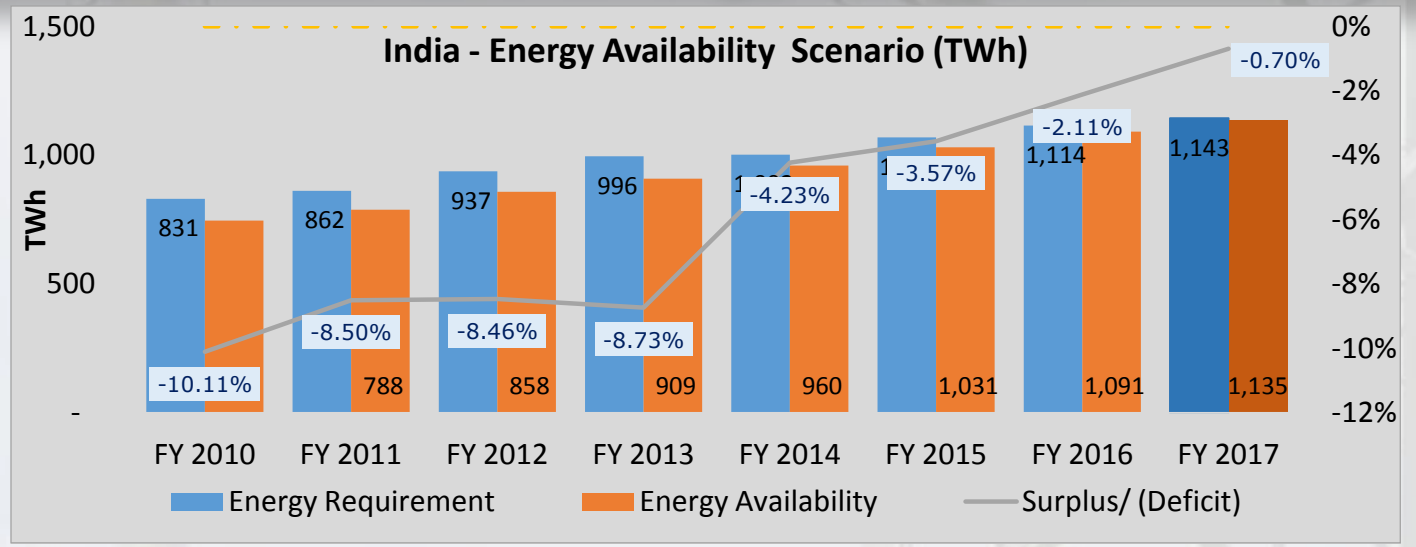
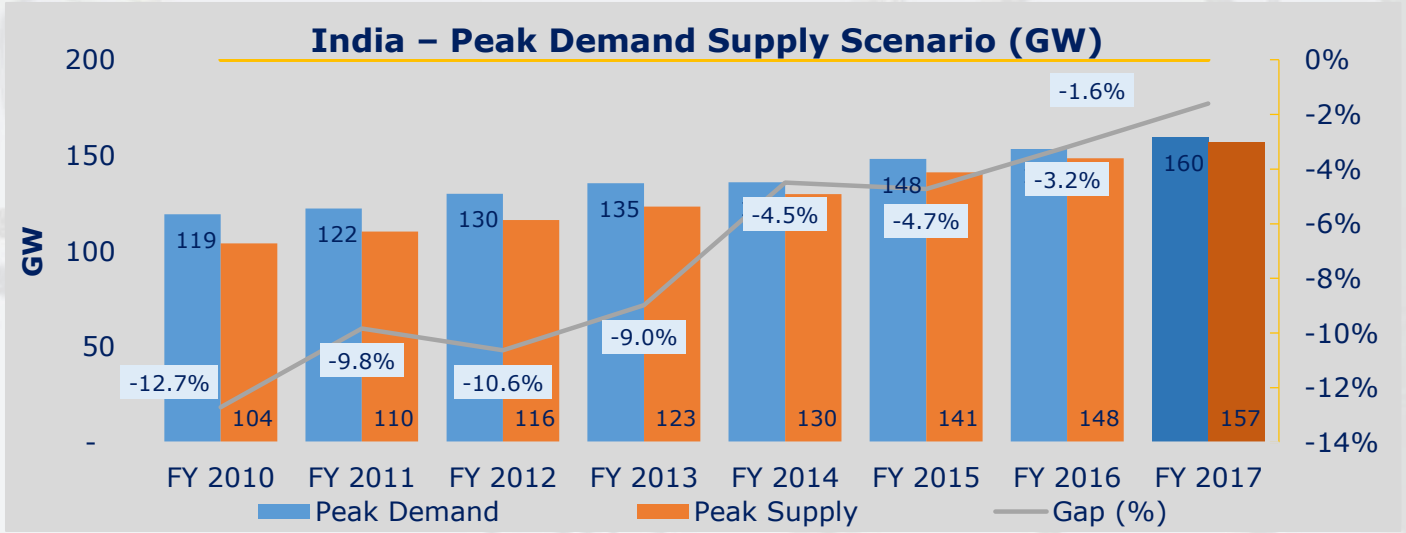
Power Sector in India – Demand and Energy Scenario

- Energy requirement has grown at a CAGR of 6% over last 6 years and the peak demand has grown at CAGR of 6.75%
- The deficit between energy and availability has steadily comedown due to lower demand growth and huge capacity additions
- Likely to be energy surplus in the current financial year and the gap between Peak Demand has come down to less than 1%.
- The demand likely to grow at CAGR of more than 8% to reach 542 GW by FY 2032

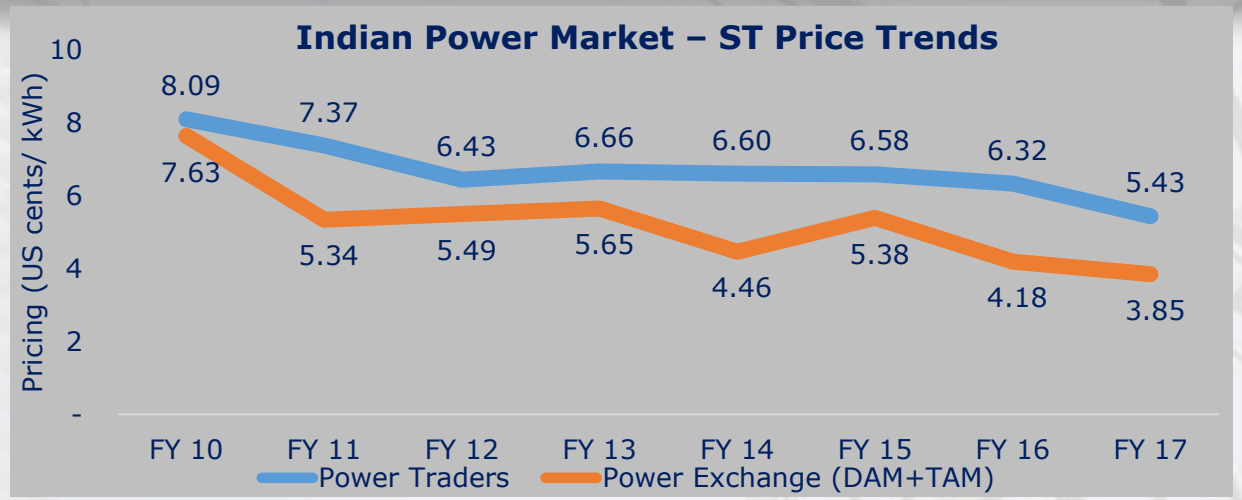


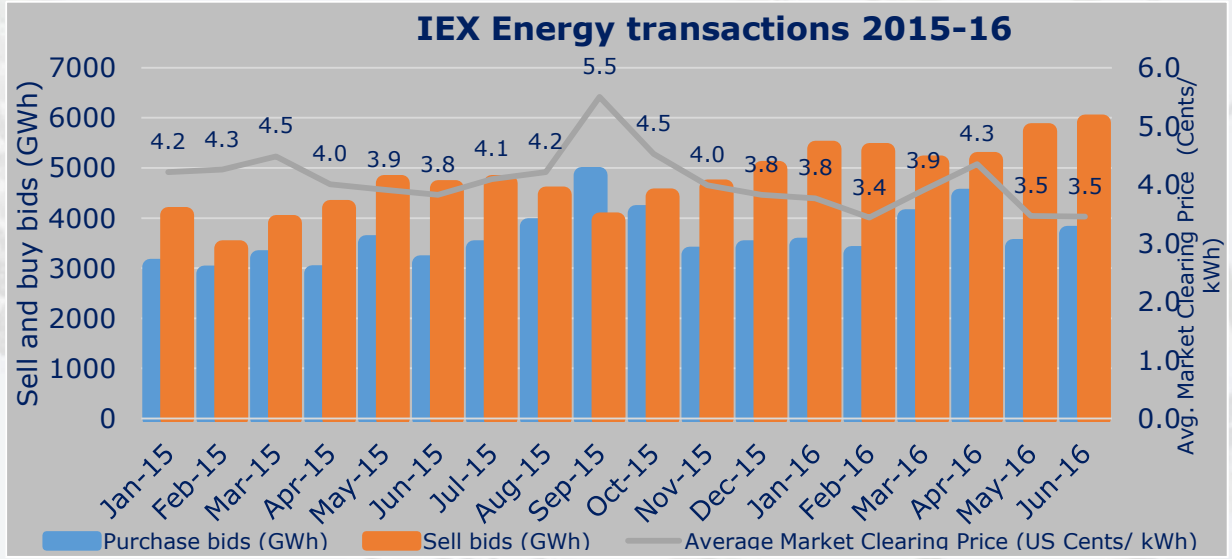


Source: Ministry of Power, Government of India

Power Sector in India – Power tariff trends

- The Average tariffs for long term PPAs has been in the range of 5.36- 7.19 US Cents/ kWh (2015)
- The power tariffs for short term are in the range of 4-6 US cents per kWh. There is surplus energy available on the power exchanges.
- Short term power is expected to remain low for short term and likely to be at premium on long term power once market aberrations are corrected

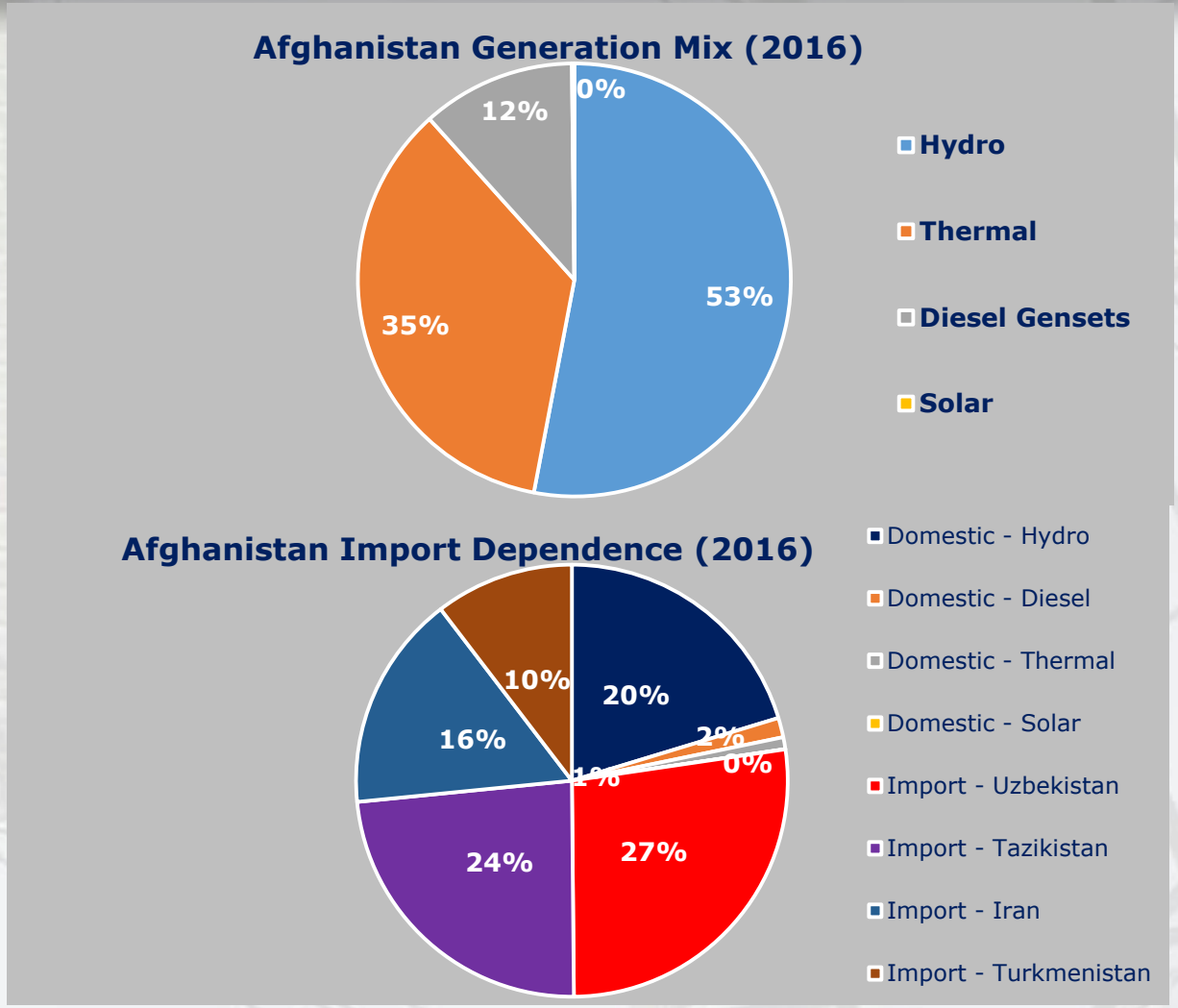




Source: CERC Monthly Monitoring Reports; IEX Web-site

Power Sector in Afghanistan – Overview

- Installed capacity of 566 MW (2016)
- Dominated by Hydro and oil
- Import 51% of total electricity requirement from Iran, Tazikistan, Uzbekistan, Turkmenistan
- 25 GW of Hydro Potential
- Access to electricity 43%
- Electricity Consumption 73 KWH per Capita



Source: Presentation Afghanistan's Energy Sector Development Plans – Amanullah Ghalib

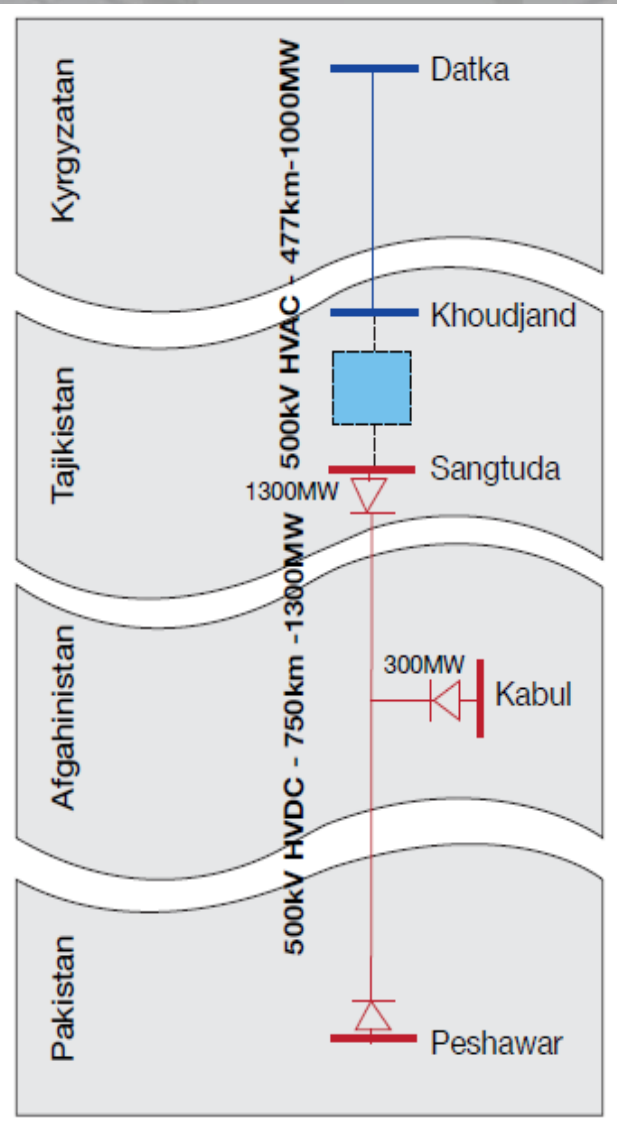
Pakistan – Afghanistan CBET Link

CASA-1000 project

- Hydropower plants (HPP) in Kyrgyzstan and Tajikistan will supply the electricity for CASA-1000
- 500 kV AC line from Datka (in the Kyrgyz Republic) to Sugd-500 (in Tajikistan)- 477 km
- 1300 megawatt AC-DC Convertor Station at Sangtuda (Tajikistan)
- 750 km High Voltage DC line from Sangtuda (Tajikistan) to Nowshera (Pakistan)
- 1300 megawatt DC-AC Convertor Station at Nowshera
- The proposed CASA 1000 transmission has the flexibility of bidirectional flows on the system

Turkmenistan-Afghanistan-Pakistan 500 kV Line (TAP-500)

- Facilitate year round power export from Turkmenistan to both Afghanistan and Pakista
- By 2020, Turkmenistan expects to generate for available export 3,500 MW of excess power.
- The tripartite agreement has been signed by the three head of states in December 2015



Power trade potential between Pakistan and India

- Various studies suggest substantial power trade potential between India and Pakistan
  - ADB study (2013) study: Annual trade of 1,873 GWh over a 200 MW and 3,129 GWh over 500 MW interconnections. Annual Benefit – 491 US$ Million.
  - A World bank Paper (2015) projects 14.9 GW power trade by year 2040 in no carbon constraint scenario and 11 GW power trade in full regional trading scenario with carbon constraints. By 2040, Export from Pakistan would be 314 TWh as against import of 225 TWh.
  - The SARI/EI/IRADe/USAID study (May 2016) has projected a power trade potential of 40 BU per year from 2021 onwards.

Source: USAID Report on Electricity Trading Potential in SA (May 2016)

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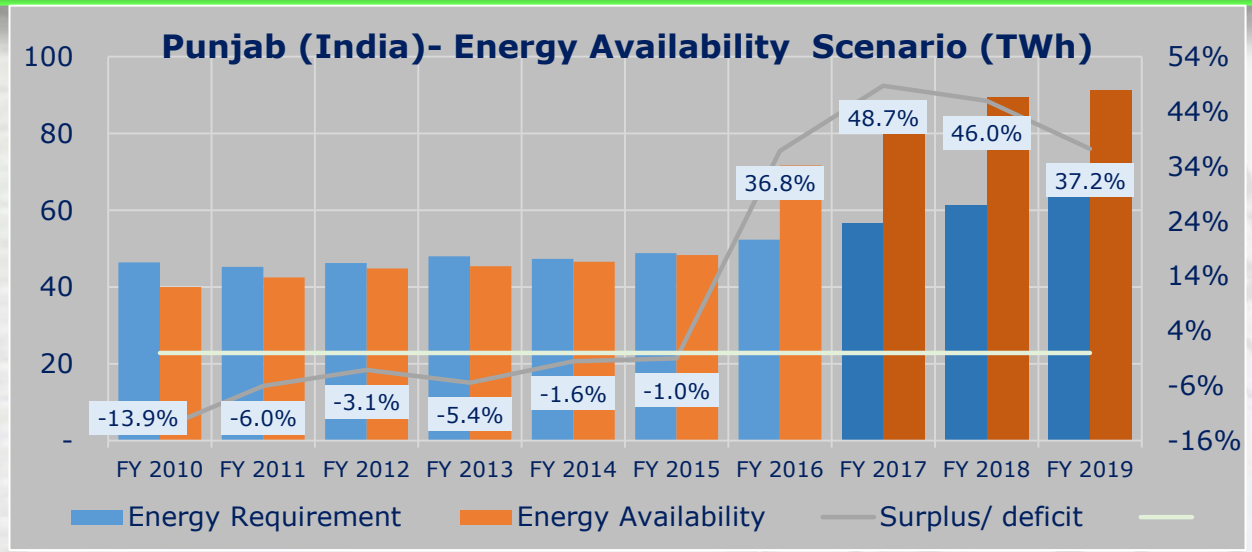
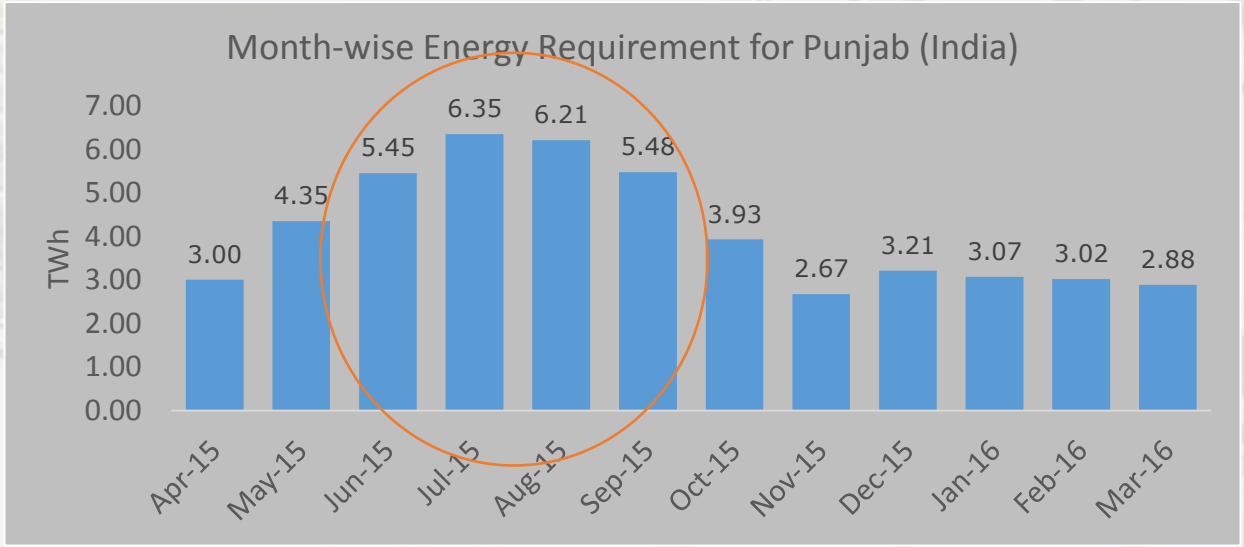
Over view of Punjab State in India

- Installed capacity 14167 MW
- State of Punjab which is in close proximity to the load centers in Pakistan, is energy surplus
- The situation is likely to improve with proposed generation capacity additions in future
- The load curve in Punjab is characterized by high demand during agricultural season (Jun-Sep) with 48% of energy consumption in these four months

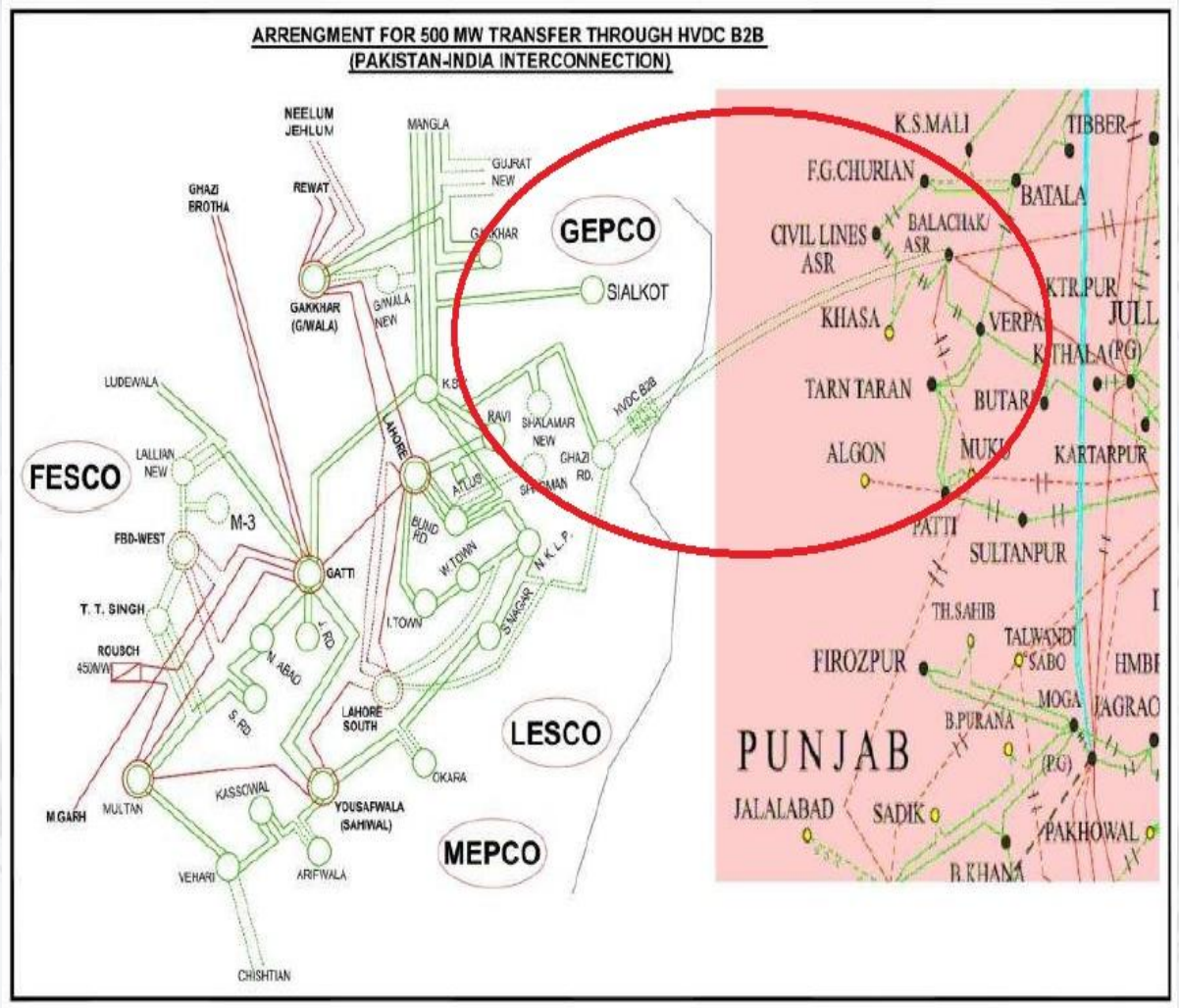




Source: Power For All Report for Punjab, Feb 2016

Cross Border Interconnection – Technical interface

- Several interconnection options between Pakistan and India have been explored since 1990s connecting
  - Amritsar (Punjab, India) and Lahore (Punjab, Pakistan)
  - Patti (India) and Dinanath (Pakistan)
  - Mundra (Gujarat, India) and Karachi (Pakistan)
- The most recent pre-feasibility study carried out in 2012-13 under World Bank project proposed the Amritsar – Lahore link with following elements
  - 400/220 kV HVDC Back-to-Back Convertor Station in Pakistan
  - 400 kV D/C Transmission Line from Balachak near Amritsar to Pak-India Border
  - 400 kV D/C Transmission Line (approx. 10 km) from Convertor Station to Pak-India Border
  - 220 kV D/C Transmission Line from Ghazi Road to Convertor Station
  - World Bank Cost Estimates(2012-13) : US$119,40 Million



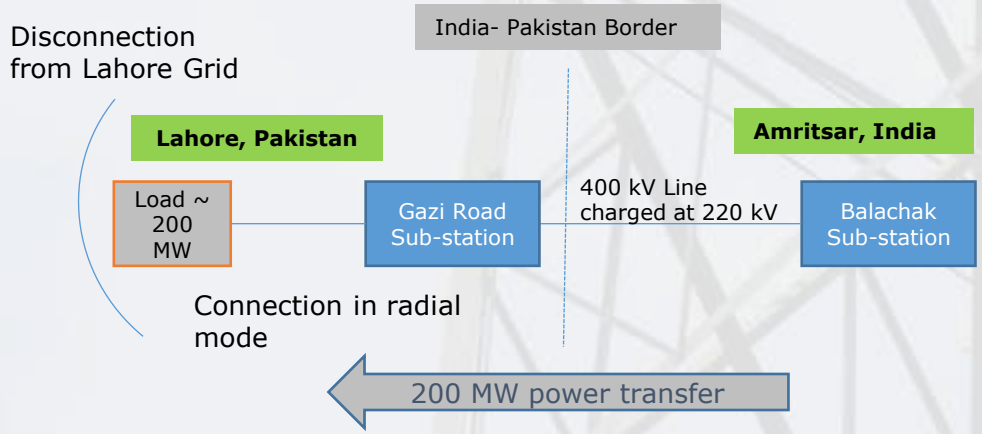
Source: NTDC presentation in SAARC Workshop, 2015

Cross Border Interconnection – Roadmap

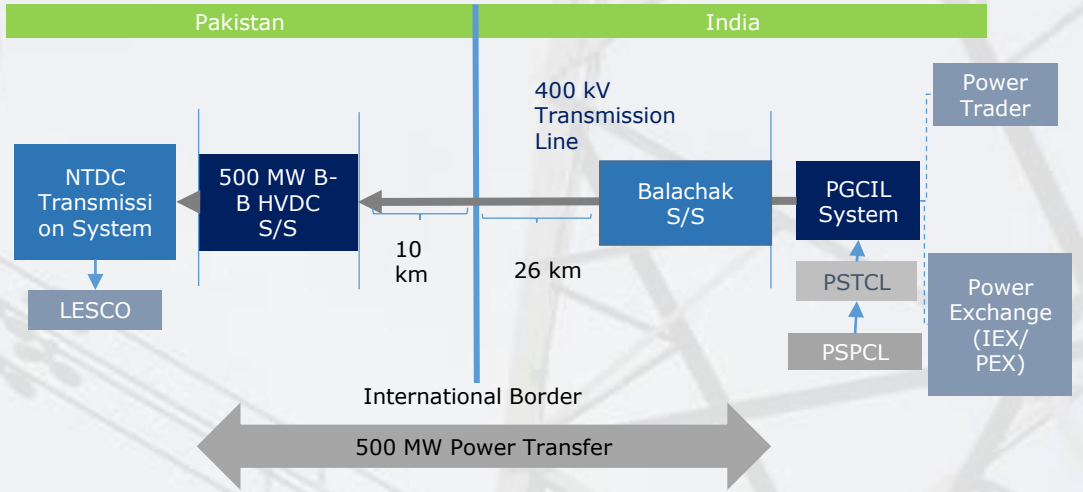
The interconnection between Pakistan and India can be developed in two stages

- Stage-1 – Interconnection Radial mode -200 MW
  - 400 kV T/L (charged at 220 kV)
  - Interconnection between Balachak near Amritsar (India) with Lahore grid in radial mode
  - Commissioning within 18-24 months (Excluding pre-award stage)
- Stage-2 - 500 MW back to back HVDC sub-station in Pakistan
  - Commissioning time 27-30 Months (Excluding pre-award stage)
  - Capacity can be enhanced in future depending on the requirement

Stage 1: Interconnection in radial mode – 200 MW



Stage 2: Interconnection by HVDC - 500 MW



Cross Border Interconnection – Cost benefit analysis

- Estimated cost of the Pakistan – India interconnection (both Stage 1 and Stage 2) is USD 125 Million (2016)- Stage 1 -16.9 US$ Million, Stage 2 -108.1 US$ million.
- The utilization of transmission line will be high given the energy gap in Pakistan
- The power will be sourced from surplus available on Indian side in state of Punjab or supplied through Power Traders
- The project will replace the costly power from Oil based and imported coal based plants in Pakistan
- The project is economically viable in the base case with an EIRR of 22.14%
- The project is likely to give a benefit of USD 210 Million for the total cost of 125 million. The B/C ratio of the project works out to be 1.68
- The benefits would even be higher in case the energy is available for industrial consumers in LESCO area

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Way Forward

Way forward

- For a pan South Asia regional grid, the interconnection between Pakistan and India is critical to connect the western part of region and augment the interconnections established on eastern side.
- Potential to bring about an integration in the power systems of Central Asian countries and South Asian countries.
- In the short to medium term, the interconnection between Pakistan and India can benefit Pakistan in meeting the generation deficit at a competitive price.
- The Project will replace the costly power from oil (Diesel and FO- about 35%) and Gas (about 30%) based Power Plants in Pakistan.
- In the long term, the interconnected system will provide opportunities for the new capacity additions within Pakistan to export to the power deficient markets in South Asia and Central Asia.
- A detailed feasibility study for grid interconnection & formation of joint committees.

Thank You

CBET interconnections – Current and Proposed

Interconnection	Current	Proposed

Bhutan – India	• Total export capacity of around 1,416 MW
	  • Tala (1020 MW)
	  • Chukha (336 MW)
	  • Kurichhu (60 MW)
		• Transmission and associated infrastructure for Punasangchhu I & II (2220 MW) and Mangdechu (720 MW) HEPs under construction
		• Capacity of 10,000 MW for export to India under the Umbrella Agreement signed between two countries

Bangladesh – India	• Current capacity of 600 MW
	  • 500 MW power being supplied from India via 400 kV Behrampur-Bheramara line with back-to-back HVDC S/S
	  • 100 MW capacity 400 kV (charged at 132 kV) Tripura – Comilla T/L in radial mode
		• Augmentation of HVDC back to back station capacity at Bheramara by 500 MW under construction
		• 2000 MW interconnection proposed between North Eastern part of India to eastern part of India through Bangladesh

Nepal – India	• Current capacity is around 250 MW
	  • Multiple interconnections (21 nos) at 11 kV to 132 kV - 150 MW
	  • 400 kV Muzaffarpur- Dhalkebar line (currently charged at 132 kV) - 80 MW and ultimately to have capacity of around 1000 MW
		• Transmission system for evacuation of power from export oriented Upper Karnali HPP (900 MW)
		• Three additional interconnections currently under discussions in the JWG

Power trade potential in Western part of South Asia

- Short term (2017 to 2020)
  - India likely to become energy surplus with the state of Punjab (India) being surplus in peak capacity and energy at least for 8 months
  - Pakistan continues to be overall energy deficit and continue to depend on high cost sources to meet its demand
  - Afghanistan continues to be net importer of electricity from the Central Asia and have to rely on high cost domestic generation from oil based plants. Lack of interconnections with Pakistan will limit the potential of export of power from South Asian region
  - Electricity trade can start between Pakistan and India with export of upto 200 MW power by India in the short term. The trading of electricity is constrained by the lack of transmission infrastructure between the two countries
- Medium term (2021 to 2025)
  - Development of CASA 1000 interconnection project to facilitate greater imports of electricity by Afghanistan, both from Central Asia and possibly from South Asia
  - Electricity trading between India and Pakistan could increase with augmentation of interconnections and can be increased to 500 MW in medium term. Pakistan could also act as transit for export of power from India to Afghanistan
- Long term (Beyond 2025)
  - Pakistan can also trade its surplus power to India or other South Asian countries if its ambitious target of power generation are realized
  - Afghanistan can explore electricity import options from South Asia in addition to the already planned capacities in Central Asian region

Cross Border Interconnection – Key Assumptions

Exchange Rate	
1 USD = INR	67.00
1 USD = PKR	105.00
Transmission Capacity Utilization	85%
Capital Cost	
Transmission Line per kM	USD 0.41 M per kM
HVDC Sub-station per MW	USD 83.3 Million per MW
Debt – Equity	70:30
Return on Equity	16%
Long term Loan	12 Year @ 5%
O&M Charges	
Transmission Line	USD 1.20 Thousand per Km
HVDC Sub-station	USD 1.87 Thousand per MW
Escalation	3.32% (Transmission Line) 2.0% (HVDC Sub-station)

Country	Reference	Rate (c/kWh)	Escalation
India	Power Traders	6.35	2%
Pakistan	Coal (Imported)	9.70	0%

Case Study: India-Nepal CBET

Power Trade Agreement (PTA) signed in Oct 2014 would be mutually beneficial to both countries

- Nepal can meet its short term energy deficit from India
- Nepal has the opportunity for monetizing the hydropower resources for the overall benefit to the economy - Facilitates development of export oriented projects in Nepal which will supply power to India. PDAs for 900 MW Arun III ($ 825 Million) and 900 MW Upper Karnali projects ($ 1.4 Billion) in 2014
- India can have access to competitively priced clean source of energy to meet its rising demand
- Allows for greater cooperation and planning in the development of transmission interconnections
- Support in export of surplus power available in Nepal grid in future.

Source: NEA Annual Report