SAARC Study

‘Harmonizing Transmission Grid Codes of SAARC Member States to Combat Regulatory Challenges for Intra-region Power Trading / Interconnections’

December 2015

SAARC Energy Centre, Islamabad

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Table of Contents

Foreword

Due to rapidly increasing electric power demand and diversities such as different peak time and seasonal variations within the neighboring countries, case for regional interconnectivity has strengthened many folds. South Asia is no exception in this regard. Such interconnections are not merely meant to fetch power export and import. This also serves the objectives of optimum utilization of the resources and creating synergy among the efforts of the Member States in enhancing the quality of lives of the people of the Region. The mission of establishing regional power interconnections to complement the demand supply situation in the Region is in total adherence with the purpose of the SAARC i.e. *to promote the welfare of the peoples of South Asia, strengthen collective self-reliance, promote active collaboration and mutual assistance in various fields, and cooperate with international and regional organizations.*

SAARC Energy Centre (SEC) undertook the short term, in-house Study 'Harmonizing Transmission Grid Codes of SAARC Member States to Combat Regulatory Challenges for Intra-region Power Trading / Interconnections' through its Action Program FY 2015. The Study is an in-house effort by Mr. Salis Usman, Research Fellow (Energy Efficiency) and was peer-reviewed by Mr. Atta ur Rehman, Director General, Central Power Purchasing Agency, Pakistan. Overall purpose of the Study is to highlight importance of the harmonizing process since it would urge the Member States to adequately prepare for meeting the diversified regulatory challenges corresponding to establishing and operating the regional power interconnections. The Study report is expected to serve as a good starting point for development of the Regional Interconnection Grid Code which is obviously a tough task but not beyond the abilities of the professionals of the SAARC Region.

Encouraged by the historical signing of SAARC Framework Agreement for Energy Cooperation (Electricity) in 2014, SEC envisions a more eager and proactive role in materializing the vision of the SAARC Leaders with respect to establishing the SAARC Energy Ring. In this context, SEC is also considering to extend its platform for experience sharing by the Member States who are in advanced stages of the power sector reforms. Overall objective is to secure quick and smooth progress with respect to creating the enabling environment for the competitive power market. Member States like Bangladesh, Bhutan, India, Pakistan and Sri Lanka may act as role model for the Afghanistan, Maldives and Nepal in terms of development and implementation of the regulatory instruments such as Grid Code.

SEC looks forward to the comments and suggestions from the professionals to add further value to the Study report besides seeking proposals for future interventions to be undertaken by the SEC especially in the context of SAARC Energy Ring.

Muhammad Naeem Malik
Director, SEC

Executive Summary

SAARC Member States are pursing power interconnectivity in a bid to export the additional power and/or to balance the prevailing, dynamic demand and supply situation. All such interventions, either bilateral or multilateral, are ultimately taking us close to the SAARC Energy Ring - vision of the SAARC leader and the fundamental rationale for the establishment of SAARC Energy Centre. With various existing and upcoming interconnections encompassing most of the Member States, jigsaw of the regional energy ring has become quite clear.

As such, no single regional entity is responsible for monitoring and controlling the interconnectivity process and thereof providing enabling environment with respect to regulatory regime. Resultantly, there remains a gap caused due to lack of institutional arrangements at regional level. Consequently, SAARC Energy Centre (SEC) undertook one of the most critical pre-requisites for the regional connectivity i.e. 'Harmonizing Transmission Grid Codes of SAARC Member States to Combat Regulatory Challenges for Intra-region Power Trading / Interconnections'. This is yet another program activity by SEC for realizing the SAARC Energy Ring.

In order to set the perspective, the Study report starts with highlighting the existing cross border interconnections providing brief history and major modalities for the power trade; these interconnections include international as well as regional instances. Introduction is further strengthened with benefits and rationale for the interconnection arrangements. Concept, composition and requirement of regulatory instruments are provided. Focus remains on Electricity Grid Code in addition to need for harmonizing the individual Grid Codes (rules, procedures and standards to build and operate power transmission networks) in view of the regional interconnectivity. Existing power trade in the SAARC region is also highlighted with major share of bilateral agreements entered into by the largest SAARC Member State, India with Bangladesh (Export), Bhutan (mainly Import) and Nepal (Export).

Journey from the vertically integrated power utilities to the competitive power market by the SAARC Member States is part of the Study report to emphasize the variety in the progress achieved by the individual Member States. Power sector institutional arrangements in the Region are followed by the legal and regulatory instruments including Electricity Acts and Grid Code while indicating the parities in terms of operating voltages and other relevant parameters.

After setting the perspective, the Study report leads to the comparison of Grid Codes of the Member States (with the exception of Afghanistan and Maldives, where the Grid Code does not exist). For this purpose, all clauses/sections relevant to regional interconnections of each sub-code i.e. Planning Code, Connection Code, Operation Code, Scheduling and Dispatch Code, Metering Code and Protection Code. During the process the relevant sections of each of the Grid Codes is also indicated for easy reference. Following are some of the contrasting aspects among Grid Codes of the SAARC Member States:

a. Regulatory compliance by the grid users with the provisions of the existing Grid Codes of all Member States with the exception of Nepal is covered under the law. In order to ensure grid security, consistency on the part of Member State Nepal is to be maintained.

b. With respect to planning dimension, it is observed that variety in aspects including permissible operating frequency voltage limits (India being the most stringent Member State), planning approach/planning criteria, responsibilities for development of plans, etc. are required to be harmonized. Obviously, the harmonized standards, processes and procedures would be applicable on the interconnection point and would not affect the individual procedures and practices prevailing in the Member States.

c. Connection Code of India is more transparent pertaining to grid connection, long term access and medium term open access than other Member States where concept of open access is yet to be introduced. Further, only Indian version also covers HVDC interconnections whereas remaining Codes are restricted to HVAC transmission.

d. With reference to Operating Code, Indian and Sri Lankan Grid Codes require that the transmission system shall survive the loss of a single generator. In view of the present operating voltage levels of the Member States, 400 kV interconnections are possible between India-Bangladesh and India-Bhutan. However, other interconnections are possible at 220 kV. However, in order to ensure, system security, HVDC are preferred between India and Bangladesh & India and Pakistan. Except for Grid Codes of India, Pakistan and Sri Lanka, no other Grid Code specifies connection requirements for wind power generators.

e. With reference to scheduling and dispatch, there exist different approaches between India and other Member states; requires to be harmonized for interconnection purposes. India Grid Code also caters this aspect with reference to competitive power market whereas no other Grid Code contains such provisions.

f. Indian Code is more stringent with respect to protection schemes than other Grid Codes; international practices go for the more stringent protection scheme of the two systems being inert-connected.

The Study culminates by providing the Way Forward mainly comprising of the proposal for development of the Regional Interconnection Code along with guidelines for each of the major sections. It is expected that the Member States will join hands to develop, approve and implement this Regional Code through synergetic efforts of the SAARC professionals.

1.0 Background

Power sector reforms aim at providing safe, reliable, efficient and affordable power for the electricity consumers. SAARC Member States are at different stages of reforms in the power sector. Regulators are responsible to ensure implementation of regulations in their respective counties. They are the key functionaries who oversee and balance the interests of all the stakeholders in a transparent manner and facilitate investments, operations and trade.

Grid Code is critical in developing, operating and maintaining the power grid and it gains even higher importance due to potential cross border interconnections whether these are bi-lateral or multi-lateral. Consequently, to realize the upcoming cross border power interconnections the most important pre-requisite is harmonization of the Grid Codes of the Member States. In view of the above, SAARC Energy Centre through its approved Action Plan for the year 2015 launched an in-house Study on 'Harmonizing Transmission Grid Codes of SAARC Member States to Combat Regulatory Challenges for Intra-region Power Trading / Interconnections'. The objective is to gather country wise information on infrastructure, discuss minimum requirements for policy, regulatory status and code harmonization needs to facilitate energy exchange and its trade.

The Study considers various roadblocks that impede the regional electric power connectivity, mechanism required for harmonization of regulations and policies in the South Asia region particularly the Grid Codes (the most important legal and regulatory instrument). The outcome of the study shall enable the Member States with contrast/deviations in the prevailing Grid Codes with respect to the cross border power transmission/exchange.

Network systems of SAARC Member States vary in many dimensions such as size, network topology, operating parameters, etc. Member States have adopted different approaches for regulating their power sector and they are at different stages of maturity levels. India, Bangladesh, Pakistan, Sri Lanka and Bhutan have independent regulatory authorities, whereas Nepal has a tariff fixation committee. Afghanistan is yet to have one. Electricity Act in Nepal is still to be adopted by her parliament. A quick review of the policies of SAARC Member States reveals that the socioeconomic aspects dominate the overall policy for the power sector. The Data Table 1.1 shows details of Laws and Acts and independent regulating bodies governing the sector in each of the SAARC Member States. India, Sri Lanka, Bhutan, and Bangladesh have taken steps towards commercialization of the sector. There is a strong point of view prevailing in South Asia that it is important to have regulating authorities out of the political influence, however, at the same time there should be adequate checks and balances so that regulators cannot over regulate the sector.

Table 1.1: Laws and Acts: Apex Legal and Regulatory Institutional Framework

Member State	Laws and Acts	Independent Regulatory Body	Appellate Authority
Afghanistan	-	-	-
Bangladesh	Bangladesh Electricity Act,1910	Bangladesh Energy Regulatory Commission **(**BERC)	BERC
Bhutan	Electricity Act of Bhutan (2001)	Bhutan Electricity Authority **(**BEA)	Concerned Ministry or Court of Law
India	Electricity Act 2003	Central Electricity Regulatory Commission **(**CERC), State Electricity Regulation Commission (SERC)	Appellate Tribunal For Electricity (APTEL)
Nepal	Electricity Act 1992	Department of Electricity Development (DoED)	
Pakistan	NEPRA Act-1997, Amended Version of Electricity Act 1910	National Electric Power Regulatory Authority (NEPRA)	Provincial High Court and Supreme Court of Pakistan
Sri Lanka	Sri Lanka Electricity Act, 2009	Public Utilities Commission of Sri Lanka (PUCSL)	Court of Appeal Sri Lanka
Maldives	-	Maldives Energy Authority	

2.0 Scope and Methodology of the Study

The overall objective of this Study is to help the SAARC Member States in providing enabling environment for establishing and sustaining SAARC Market for Electricity.

2.1 Terms of Reference

The SEC undertook a study under its thematic area of Programme on “Energy Trade between the SAARC Countries” (PENT). The study aims to identify the contrast/deviations/ inconsistencies in the grid codes of the Member States with respect to the cross border power transmission. Following are the broad terms of reference for this Study.

a. Review of all the relevant procedures/Grid Codes/standards/etc. together with the related documents, for SAARC Member States. These will include, but not limited to, the following:
   - Grid Code
   - Power system operating procedure
   - Grid standards including but not limited to the specified permissible limits of voltage and frequency variations, as per regulation

b. Review the prevailing organizational structure and the ‘Roles & Responsibilities’ together with the linkages covering load dispatchers, transmission/distribution utilities, generation utilities, electricity regulators, role of government agencies and relevant other electricity utilities/agencies.

c. Review the type of scheduling and dispatch, open access in transmission in each of the SAARC Member States

d. Communication Protocol framework: Review the existing communication protocol frameworks between the Load Dispatch Centers of the respective Member States for day to day scheduling and information sharing

Based on the above review, identify the provisions in each of the Grid Codes and operating procedures that have an impact on optimal, reliable and economic operation of cross border electricity trade across the SAARC Member States. The outcome of the study would focus on recommendations for harmonizing the grid codes of the Member States, wherever required, to accommodate Regional Power Interconnections.

2.2 Objectives

The main objectives of undertaking this study are to:

a. Review of the Grid Codes of the respective SAARC Member States covering procedures/ codes/standards such as operating procedures, protection code, metering code, connection code, planning code, system security, demand estimation systems, outage planning, recovery procedures etc.

b. Identify relevant provisions in each of the above documents operating procedures/ Grid codes and standards that have the potential to impact “cross border electricity trade”; and

c. Suggest the way forward with respect to harmonizing the grid codes of the SAARC Member States to facilitate/promote optimal and economic “cross border electricity trade” in the South Asia.

2.3 Methodology

It is an established understanding that technical, regulatory and legal harmonization of Grid Codes of different jurisdictions is a rather long term process. This Study has been undertaken to ultimately evolve Regional Grid Code / Interconnection Code by harmonizing the provisions of the existing Grid Codes of the SAARC Member States. Some of the general recommendations considered for grid harmonization based on the review of best practices across other regional grids are:

a. Grid Code requirements must be comprehensive and transparent in order to avoid misinterpretation.

b. Requirements should be as explicit as possible, and include clear, commonly shared definitions of the terms used for generation, specifically for intermittent renewable energy systems and other equipment.

c. The technical requirements should focus on the essential aspects of technical performance, leaving an opening for ancillary services.

d. Requirements for generating power plants should not be excessive or discriminatory towards any one kind of generation.

e. If possible, a common language and formats/ templates should be adopted for the Cross Border Grid Code. If need be, all TSOs should use similar formats to ensure uniformity in designation, parameterization, definitions, units, diagrams, references to standards and control methodologies.

f. Periodical efforts must be made to provide an opportunity for stakeholders from the energy ecosystem — utilities, manufacturers, regulators and customers — to collaborate and discuss the harmonization of the standards that critically impact, enhance, and accelerate the deployment of a smart regional grid.

Best practices of other regional grids will be studied along with the grids of the SAARC Member States, to identify the most appropriate Grid Code for the SAARC Region.

Best practices of other regional grids will be studied along with the grids of the SAARC Member States, to identify the most appropriate Grid Code for SAARC Region. It must be highlighted, that while standards certainly contribute to the facilitation of interoperability, the standards, themselves rarely, cover all levels of agreement and configuration required in practice, and compliance with a standard does not absolutely guarantee interoperability. Additional tests and certifications may be necessary to guarantee interoperability.

3.0 Introduction

Electric grid interconnections are pivotal for the development of electric power systems. Most of the interconnected power systems that exist today began as isolated systems, often with a single generator feeding selected pockets in the urban areas. As power systems expanded out from their urban cores, interconnections among neighboring systems became increasingly common. Groups of utilities began to form power pools, allowing them to trade electricity and share capacity reserves. The first such power pool was formed in 1925 at the Connecticut Valley in the United States. As transmission technologies improved, long distance inter-connections developed, sometimes crossing national borders too.

Many interconnections were aimed at exploiting the natural synergy which exists between different systems which were predominantly hydro-based and those which were based on thermal plants. Production from hydro systems varies with rainfall and water inflow sequences, and, therefore, can sometimes be highly variable. Interconnecting with a thermal based system allows the surplus hydro production to be fully utilized and also “firms up” the hydro system capacity in times of drought. Many interconnections in and between the US and Canada, Scandinavian countries, the USSR and Europe were of this nature.

Interconnections are also established where a large energy resource such as hydro or thermal is developed to cater the needs of multiple systems. The transmission lines, meant for evacuating the respective shares of the output power of the particular resource, form interconnections between the systems involved. The Niagara Falls developments in the US and Canada, the Snowy Mountains hydro-electric scheme in Australia and the Kariba hydro-electric scheme on the Zambesi River, linking Zambia and Zimbabwe, Tala project between Bhutan and India are well-known examples of such power interconnections.

In the context of Cross-Border Electricity Trade in South Asian region, it would be appropriate to highlight the examples of some of the well-known cross-border interconnections in the world.

3.1 Existing Cross Border Grid Interconnections

In a bid to set the perspective in terms of the best practices pertaining to regulatory instruments for cross border grid interconnections, features of European grid interconnection are provided in this section as case study.

3.1.1 European Interconnection

The first cross-border interconnection in Europe was established in 1906, when Switzerland built transmission links to France and Italy. It is reported that in 1920s, electricity was transmitted from Nancy, France via Switzerland to Milan in Italy covering a distance of 700 km. Subsequently after World War II, the Union for the Co-ordination of Production and Transmission of Electricity (UCPTE) was formed in 1951 to unveil the interconnection among its eight founder member countries Belgium, Federal Republic of Germany, France, Italy, Luxemburg, Netherlands, Austria and Switzerland [1]. The focus of these members was to extend their network substantially towards east and to the west through the grid of Greece, Yugoslavia, Portugal and Spain later on. The main objective of UCPTE was to optimize on the generation resources by preventing loss of surplus generation thereby allowing savings on coal consumption. Other countries of continental Europe soon followed and a wide-area synchronous grid was represented by UCPTE. British grid is asynchronously connected with the grid of continental Europe. With the restructuring and unbundling of services, the UCPTE has transformed into the transmission grid only approach and consequently changed its name to UCTE dropping production/generation function by 1999. The UCPTE was characterized by tasks which it had to perform in relation to operational activities and was supplemented by the following economic aspects:

a. Exemption of the exchange of electricity from customs and foreign exchange control
b. Introduction of a uniform method of control (load-frequency control, network characteristic method)
c. Definition of tariff periods and exchange intervals / program structuring
d. Recording and settlement of the exchange of electricity
e. Improvement of the exchange of information
f. Coordination of measures in the event of major failures
g. Coordination with regard to observing synchronous time
h. Coordination of protection of the grid

In May 2001, the "new" UCTE was established as an association of Transmission System Operators (TSOs). With increasing focus on renewables and energy efficiency, the TSOs association embarked on an intensified cooperative commitment which has given a legal foundation through establishment of new Pan-European body ENTSO-E (European Network of TSOs for Electricity) in 2008. In order to ensure reliable and efficient operation of TSOs, the following activities were envisaged:

a. Management of all operational issues (including those related to frequency control, scheduling and accounting, and coordination services);
b. Regional Technical Network Codes for the different Synchronous Areas;
c. Implementation of codes and the procedures in the event of infringements (Multilateral Agreement);
d. Compliance monitoring for the Regional Technical Network Codes;
e. Interoperability assessments (DC links, underground and submarine cables, integration of renewable energy sources and requested extensions of the synchronous system) within the framework of the ENTSO-E System Development Committee.

As of 2014, 16 countries accounting for three-quarters of Europe's power consumption completed the adoption of a common system for cross-border trading for setting wholesale electricity prices and the European Commission's (EC) vision is for this common system to absorb more markets until it covers all of Europe's cross-border trading. However, some countries concerned about the efficiency and safety of the system are holding out for upgrades that take better account of the physics of the transmission grid. Integrating the world's largest synchronized power grid has been made possible because of a sophisticated optimization algorithm for Europe's day-ahead power markets - the Pan-European hybrid electricity market Integration algorithm. This algorithm crunches every buy and sell bid submitted to the participating national and regional power markets. It simultaneously allocates rights to trans-border transmission and sets the power prices for each market, outputting a selection of trades for the following day. In cases, where there are price differentials in neighboring markets, the process is designed to make sure there's full use of the transmission paths between them. EC's vision is to manage trading across the system's real transmission constraints rather than the geographical borders between the member countries. Short analysis of the critical regulations under the domain of network codes [2] and cross border interconnections being followed in Europe is given below:

Planning Guidelines

The Transmission System Operator (TSO) is responsible for all transmission related activities. Planning scenarios are defined to represent future developments of the energy system. The essence of scenario analysis is to come up with plausible pictures of the future. Scenarios are means to approach the uncertainties and the interaction between these uncertainties. Planning scenarios are a coherent, comprehensive and internally consistent description of a plausible future characterized by:

a. Several time horizons
b. Technical Parameters
c. Economic parameters
d. Generation portfolio
e. Demand Forecast
f. Exchange Patterns

As it can take up to ten years to build new transmission infrastructure, the objective is to construct scenarios that look beyond the coming ten years. However, when looking so far ahead, it becomes increasingly difficult to remain accurate. Thus, the objective of these scenarios is to construct contrasting future developments that differ enough from each other to capture a realistic range of possible future pathways that could challenge the grid.

Horizons which do not have separate data sets are described through interpolation techniques. The output of market analysis is used as an input for load flow analysis to choose the most representative planning cases to be studied. The transmission adequacy is measured and the required reinforcement projects are identified for supporting the power flow patterns. It is important to keep the number of cases that are fully calculated as a limited case set.

System planning studies are often based on deterministic analysis, in which several representative planning cases are taken into account. Additionally, studies based on a probabilistic approach may be carried out. This approach aims to assess the likelihood of risks of grid operation throughout the year and to determine the uncertainties that characterize it. The objective is to cover many transmission system states throughout the year by creating multiple cases depending on the variation of uncertain variables. The values to be considered for each of the variables and estimation of the probability of occurrence are considered.

Planning Criteria

All TSOs are obligated to serve under an 'N-1' principle which is developed with the goal of preventing propagation of an incident. Each TSO is expected to continuously monitor and warn neighbors of any risks foreseen within the system. Awareness of impact of any domestic decision on the neighbors and bi/multilateral coordination before any such operation is also made mandatory. Best efforts are required to set up remedial actions, even if the actions of a single TSO is insufficient. Risk assessment and coordination is the major requirement of this principle.

Considering the operation of a power system from the point of view of risk management implies the definition of a risk level that should be respected for any kind of events. This risk level is assessed by a reference value of the product "Event probability x Expected loss". The greater the probability of an event occurrence, the lower should be the accepted loss. The loss may be defined either by a financial loss or more commonly for a power system in terms of a potential power cut or energy loss.

System Modeling Details

TSOs of interconnected systems are obliged to monitor the N-1 principle not only for their own grid but also for the tie lines to neighboring grids. This is called the responsibility area of the TSO. Due to the increase of interconnections among TSOs, the assessment of security is more and more interdependent. This mandates the TSO to take into account the influence of the surrounding grid on its responsibility area. Each TSO periodically analyses, by numerical calculations, the external transmission network with influence on its responsibility area. An external contingency list is prepared that includes all the elements of surrounding areas that have an influence on its responsibility area higher than a certain value, called the contingency influence threshold. Each TSO has to take into account the elements of this external contingency list in its contingency analysis.

It is necessary to model the external grid wide enough to guarantee accurate estimations in the responsibility area, when performing the N-1 analysis of the elements of the external contingency list. That means that not only the branches of the external contingency list have to be modeled but other surrounding branches, with lower influence on the responsibility area, have to be part of the model. This will ensure correct simulations of the effects of external outages. All the external elements with an influence on the responsibility area higher than a certain value, called the observability influence threshold, constitute the external observability list.

Based on this area, all TSOs establish an individual grid model on year-ahead basis and update it on week-ahead basis or more frequently, as required. Apart from the system topology modeled down to 132 kV, the individual grid model includes the thermal limits, voltage limits, stability limits and fault current thresholds. The European Merging Function merges these individual grid models to establish a common grid model for monitoring the system.

Generation and Load Modeling Requirements

Large scale wind farms or other large MW-scale distributed generation plants connected to the transmission system are to be modeled in detail like any other large generating plant in the system. However, because of its low load factor, supply to any part of the transmission system should not depend on wind generation.

A pre-arranged complete shutdown of a generation station or part of it during a suitably chosen low-load period may be tolerated, when necessary. During such a shutdown, relevant planned maintenance or other scheduled voluntary outages of generation and/or transmission equipment elsewhere is assumed to be minimal.

All tests shall be carried out on current energy and peak demand forecasts. The performance of the planned system should meet all planning security limits at peak and other load levels. Planning of the system shall be carried out on the basis of normal distribution feeding arrangements.

Permissible Normal and Emergency Limits

Steady State Criteria

a. Cascade tripping: A single contingency must not result in any cascade tripping that may lead to a serious interruption of supply within a wide-spread area.

b. Maximum permissible thermal load: The base case and the case of failure must not result in an excess of the permitted rating of the network equipment. Taking into account duration, short term overload capability can be considered, but only assuming that the overloads can be eliminated by operational countermeasures within the defined time interval, and do not cause a threat to safe operation.

c. Maximum and minimum voltage levels: The base case and the case of failure shall not result in a voltage collapse, nor in a permanent shortfall of the minimum voltage level of the transmission grid, which are needed to ensure acceptable voltage levels in the sub-transmission grid. The base case and the case of failure shall not result in excess of the maximum admissible voltage level of the transmission grids defined by equipment ratings and national regulation, taking into account duration.

Maximum Loss of Load or Generation should not exceed the active power frequency response available for each synchronous area.

Short Circuit Criteria: The rating of equipment shall not be exceeded to be able to withstand both the initial symmetrical and single-phase short-circuit current (e.g. the make rating) when energizing on to a fault and the short circuit current at the point of arc extinction (e.g. the break rating). Minimum short-circuit currents must be assessed in particular in bus-bars where an HVDC installation is connected in order to check that it works properly.

Voltage Collapse Criteria: The reactive power output of generators and compensation equipment in the area should not exceed their continuous rating, taking into account transformer tap ranges. In addition, the generator terminal voltage shall not exceed its admissible range.

Stability Criteria: Taking into account the definitions and classifications of stability phenomena, the objective of stability analysis is to ensure the rotor angle stability, frequency stability and voltage stability in case of listed contingencies i.e. incidents which are specifically foreseen in the planning and operation of the system.

a. Transient stability: Any 3-phase short circuits successfully cleared shall not result in the loss of the rotor angle stability and the disconnection of the generation unit (unless the protection scheme requires the disconnection of a generation unit from the grid).

b. Small Disturbance Angle Stability: Possible phase swinging and power oscillations (e.g. triggered by switching operation) in the transmission grid shall not result in poorly damped or even un-damped power oscillations.

c. Voltage security: Ordinary contingencies (including loss of reactive power in-feed) must not lead to violation of the admissible voltage range that is specified by the respective TSO (generally 0.95 p.u. – 1.05 p.u.)

Remedial Actions

The goal of remedial actions is to fully respect the N-1 principle taking into account inter-TSOs coordination. After a normal or exceptional type of contingency, the situation should be without constraints after implementation of remedial actions when needed. In any case, cascading effects across borders must be prevented by remedial actions. Preventive (before occurrence of the contingency) and curative (after occurrence) remedial actions are due to be prepared in operational planning stage and to be duly applied in real time. These remedial actions (preventive/curative) have to be previously assessed by numerical simulations in order to evaluate the influence of those measures on the constraints and also to prevent negative effects to neighboring TSOs. Remedial actions are defined for the two reference grid constraints related to Power flows and Voltage.

Remedial actions for power flow constraints:

a. Network reconfiguration

b. Use of phase shifter transformers

c. Cancellation of maintenance

d. Changes in the pattern of reactive power flow
e. Automatic unit tripping triggered by line outage
f. Deployment of tertiary reserves
g. Contracted generation re-dispatch within the TSO's own control area
h. Cross-border re-dispatching with neighboring TSOs
i. Counter-trading with neighboring control areas
j. Intervention in scheduling
k. Reduction of interconnection capacities
l. Start-up of tertiary reserve
m. Pump tripping
n. Manual load shedding of interruptible loads (customers)
o. Automatic shedding of interruptible customers triggered by line outages.
p. Automatic or manual load shedding of loads

Remedial Actions for Voltage Constraints

a. Requesting maximum or minimum values of generation for active and reactive power
b. Manual tap changing of 400/-- & 220/-- kV transformers
c. Adjusting of power flows
d. Switching on/off shunt reactors or capacitors
e. Preventive start of units with provision of additional reactive power
f. Line opening in case of high voltage conditions (off-peak periods)
g. Stop of voltage and reactive power optimization
h. Stop of maintenance, switching-on of all elements previously in maintenance
i. Limitation of intraday trade (influence on transits)
j. Blocking of OLTC (On Load Tap Changers) of transformers
k. Changes of voltage regulator set points on transformers at distribution level
l. Manual load shedding of interruptible loads (customers)
m. Automatic or manual load shedding

Connection Guidelines (Cross Border Grid Interconnections)

The connection code is applicable to all grid users (power generating modules, demand facility owner or distribution network operator) who are already connected as well as those seeking new/modified connection. This network code shall not apply to the small isolated systems and in the micro isolated systems.

Procedure for Connection

A grid user who is willing to take new connection shall demonstrate and submit sufficient evidence to the relevant network operator. The relevant network operator shall confirm the user connection as per procedures mentioned in the network code, with the approval of National Regulatory Authority. If the user intends to modify the technical capabilities of the existing connection then he shall notify the relevant network operator.

Connection Agreement

The connection agreement is signed between the relevant network operator and the user (i.e. the power generating facility owner or the demand facility owner or the distribution network operator). The agreement includes relevant site and technical specifications for the Power Generating Facility or distribution network connection, like maximum import and export capabilities etc.

Reactive Power Requirements

a. User shall be capable to maintain their steady state operation at their connection point within a reactive power range specified by the relevant TSO and as per the agreement; the relevant TSO and relevant network operator will determine the optimal solution for reactive power exchange.

b. For transmission connected demand facilities without onsite generation, the actual reactive power range specified by the relevant TSO for importing reactive power shall not be wider than 0.9 to 1 Power Factor of their maximum import capability. [$0 < Q_{import} < 0.48\ Pmax_{import}$]

c. For the Transmission connected demand facilities/distribution networks with onsite generation, the actual Reactive Power range specified by the Relevant TSO shall not be wider than 0.9 Power Factor of the larger of their maximum import capability or maximum export capability in import to 0.9 Power Factor of their maximum export capability in export. [$0 < Q_{import} < 0.48 Pmax_{import}$; $Q_{export} < 0.48\ Pmax_{export}$]

d. Transmission Connected Distribution Networks shall have the capability at the connection point to not export reactive power (at nominal Voltage) at an Active Power flow of less than 25% of the Maximum Import Capability.

Frequency

The normal operating frequency for Europe is 50 Hz. Permissible frequency deviation at the connection point is 49 Hz to 51 Hz. However, wider frequency ranges or longer minimum frequency recover times for operation can be agreed between the user and network operator in coordination with the relevant TSO.

Voltage

Wide range of operating voltage is agreed between the user and system operator at the connection point; any user with a connection point at 110 kV or above shall ensure its equipment is capable of withstanding without damage the defined voltage range, at the connection point. The establishment of the reference nominal voltage shall be subject to coordination between the adjacent TSOs.

Short Circuit Requirements

a. The relevant TSO shall deliver to the user an estimate of the minimum and maximum short circuit currents at the connection point as an equivalent of the Network.

b. As soon as possible (less than a week), the relevant TSO shall inform the user of an unplanned / planned event, of the changes above a threshold in the maximum short circuit current that it shall be able to withstand from its network and vice versa.

Protection and Control

With regard to electrical protection schemes and settings:

The relevant Network Operator shall define the schemes and settings necessary to protect the network taking into account the characteristics of the Power Generating Module and Transmission connected distribution network.

With regard to control schemes and settings:

a. Schemes and settings for the different control devices of the transmission connected distribution network or Transmission connected demand facility, relevant for system security, shall be agreed by the relevant TSO, and the user. This agreement shall cover the following aspects:

    - isolated (Network) operation;
    - damping of oscillations;
    - disturbances to the Network;
    - automatic switching to emergency supply and come-back to normal topology; and
    - Automatic circuit-breaker re-closure (on 1-phase faults)

b. Any changes to the schemes and settings of the different control devices of the transmission connected system relevant for system security shall be agreed between the Relevant TSO, and the user.

With regard to priority ranking of protection and control:

The user shall organize the protection and control devices of its transmission connected system respectively.

Simulation Model

The relevant Network Operator in coordination with the relevant TSO shall have the right to request the user (Power Generator or Transmission connected distribution network) to provide simulation models, that shall properly reflect the behavior of the user in both steady-state and dynamic simulations (50 Hz component) and, where appropriate and justified, in electromagnetic transient simulations at the connection point and the provision of documentation of models structure and block diagrams.

Information Exchange

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

Safety

Users shall be responsible for the safety of the personnel in accordance with the network code.

Schedule of Assets of Regional Grid for Outage Planning

Relevant TSO/ relevant DSO/ Closed DSO is a person responsible for operating, ensuring the maintenance of and, if necessary, developing the Transmission system / distribution Network in a given area and, where applicable, its interconnections with other networks and for ensuring the long-term ability of the Network to meet reasonable demands for the distribution of electricity.

Connectivity Standards Applicable to Wind and other Generating Stations Using Inverters

The standard for characterizing the power quality of wind turbines and for the measurement of the related quantities is IEC 61400-21 [2008]. The relevant parameters are active and reactive power, including maximum value, voltage fluctuations (flicker), number of switching operations (and resulting voltage variations), harmonic currents and related quantities.

Operation Guidelines

Operating States

To analyze the security of a power system during operation, it is helpful to classify the operating conditions into five states: normal, alert, emergency, blackout (extreme emergency) and restoration.

In the normal state, all system variables are within the normal range and no equipment is being overloaded. The system operates in a secure manner and is able to withstand a contingency without violating any constraints.

If the security level falls below a certain limit of adequacy or if a possibility of disturbance increases due to any external factor, the system enters alert state. In this state, all system variables remain within acceptable limit and all constraints are still satisfied. However, the system has weakened to a level where a contingency may push the system to emergency state. If the disturbance is very severe, the system could directly fall to blackout state. Preventive action can be taken to restore system to normal state.

The system enters emergency state if a severe disturbance occurs during an alert state. Here, the voltages at many buses are low and/or equipment loadings exceed short-term emergency ratings. The system still remains intact and can be restored to alert state by initiating emergency control actions.

If the above actions are not applied or are ineffective, the system results in cascading outages and possibly a shutdown of a major portion of the system i.e. blackout. Control actions like load shedding are taken up to save as much of the system as possible from a widespread blackout.

The restoration state represents a condition in which control actions are being taken to reconnect all the facilities and to restore the system load. The system may transit from this state to alert or normal state, depending on the system conditions.

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

a. Normal State
b. Alert State
c. Emergency State
d. Black Out State
e. Restoration

The determination of the system operation state must be done at least every 15 minutes by performing contingency analysis in real time, monitoring the parameters against pre-set criteria, considering remedial actions and measures of system defense plan. A remedial action is a measure applied by a TSO or several TSOs, manually or automatically, in order to maintain operational security. A system defense plan is a summary of all technical and organizational measures to be undertaken to prevent the propagation or deterioration of an incident in the transmission system, in order to avoid a widespread disturbance and blackout state.

The following tools and facilities are required to monitor the operating state of the system:

a. Facilities to monitor and estimate the state of the system
b. Means of controlling switch
c. Means of interconnection among TSOs
d. Tools for operational security analysis

Additional measures to monitor and maintain system security during operational phase are:

a. TSOs define their reactive power limits and ensure sufficient reactive power reserves.
b. TSOs operate within their maximum allowable short circuit current (predefined considering circuit breaker ratings) and their minimum allowable short circuit current

(predefined considering minimum currents required for operating relay). A deviation is tolerated only during switching.

c. The permanent and temporary allowable transmission line limits have to be maintained within the operational security limits during normal state as well as post contingency for a contingency defined in the contingency list.

d. During operation phase, whenever the system operational parameters indicate the occurrence of contingencies, the pre-set remedial measures are applied. This N-1 stage is considered as the new Ñ stage and its Ñ-1 security is assessed by performing necessary studies. To be able to perform this N-1 security assessment in real time, most of the simulations are automated. If the system does not seem secure, necessary preventive remedial actions are applied As Soon As Possible (ASAP). This ASAP restoration is carried out within a defined ASAP duration. The definition of this duration is critical because if a second contingency occurs during this duration, system can go to emergency state. During this period, neighboring TSOs which may get impacted are kept informed.

e. TSOs monitor the dynamic state of the system in terms of frequency, voltage and rotor angle stability by means of wide area measurements to identify stability limits and potential threats. Rules are defined to decide when dynamic stability analysis needs to be performed in real time. They must ensure that the fault clearing times are maintained under the critical clearing time, especially for faults having wide area stability impact.

f. If the studies indicate the need to maintain a minimal inertia within an area for system stability, it is maintained by the TSO.

Requirement for Generators

As per the European Grid Code, the power generating modules are categorized as follows:

Type A - If the connection point is below 110 kV and its maximum capacity is 0.8 MW or more. They have limited automated response and minimal system operator control of generation. They ensure there is no wide scale loss of generation over system operational ranges

Type B - If its connection point is below 110 kV and its Maximum Capacity is at or above a threshold defined by each relevant TSO. They provide a wider level of automated dynamic response with higher resilience to more specific operational events to ensure use of this higher dynamic response and a higher level system operator control and information to utilize these capabilities. They ensure automated response to alleviate and maximize dynamic generation response to system events, greater power generating module resilience of these events to ensure this dynamic response and better communication and control to leverage these capabilities.

Type C - If the connection point is below 110 kV and its maximum capacity is at or above a threshold defined by each relevant TSO. They provide refined, stable and highly controllable (real time) dynamic response to provide principle ancillary services to ensure security of supply. These requirements cover all operational network states with consequential detailed specification of interactions of requirements, functions, control and information to utilize these capabilities. They ensure real time system response necessary to avoid, manage and respond to system events. These requirements provide sufficient generation functionality to respond to both intact and system disturbed situations, and the need for information and control necessary to utilize this generation over this diversity of situations.

Type D - If the connection point is at 110 kV or above, A synchronous power generating module or power park module may also be Type D if its connection point is below 110 kV and its maximum capacity is at or above a threshold defined by each relevant TSO (not to be above the threshold). They ensure stable operation of interconnected network, allowing use of ancillary services from generations Europe wide.

Generation Reserves

The European TSOs have the option to access reserve capacity connected to another LFC Area, LFC Block, or 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.

Frequency containment reserves (FCR) are primary reserves necessary for constant containment of frequency deviations (fluctuations) from nominal value in order to constantly maintain the power balance in the whole synchronously interconnected system. This category typically includes operating reserves with the activation time up to 30 seconds. Operating reserves of this category are usually activated automatically and locally.

The objective of primary control is to maintain a balance between generation and demand within the synchronous area. This control action is used after a disturbance or incident to only stabilize the frequency at a stationary value, in the time-frame of seconds, and not to restore the frequency and the power exchanges back to its reference values. This control is triggered before the frequency deviation exceeds ±20 mHz.

Frequency restoration reserves (FRR) are secondary reserves necessary to restore frequency to the nominal value after sudden system disturbance occurrence and consequently replace FCR if the frequency deviation lasts longer than 30 seconds. This category includes operating reserves with an activation time typically between 30 seconds up to 15 minutes. Operating reserves of this category are typically activated centrally and can be activated automatically or manually.

The objective of secondary control is to maintain a balance between generation and demand within each control area / block as well as the system frequency within the Synchronous area in the time-frame of seconds up to typically 15 minutes after an incident. Secondary control makes use of a centralized and continuous automatic generation control and is based on secondary control reserves that are under automatic control.

After 30 seconds at the latest, the secondary controller must initiate corrective control actions and must correct the Area Control Error as quickly as possible, within 15 minutes at the latest.

Replacement reserves are tertiary reserves necessary to restore the required level of operating reserves in the categories of FCR and FRR reserves due to their earlier usage. This category includes operating reserves with activation time from several minutes up to hours.

The operational control actions are performed in following successive steps, each with different characteristics and qualities, and all depending on each other.

Tertiary control uses tertiary reserve that is activated manually or scheduled to activate periodically by the TSOs in case of observed or expected sustained activation of secondary control. It is primarily used to free up the secondary reserves in a balanced system situation, but it is also activated as a supplement to secondary reserve after larger incidents to restore the system frequency and consequently free the system wide activated primary reserve.

Special Requirements for Wind and **Solar Generators**

The European Grid Code states that Wind and Solar generators must not be considered for power exchange calculations and transfer capacity.

Short Term Demand Estimation

All TSOs should perform annual summer and winter generation adequacy assessments before May 21st and November 21st respectively, by forecasting the weekly peak demand for each period of study for both normal and severe conditions. This is used in generation adequacy assessment which deals with the ability of a power system to supply its demand in all the steady states that it may face. Due to the larger fluctuations in generation, demand, and cross border flows, it becomes more and more important to accurately assess and forecast adequacy.

Operational Liaison

Operational Liaison of European Grid Code defines the provisions for quick exchange of information between significant grid users regarding past/current/foreseen events which impact the grid or the users.

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

The data could be exchanged between a network operator (TSO/DSO/CDSO) and any Significant grid users which include owners of:

a. Existing and New Power Generating Modules of type B, C and D;

b. Existing and New Transmission Connected Demand Facilities and all Existing and New Transmission Connected Closed Distribution Networks;

c. Significant Demand Facilities, Closed Distribution Networks and Aggregators, in case they provide Demand Side Response directly to the TSO; and

d. Re-dispatching Aggregators and Providers of Active Power Reserve

An aggregator is a legal entity which is responsible for the operation of a number of Demand Facilities by means of Demand Aggregation

The data is categorized under the following classifications:

a. Structural Data;

b. Scheduled Data;

c. Forecasting Data;

d. Real-time Data; and

e. Individual instructions by TSOs or DSOs

The common proposal for data exchange should 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.

Load Shedding Schemes

Frequency thresholds are defined for load shedding by each TSO. The UCTE recommends that the frequency threshold should not be set lower than 49 Hz. Load shedding should be established in stages to minimize the risk of further uncontrolled separation, loss of generation, or system shutdown.

In case of a frequency drop to 49 Hz the automatic load shedding begins with a minimum of 10 to 20% of the load. Each TSO determines shedding plans on its own. In case of lower system frequencies, load shedding should be performed to the amount of about 10 to 15% of the load. The partners accept load shedding even if the failure occurs outside its area.

When frequency drops, the synchronously interconnected network may get divided into partial networks due to isolation of plants. This could lead to more difficult conditions in those partial networks affected by a shortfall in capacity. For this reason, the staggered operation of relays for load shedding in response to a frequency criterion reduces the load to a sufficient extent for the restoration of balanced conditions in these partial networks, before the threshold for the isolation of plants for the supply of auxiliaries or the tripping of generators is reached.

Outage Coordination

The process of outage coordination of the elements in an interconnected electricity network plays an important role in the operational management of that network. In order to keep the network in a secure operating condition to guarantee a suitable level of security and market access, it is necessary to regularly carry out maintenance work which requires outages of assets. Furthermore, outages are also indispensable for carrying out reinforcement work in substations or to install new network elements.

The outages of interconnecting lines or network elements in the vicinity of these lines directly impact transfer capacity values and possibly reduce the import and export potential between connected areas as well as the potential of mutual support, and consequently have to be planned/prepared carefully in order to prevent lowering the network security in those areas.

The outages of such lines may also affect the security of areas that are in close vicinity of the outage.

Outage coordination process is an iterative process that starts in the second half of the preceding year and finishes on the day preceding actual operation (day-ahead). An outage coordination region is formed by grouping responsibility areas based on the extent of interconnection, for an efficient coordination. The set of power system assets which influence two or more TSOs while being out of operation are identified as relevant assets. Of these, which are considered to have a major influence on the operational management of the neighboring systems are identified as critical assets. The outage coordination planning takes all relevant assets into account. For every Relevant Grid Element, the Outage Coordinating TSO operating it shall be appointed as its Outage Planning Agent. The planning is split into three time horizons, namely the long term (previous year end), the medium term (monthly reassessment) and the short term planning (week ahead). In order to coordinate possible congestions and other matters, a weekly teleconference call is organized to share operational information.

The coordination process is reassessed whenever a TSO identifies incompatibilities, involving all affected TSOs, until no incompatibility remains. TSOs perform joint studies on the impact of planned outages to relief these outage incompatibilities. TSOs in the same regional group continuously update a common set of data with information on the relevant assets considered, the critical assets agreed and the joint plan of outages for the rest of the year.

Each Outage Coordinating TSO establishes and manages a coordination process to ensure the available/unavailable status of relevant assets in its responsibility area in case of forced outages and when operational security is endangered. This process ensures minimum possible violations of technical limits. During forced outage, the Outage Planning Agent must inform outage coordinating TSO and other affected parties of the cause, duration and possibly the impact of the outage. In case operational security threat is felt, the outage coordinating TSO gives the maximum tolerance time to the agent and the agent must try to respect this time.

During real time execution, the TSO must ensure that all available elements participate while all unavailable elements do not participate in the network. Before switching an element to unavailable state, all necessary conditions must be fulfilled.

Recovery Procedures

Each TSO has to prepare in advance and update regularly a restoration plan. TSOs have to know the status of components of their power system after a blackout before starting the restoration process. This process must be started only after the grid reaches a stabilized situation.

A frequency leader (for coordination of frequency management within a synchronous area) and a resynchronization leader (in charge of coordinating frequency leaders during the resynchronization process of two neighboring areas) are identified. During the reenergizing processes, following considerations are taken into account:

a. Each TSO has to develop proper re-energization procedures, at least by simulation or offline calculations.

b. Each TSO has to evaluate the number of units capable of black start and islanded operation to contribute to the restoration and to get knowledge of units in house load operation.

c. TSOs have to know the status of any component of their power system after a blackout.

d. The re-energization process is initiated by one of the following 2 processes:

  - Top-down approach - the grid shall be reenergized step by step starting from tie lines in cooperation with neighboring TSO.
  - Bottom-up approach - TSOs manage the restoration of the system with the black start capabilities and/or with the units in house load operation. These units provide the capability of controlling voltage and speed/frequency during supplied isolated operation and stable operation in an islanded network

e. During re-energization, the relevant frequency leader's load frequency secondary control is switched to frequency control mode while the other load frequency secondary controllers remain in frozen control state.

f. The consumption and production are balanced by the resynchronization leader with the aim of returning near to 50 Hz, with a maximum tolerance of ±200 mHz, under the coordination of the area's frequency leader. The TSO shall reenergize the shed load when system frequency is not below 49.8 Hz, keeping a generation margin sufficient at least to cope with the next block of load to reenergize. The process of reenergizing customers should be done stepwise in block loads of maximum size defined by the TSO with respect to the load of the TSO's grid.

g. The TSO has to coordinate the reconnection of generators tripped due to abnormal frequency excursion.

h. The resynchronization leader of the concerned areas and in collaboration with the two frequency leaders of their respective areas will apply the required actions in order to operate the resynchronization under the following criteria:

  - Both systems must be in a stable state and both frequencies must be near to 50 Hz to resynchronize as securely as possible.
  - Use of 380 - 400 kV line(s) of high loadability.
  - Make provisions for closing immediately a second line that is electrically close to the first line.

- To choose, by preference, a line for synchronization not in the vicinity of large thermal units in operation.
- The re-synchronization leader gives orders to frequency leaders for actions in the proper direction to minimize the frequency and voltage deviation between both areas just at the time of re-synchronization.

Event Information for System Recovery

Each TSO shall provide the following information in due time for the purposes of System Defence Plan procedures and Restoration Plan procedures:

a. To neighboring TSOs

    - The extent and borders of the Synchronized Region or Synchronized Regions to which its Responsibility Area belongs;
    - Restrictions to operate Synchronized Region;
    - Active and Reactive Power limits at Interconnectors; and
    - Other technical or organizational restrictions

a. To the Frequency Leader

    - Restrictions to maintain Island Operation;
    - The available additional load and generation; and
    - The availability of Operational Reserves

a. To Transmission Connected DSOs

    - The System State of its Transmission System;
    - Limits of Active and Reactive Power, Block Loading, tap and circuit breaker position at the connection points;
    - Information on the current and planned status of Power Generating Modules connected to the DSO; and
    - All necessary information leading to further coordination with distribution connected parties

a. To DSOs, Significant Grid Users, Defence Service Providers and Restoration Service Providers

    - The System State of its Transmission System;
    - Scheduled measures which require participation of Defence Service Providers; and
    - Ability and plans to re-energize couplings;

Each TSO, DSO, Significant Grid User and Restoration Service Provider shall have at least one redundant voice communication system to exchange the necessary information for

Restoration Plan, which shall have backup power supply for at least 24 hours and shall be prioritized.

Schedule & Dispatch Guidelines

Scheduling and Dispatch Procedure

Each Market Participant and Market Coupling Operator, to which requirements for scheduling apply, shall appoint a Scheduling Agent. For regions with central dispatching of generation, the operator responsible for of the central dispatching of generation shall appoint or act as a Scheduling Agent and establish the provisions necessary to produce Schedules. The agents are responsible for the transmission of their cross border schedule nominations to the responsible control area operator.

Data exchanged for matching purposes between control areas, termed as Control Area Schedule (CAS), documents the cross border exchange per registered market party nominating schedules for a defined process (Day Ahead, Intra Day etc.) and border. The Control Area Exchange (CAX) data, transmitted from the control area (CA) to its control block (CB), enables the matching between control blocks. The CAX is made up of the matched values of the CAS but must contain only the aggregated and netted values of all nominations per control area border, thereby containing only the total bilateral exchange per border and includes the compensation program for unintentional deviations of the control area.

On a bilateral basis, the Control Block Schedule (CBSb) is exchanged and used for the matching between control blocks. It is assembled out of the aggregated CAX values for every time interval for the common control block border. On a multilateral basis, the control block schedule (CBSm) is transmitted from the control block to the Co-ordination Centre (CC) and enables the matching between the CC's in this case it is assembled out of the matched CAX values at all control block borders and includes the compensation program for unintentional deviations of the control block.

The data exchanged between CC's for matching purposes is termed as the Co-ordination Centre total exchange (CCT). It is assembled out of the values of the related CBSm and contains the exchange programs between control areas located at the coordination center border and the compensation program for unintentional deviations of the co-ordination center.

Scheduling Timeline

The day ahead and intraday scheduling timelines are shown as follows:

Day Ahead		Intra Day	
Time	**Deadline**	**Time**	**Deadline**
15:45	CAX from CA to CB	T-45 min	Market Schedule Gate Closure Time
16:00	CBSb among affected CBs	T-40 min	CAS among affected CAs

Day Ahead		Intra Day	
Time	**Deadline**	**Time**	**Deadline**
16:15	Matching at CB level	T-32 min	Matching at CA level
16:30	CBSm from CB to CC	T-29 min	CAX from CA to CB
16:45	CCT among affected CC	T-26 min	CBSb among affected CBs
17:00	Matching at CC level	T-24 min	Matching at CB level
17:05	Confirmation from CC to affected CB	T-21 min	CBSm from CB to CC
17:10	Confirmation from CB to affected CA	T-18 min	CCT among affected CC
17:15	CA regards the confirmation	T-16 min	Matching at CC level
		T-13 min	Confirmation from CC to affected CB
		T-10 min	Confirmation from CB to affected CA
		T-05 min	Begin ramping
		T-00 min	Execute Schedule

Congestion Management

The responsibility for the process of capacity determination and allocation of transmission rights is carried out by the TSO. TSOs implement countertrade primarily as a preventive measure, normally at a day-ahead time horizon. During the day of operation, TSOs initiate re-dispatch primarily as a curative measure. Countertrade means TSO-initiated trade between two adjacent price areas relieving the congestion caused by trade between these two areas with an amount equal to the countertraded quantity. Re-dispatch is a countermeasure where the TSOs change the generation and/or load pattern to redistribute the physical flows in the grid. The TSOs choose the participants on the basis of their physical location in the grid to achieve the maximal relieve of the actual congestion. The relief in congestion can exceed the re-dispatched amount, with an increase of the actual cross border electricity exchange.

Regulation (EC) No 1228/2003 of 26 June 2003 on conditions for access to the network for cross-border exchanges in electricity states that Transaction curtailment procedures shall only be used in emergency situations where the transmission system operator must act in an expeditious manner and re-dispatching or countertrading is not possible. Except in cases of "force majeure", market participants who have been allocated capacity shall be compensated for any curtailment.

The existing cross border re-dispatch agreements are mostly based on 'requester pays' principle. Here, the TSO(s) calling for action bear(s) all costs, without being compensated by other TSOs. In some exceptional cases, the costs of remedial actions concerning cross border lines are shared 50:50.

Charges for Losses

ENTSO-E operates the Inter Transmission System Operator Compensation (ITC) mechanism, through the ITC Agreement, and the Agency for the Co-operation of Energy Regulators (ACER) oversees and reports on the implementation. 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. TSOs participating in the mechanism either contribute to the fund, or are compensated, according to their net imports / exports.

3.1.2 Grid Interconnections in American Continent

In North America, the power interconnection started in 1905 with the formation of Great Southern Grid linking seven separate independent networks of North and South Carolina, Georgia and Tennessee. The first power pool for trading of electricity and sharing the capacity reserve was formed in Connecticut Valley in 1925. At present, the North America operates as five interconnected AC systems with High Voltage Direct Current (HVDC) connections between them. A similar long–term plan for market integration is underway in South America with interconnection between several South American Countries including Brazil, Argentina, Chile and Peru.

3.1.3 Grid Interconnections in Africa

The Southern African Power Pool was formed in December 1995 with the signing of Inter-Government MoU by the seven out of 12 Southern African Development Community Members and is the first international power pool in the developing world. The power pool began its operation as a loose pool with formal bilateral contracts only. Each system is expected to provide for its own requirements, including a margin of reserve plant acceptable to the participants. Power flows on the interconnections between the participating systems are controlled to agreed schedules.

3.1.4 Other Systems around the World

Many countries which were former members of Soviet Union are synchronously interconnected to form the widest synchronous grid referred to as IPS/UPS (Integrated Power System/Unified Power System of Russia). Cross- border transmission links have been established between Pakistan-Iran based on bilateral agreements. In Middle East, Gulf countries are interconnected and they share their resources. A new electricity transmission system to connect Kyrgyz Republic, Tajikistan, Pakistan and Afghanistan, called CASA-1000 project is also under way.

3.1.5 Grid Interconnections in South Asia

In South Asia, cross-border links for electricity trade have been established between India-Bhutan, India-Nepal, Bangladesh-India, Pakistan-Iran etc.; many more are in the planning phase. The first major interconnection between Bhutan and India was commissioned in 1984 at 220kV between Chukha (Bhutan)-Birpara (India/ West Bengal). This was followed by 400kV interconnection with two 400kV, double circuit, Tala (Bhutan)–Siliguri (West Bengal) lines. Indo-Nepal Power Exchange began in year 1971 with exchange of about 5 MW of power on the principle of catering to the power needs of isolated local areas on both sides of the border. The power exchange takes place on radial mode through a number of AC interconnections at 11kV, 33kV and 132kV. A 400 kV Muzaffarpur (India)-Dhalkebar (Nepal) double circuit line is under construction and is likely to be completed within the year 2015. The Bangladesh and India interconnection was agreed in 2009 with 500 MW cross border link and commissioned in October 2013. By 2017 end, its capacity is planned to be doubled to 1,000 MW.

The evolution of South Asia or SAARC Grid has begun with the above developments with India being at a central position in the region and already connected with Nepal, Bhutan and Bangladesh. The strengthening of these cross-border interconnections is underway. Interconnection of India with Pakistan and Sri Lanka is on the drawing board. The evolution towards interconnection with Central Asia is also possible since Iran and Afghanistan could be connected to Pakistan and India, and through India to Nepal, Bhutan, Bangladesh and Sri Lanka.

It is noted that, SAARC Grid should not be imagined as something distinct or stand-alone because such a grid would not be able to disperse power into the respective national grids. SAARC grid is the stitching of national grids with strong and multiple cross-border interconnections capable of transferring requisite amount of power across international boundaries. In 2014, SAARC Member States entered into SAARC Framework Agreement for Energy Cooperation (Electricity) [3] aiming to for setting up a SAARC power grid. This agreement provides for unrestricted cross-border trade, commercial negotiation of PPAs, non-discriminatory open access, private sector trading, and participation in power exchanges. With the energy pact in place, all the SAARC Member States have agreed to enable the concerned agencies in their respective countries to develop transmission interconnectivity within the region. The agreement would allow power flow from countries with surplus power to those which are power deficit. The Member States have also agreed to gradually lift barriers, including the customs duty for enhancing the regional connectivity as per the laws and acts of all the member states. Under this scenario, development of 400 kV transmission links between India-Nepal, HVDC link between India-Sri Lanka etc. could be termed as progress towards SAARC Grid.

3.1.6 Benefits Of Cross Border Grid Interconnection

The histories of cross border interconnection were largely aimed at exploiting the natural synergy between the predominantly hydro-based and thermal based plants. The hydro based generation is dependent on the rainfall and the water inflow sequences which are highly variable. The hydro based generation has considerable seasonal variations and exhibits a natural cycle of surplus much of the time and deficient for extended period of time.

Interconnecting with the thermal based system allows the surplus hydro production to be fully utilized and also firms up the hydro capacity in times of draught.

Also, for a given region, availabilities of the different sources of energy and the demand show considerable daily and seasonal variations. The total demand for electric energy in a country depends on factors such as the extent of electrification, industrialization, standard of living, population, climate, energy prices, etc. If total generation is unable to meet either the peak power demand or the total energy demand of a country then it significantly affects the economy of the country. To continue increasing the total generating capacity for matching the ever increasing power demand of a country is a long term process involving large capital investment and is influenced by policies, institutional and regulatory frameworks and political environment in general. Therefore, for a generation deficient country, economically feasible solution to meet the demand in the immediate years is to import power from another country by establishing a cross-border transmission link and agreement. For a generation surplus country, cross-border transmission links and agreements will enable to earn revenues by exporting power and will facilitate tapping of the remaining generation potential. Many cross-border links between US and Canada, Scandinavian countries, the erstwhile USSR and Europe are of this nature.

In addition to significant reduction in power deficit and improvement in the continuity of electric supply as explained above, interconnection of grids has many other significant advantages. The amount of reserve generation capacity that individual countries must hold is reduced by sharing reserve burden with other countries. Synchronous interconnections will increase frequency regulation and hence the band of frequency variation reduces. Mutual assistance during system disturbances improves system reliability. It would also facilitate large scale integration of renewable energy which reduces dependency on fossil fuels and also diversifies energy supply. By interconnecting systems with different load curves and diversity, overall load factor improves and generating capacity is efficiently used.

3.1.7 Feasibility of a Cross Border Interconnection

The feasibility of a cross border interconnection is a function of a large number of critical factors such as the following:

a. Technical feasibility of interconnection
b. Financing availability
c. Economic viability
d. Long-term PPA or agreement on market coupling
e. Acceptability of commercial terms & conditions
f. Satisfactory dispute resolution mechanism
g. Social acceptability
h. Security of transmission corridor

i. Political consensus

j. Feasibility of integrated grid operation

3.1.8 Electricity Grid Codes and other Regulations Governing Electricity Sector

Electric Power System is a large, complex system involving a number of entities executing their respective activities and responsibilities. The power sector institutional setup is also changing from the vertically integrated structure where all the generation, transmission, distribution assets were owned and operated by one or a few government-owned/ heavily regulated companies. A de-regulated structure is emerging with many private generation and distribution entities and a functional electricity market where power, energy, ancillary services etc. are bought and sold.

In such a scenario, for safe and reliable operation of the grid, the generation and distribution licensees, system operators and other participants in system operation should function in proper co-ordination with each other and follow the regulations, standards and procedures established by the concerned agencies. A legal, regulatory and institutional framework is essential to implement and monitor the grid. Generally, the Electricity Act, Electricity Policy and Electricity Grid Code provide such framework. Electricity Act/Legislation is a consolidation of all laws, polices and strategies enacted by the legislature or governing body of a country for regulating the various activities of Generation, Transmission and Distribution of Electricity. It also establishes institutional and legal frameworks for achieving the aims set out in the policies of Electricity Sector. Electricity Policy outlines the goals and activities planned for achieving them by the Ministry concerned with the Electricity Sector.

Grid Code is a technical document containing rules, procedures, guidelines, criteria and responsibilities to be complied by the users, owners and operators of the transmission system. Grid Code also provides basic planning, design criteria and operational rules and responsibilities of all stakeholders of the power system. Grid Code is usually approved by a regulatory body or government in exercise of powers conferred to it under the relevant electricity act/legislation.

In Grid Code, there are many rules and criteria dealing with system operation, generation, transmission, distribution, protection, metering, maintenance, buying and selling power, ancillary services, etc. Electricity Grid Code of a country depends on the past practices of its electricity sector, present hierarchical structure of its electricity sector, energy sources available and various legal, technical and commercial aspects. Many common specifications also appear in Grid Codes. Grid codes are comprehensive documents; its different sections have varying significance to different stakeholders. Some of the rules may be for promoting competitive environment for generators whereas some of the rules may be critical for the operation/maintenance of the generating plant.

3.1.9 Requirement to Harmonize Grid Codes

It is essential that before interconnecting two grid systems, the respective Grid Codes are compared and reviewed to understand the underlying principles of individual systems and then harmonize the relevant rules to suit cross border interconnection and trading. Respective TSOs of a planned regional grid interconnection should first establish a common framework for preparation and implementation of operating guidelines and procedures, maintenance schedules, exchange of data, dispute settlement, power exchanges, electricity market mechanisms, etc. Therefore, harmonization of the Grid Codes is an important pre-requisite for facilitating cross-border power trade.

Harmonization means adjustment of differences and inconsistencies among measurements, methods, procedures, schedules, specifications, or systems to make them uniform or mutually compatible [4]. 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 whereas in case of asynchronous interconnection, the fault on one side is not passed on to the other, so the two sides have to worry less about each other. Nevertheless, the tripping of HVDC terminal would itself constitute a disturbance in terms of loss of load or loss of supply. Irrespective of nature of interconnection, there has to be real-time communication through hotline, data transfer and cooperation between the grid operators. Grid details have to be shared and the two grid operators have to prepare joint emergency response and recovery procedures. Mutual trust between the grid operators is very important. In this direction, article 5 of the SAARC Framework Agreement stipulates, "Member States shall share and update technical data and information on the electricity sector in an agreed template". It may be emphasized that the objective of harmonization is to arrive at a practical working arrangement for secure and reliable grid operation, and it should not be construed as an attempt to impose a uniform Grid Code.

In the SAARC grid, Bangladesh, Bhutan, India and Nepal operate on 400 kV transmission system voltage. In case of Bhutan, 132 kV, 220 kV and 400 kV transmission lines run across the Bhutan-India border. Similarly, in cases of India-Nepal and Bangladesh-India, 400 kV lines run across. However, in case of Pakistan, the standard AC voltage is 500 kV. Hence, it may call for HVDC back to back terminal to be set up to exchange electricity between India and Pakistan. The voltage of the AC lines connecting the HVDC terminal with the AC substations would have to be matched. With this, the two countries would maintain their own voltage standards. The time-line for scheduling cross-border power would have to be coordinated which does not require any change of hardware.

Figure 3.1 depicts national Grid Code with associated sub-codes for smooth cross border electricity trading among the SAARC Member States.

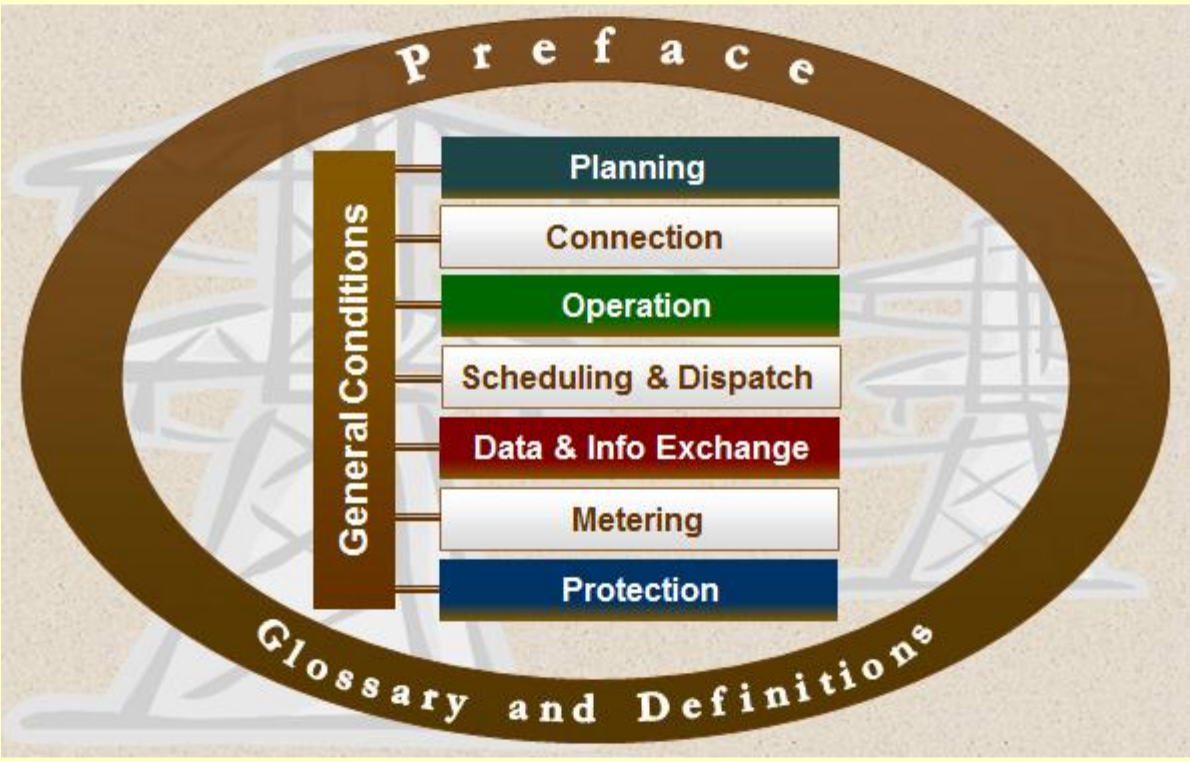

Figure 3.1: Composition of Grid Code

a. Planning Code provides for the supply of information and stipulates the various criteria to be adopted for planning and development studies.

b. Connection Code specifies a minimum of technical, design and operational plant criteria to be complied with by the existing and prospective users for connecting to the grid.

c. Operation Code contains details for high level operational procedures for example demand control, operational planning and data provision.

d. Schedule and Dispatch Code describes the procedures to be adopted for scheduling and dispatch of generation and allocation of power drawl.

e. Metering Code describes the meter placement, compliance of metering hardware according to standards in terms of accuracy levels, accessibility of the meters, maintenance responsibility of meters, etc.

f. Protection code describes the general protection guidelines to be followed for generator, transmission licensees.

3.1.10 Open Access to Electricity Grids in South Asia

Electricity reforms have been carried out in many SAARC Member States to a varying degree. Open access was introduced in India consequent to the legislative mandate of 2003. India is the only country in South Asia to have implemented open access in transmission. The charges as well as access procedures are non-discriminatory. Combined with liberalized generation and transparent scheduling and energy accounting procedures, it enables the functioning of an electricity market. Based on the Indian success story, cross-border electricity trade may be initiated in South Asia. However, there are certain inconsistencies. The trading entities on the other side of Indian border are mainly government entities that have deemed transmission access in their respective countries. In India, the main beneficiaries of open access in inter-state transmission are private sector distribution utilities, generating companies and some large size consumers. Open access in India has facilitated optimization of resources to a significant extent. Open access has helped the Indian States not only to harness cheaper power but also enables them to overcome peaking and energy shortage or vice versa to sell their surplus power. Typical market dynamics of buyer's perspective (i.e. always chase cheaper power irrespective of the States boundaries) has created tremendous pressure on the inter-state and inter-regional transmission links.

Like India, cross-border links between SAARC Member States, will optimize the resources on regional scale. However, to happen this, it is important to harmonize respective grid codes and allow regional electricity market to evolve.

3.1.11 Prevailing Electricity Trade between SAARC Member States

The cross border electricity trading between India, Bangladesh, Bhutan and Nepal for the 2014-15 is presented in Table 3.1.

Table 3.1: Cross-border Electricity Trade between India, Bangladesh, Bhutan and Nepal for 2014-15 [5]

Month	From Bhutan to India		From India to Nepal		From India to Bangladesh	
	Energy (MU*)	Power (Av.MW)	Energy (MU)	Power (Av.MW)	Energy (MU)	Power (Av.MW)
Apr-14	78	108	80	111	277	384
May-14	271	365	77	103	274	380
Jun-14	586	815	65	90	283	392
Jul-14	989	1,329	67	89	291	404
Aug-14	1,004	1,349	65	88	269	374
Sep-14	980	1,361	72	100	272	378
Oct-14	608	817	67	90	311	431
Nov-14	244	339	76	105	225	313
Dec-14	136	182	108	145	214	298
Jan-15	81	109	109	147	243	337
Feb-15	56	83	103	153	294	408
Mar-15	78	106	109	134	319	442
Total MU/ Avg. MW	**5,109**	**580**	**997**	**113**	**3,272**	**378**

*U = kWh

Based on the projects under construction, the electricity trade between Bhutan and India will touch 15,000 million units per annum by 2018-19. Trade between India and Bangladesh is planned to be doubled by 2018. Similarly, trade between India and Nepal may increase to 300 - 400 MW after the 400 kV Muzaffarpur-Dhalkebar line is commissioned this year.

4.0 Power Sector Organization Structure in South Asia

For the purpose of this Study, it is important to understand the structure of power system, role and responsibilities of various agencies in South Asia. This will help to know the issues with present structure and to plan future requirements for smooth cross border power transactions. Consequently, fundamental information pertaining to institutional structure of power sector in all Member States is presented in this section.

4.1 Afghanistan [6]

The Islamic Republic of Afghanistan is a landlocked country bordered by Iran to the West, Turkmenistan, Uzbekistan, and Tajikistan to the North, China in the Far North-East and SAARC Member State Pakistan to South and East. Hence, Afghanistan can possibly facilitate interlink between Central Asian nations with SAARC Member States. Due to war, electricity infrastructure has been badly damaged and the current generation capacity is even less than that of in 1980s. The country's transmission system is made up of many non-connected networks. The major networks are the North East Power System (NEPS); the South East Power System (SEPS); the Turkmenistan System; and the Herat. Huge efforts are underway to interconnect these grid islands for transforming into a national transmission grid. As Afghanistan is highly dependent on power imports from the neighboring Uzbekistan, Tajikistan, Iran and Turkmenistan more cross border transmission links have also been planned. [7]

Ministry of Energy and Water (MEW) is responsible for regulatory and policy framework for power and electricity including planning and implementation. Under MEW, the Renewable Energy Department is responsible for making use of Afghanistan's renewable energy resources to generate power/energy. Ministries of Economy, Finance and Mines & Natural Resources are also involved in electricity sector. Inter-Ministerial Commission for Energy (ICE) was established in 2006 to coordinate government policy in energy, leverage donor resources and integrate sector planning. It is chaired by Minister of the Economy. Electricity sector is vertically integrated through Da Afghanistan Breshna Sherkat (DABS), an autonomous company which operates and manages electric power generation, import, transmission, as well as distribution throughout Afghanistan on a commercial basis. It is the single buyer of power from IPPs. DABS is a limited liability company with all its equity shares owned by the Government. A draft of the Electricity Law is awaiting review by Cabinet and Parliament. As such, Grid Code for Afghanistan does not exist, it is expected to be developed and enforced along with other regulatory instruments with the evolution of regulatory regime.

4.2 Bangladesh [8]

The People's Republic of Bangladesh is bordered by India to the West, North and the North-East, Myanmar to the South-East and the Bay of Bengal to the South. It has large natural gas resources followed by oil, hydro and coal. Renewable and nuclear plants are also being promoted. Severe power deficit and resultant outages have plagued the electricity sector.

Cross border transmission link with India is in place to import power (500 MW) and augmentation of capacity of the link along with another interconnection are planned.

Power Division under the Ministry of Power, Energy and Mineral Resources (MPEMR) is in charge of electricity sector [9]. Ministry of Finance and Ministry of Planning are also involved in Power sector. Electricity Sector in Bangladesh is vertically integrated. Majority of generation and distribution in urban areas is under Bangladesh Power Development Board (BPDB). Power Grid Company of Bangladesh (PGCB), a subsidiary of BPDB, owns and operates the national grid. BPDB is the single buyer of power from IPPs. Bangladesh Energy Regulatory Commission (BERC), established under BERC Act-2003, is the regulatory body responsible for issuing licenses, tariff fixation, frame Grid Codes [10] and standards, etc. Electricity Act, 1910 and its Amendment (2006) are the principal legislations governing power sector. Electricity Rules 1937, Emergency Energy & Power Supply Special Act 2010, Sustainable Renewable Energy Development Authority Act 2012, Rural Electrification Board Act 2013 are the other legislations.

The main players in power sector are:

a. Regulator

b. Bangladesh Energy Regulatory Commission (BERC)

Major functions of BERC are as follows:

- Issue, cancel, amend and determine conditions of licensees
- Determine tariff safety enhancement
- Frame codes and standards and make enforcement of those to ensuring quality of service
- Resolves dispute between licensees and between licensees and consumer and refer those to arbitration if necessary.
- Advice to the Government regarding electricity generation, transmission, marketing, supply distribution and storage of energy.

c. Power Generation

- Bangladesh Power Development Board (BPDB)
  - Partially integrated public utility
  - Generates power
  - Purchaser & seller of power as a "Single Buyer"
  - Distribution business in nation-wide urban areas, except Dhaka and West Zone
- Ashuganj Power Station Company Ltd. (APSCL)
- Electricity Generation Company of Bangladesh (EGCB)

- Independent Power Producers (IPPs)
- North West Zone Power Generation Company (NWPGC)

c. Power Transmission

- Power Grid Company of Bangladesh Ltd (PGCB)

Major functions of PGCB are as follows:

  - Operation & maintenance of grid substation and transmission line
  - Generation planning & schedule preparation
  - System control by maintaining load-generation balance
  - Operational record keeping
  - Operation & maintenance of SCADA system
  - Protection, relay co-ordination of transmission system
  - Transmission network planning

d. Power Distribution

- Bangladesh Power Development Board (BPDB): Urban area of North, South and central zone with its six distribution zones: Chittagong, Mymensingh, Rajshahi, Comilla, Sylhet, Rangpur (24% of total national sales),
- Dhaka Power Distribution Company (DPDC): Distribution. Operator for southern part of the Capital (20% of total national sales)
- Dhaka Electric Supply Company Ltd (DESCO): Distribution. Operator for northern part of Capital City (11% of total national sales)
- West Zone Power Distribution Company (WZPDC): Distribution Operator for Khulna & Barisal Division and Faridpur (6% national sales)
- Rural Electrification Board (REB): Responsible for rural electrification through 70 PBSs (39% of total national sales)
- BPDB is functioning as a single buyer in the power market of Bangladesh; it purchases the electricity from the public and private generation entities and sells bulk electricity to all the distribution utilities covering six distribution zones.

4.3 Bhutan [11]

Bhutan is a landlocked country at the Eastern end of Himalayas, bordered by China to the North and India to South, East and West. It has rugged terrain and many perennial rivers and therefore blessed with immense hydropower potential. Apart from very small diesel power capacity, the national power generation is dominantly hydro-electric. In general it has surplus generation, most of which is exported to India. However, during dry season hydro generation reduces, and Bhutan imports power from India to meet its national need.

Ministry of Economic Affairs is the line ministry for the Electricity Sector. Electricity Act of Bhutan, 2001 divided the former Department of Power under the Ministry of Trade and Industry into three separate entities namely Bhutan Power Corporation Limited (BPC), Department of Energy (DoE) and Bhutan Electricity Authority (BEA).

The generating stations were being operated and maintained as independent generating companies until the commissioning of Tala in 2006-07. Since 2008, generating companies have been amalgamated under a single company called Druk Green Power Corporation Limited (DGPC). Followed by the establishment of DGPC, Transmission/Distribution and Generating utilities and independent, and autonomous regulator - Bhutan Electricity Authority (BEA) were established in 2010.

Further in 2011, the DoE under the Ministry was further restructured into three new Departments namely:

a. Department of Hydropower and Power Systems (DHPS);
b. Department of Renewable Energy (DRE); and
c. Department of Hydro-Met Services (DHMS)

With this restructuring, the DHPS is made responsible for the policy and planning aspects of the hydropower development with capacities greater than 25 MW and transmission planning for reliable, secure and affordable supply of electricity. Some of the important functions of the DHPS are as follows:

a. Formulate hydropower development policies, plans and programs including associated transmission systems for domestic supply and export;
b. Hydropower project planning, investigations & design and allotment of projects for implementation;
c. Formulate and negotiate various MoUs, Agreements, PPAs/power export tariffs etc.;
d. Coordination with regional institutions like SAARC/BIMSTEC/SASEC/ADB etc.; and
e. Implementation of the Bhutan Sustainable Hydropower Development Policy 2008

BEA is an autonomous regulator for the electricity sector with the following functions [12];

a. Develop regulations, standards, codes, principles and procedures, and monitoring the performance of licensees;
b. Process applications and issue, modify and revoke licenses for generation, transmission, system operation, export, import, distribution and sale of electricity.
c. Determine, or approve tariffs proposed by the licensees, and review existing domestic tariffs; and
d. Prescribe and collect fees, charges or royalties from licensees

e. Impose any fines, sanctions or penalties for any breach of provisions of the Electricity Act 2001, regulations, standards, codes, licenses or contracts to be approved by the Authority, and concession agreements entered into between licensees and the Government; and

f. Develop and implement Dispute Resolutions Procedures relating to enforcement of Electricity Act, Regulations, Codes [13] and Standards.

Bhutan Power Corporation Limited (BPC) is a public owned utility company responsible for transmission, distribution and supply of electricity in the Kingdom. It provides transmission access for export of surplus power. With the establishment of National Load Dispatch Centre under BPC as an interim measure, System Operator role is taken care by NLDC.

Druk Green Power Corporation (DGPC) is responsible for the following functions:

a. Effectively and efficiently manage hydropower plants, and maximize returns to the shareholder;

b. Take a lead role in accelerating hydropower development in the Kingdom by developing new hydropower projects independently, through joint ventures or through any other arrangements with domestic and international partners;

c. Provide energy security for domestic consumption, fuel economic growth, and also explore other forms of renewable energy other than hydropower;

d. Build capacity in hydropower development and management through recruitment and training of professionals to meet the current human resources requirements of the company while at the same time ensuring a robust expansion and succession plan; and

e. Be a responsible, proactive and progressive company with a highly motivated and dedicated team of professionals.

Currently, a competitive market structure does not exist in Bhutan. The electricity supply in Bhutan remains a monopoly, in spite of the restructuring process carried out by the government. The BPC has a monopoly on all transmission, distribution and supply activities in the country, whilst the DGPC is the sole government entity in the generation sector.

4.4 India

The Republic of India is the biggest generator and consumer of energy among SAARC Member States and has five SAARC Member States including Bangladesh, Bhutan, Nepal, Pakistan and Sri Lanka as its neighbors. Electricity is a concurrent list subject i.e. both federal government and state governments are involved in establishing policies and laws for electricity sector.

The federal Ministry of Power is the main line ministry for the development of electrical energy in the country. Other ministries such as Coal, Petroleum and Natural Gas, New and Renewable Energy and Department of Atomic Energy are also involved in electricity sector. Electricity Act, 2003 is the principal legislation governing electricity sector. Salient features of the Act are de-licensing of generation, unbundling of State Electricity Boards, provision for open access to transmission and distribution systems, encouraging private sector participation and promoting renewable energy and electricity trading. The federal government notified the National Electricity Policy in 2005. The Central Electricity Regulatory Commission (CERC) is the key regulatory body performing tariff regulation, issuing licenses, specifying Grid Code [14], etc. Both government-owned and private-owned companies are involved in generation activities. Central Transmission Utility (CTU) is a government company notified by the federal government and responsible for Inter-State Transmission System (ISTS). Similarly, State Transmission Utility (STU) is a government company or board notified by the state government and is responsible for the respective intra-state transmission system. Both CTU and STUs are the transmission licensees. National Load Dispatch Centre (NLDC), Regional Load Dispatch Centre (RLDC) and State Load Dispatch Centre (SLDC) are the system operators. Public as well as private companies are involved for distribution activities in urban areas.

Statutory Bodies: Central Electricity Authority [15] (CEA), Central Electricity Regulatory Commission [16] (CERC), Appellate Tribunal for Electricity (ATE), State Electricity Regulatory Commission (SERC), Central Transmission Utility [17] (CTU), State Transmission Utility (STU), National Load Dispatch Centre (NLDC), Regional Load Dispatch Centers (RLDC), State Load Dispatch Centers (SLDC), Regional Power Committees, Bureau of Energy Efficiency [18] (BEE), Bhakra Beas Management Board (BBMB) and Damodar Valley Corporation (DVC)**.**

Public Sector Undertakings: National Thermal Power Corporation Limited (NTPC), National Hydroelectric Power Corporation Ltd. (NHPC), Rural Electrification Corporation (REC), North Eastern Electric Power Corporation Ltd. (NEEPCO), Power Finance Corporation Ltd. (PFC), Power Grid Corporation of India (Power Grid), Power System Operation Corporation Limited (POSOCO).

Ministry of New and Renewable Energy (MNRE) is the nodal Ministry at the federal level for all matters relating to new and renewable energy. The Ministry has been facilitating the implementation of broad spectrum of programs including harnessing renewable power, renewable energy to rural areas for lighting, cooking and motive power, use of renewable energy in urban, industrial and commercial applications and development of alternate fuels and applications. The roles and responsibilities of various, relevant organizations are presented in Table 4.1.

Table 4.1: Roles and Responsibilities of Relevant Organizations in India

Organization	Contemplated Roles and Responsibilities
Central Electricity Authority (CEA)	• Specify grid standards for O&M of transmission lines • Specify conditions for installation of meters for supply &

Organization	Contemplated Roles and Responsibilities
	transmission of electricity • Specify the technical standards for construction of electrical plants, electric lines and connectivity to the grid • Specify the safety requirements for construction, operation and maintenance of electrical plants and electric lines • Notify National Electricity Plan • Advice government in matters relating to National Electricity Policy
Central Electricity Regulatory Commission (CERC)	• Regulate the tariff of generating companies for Inter-State transactions. • Regulate & determine tariff for the inter-State transmission of electricity. • Grant licenses for inter-State transmission and trading. • Formulate Indian Electricity Grid Code with regard to Grid Standards.
State Electricity Regulatory Commission (SERC)	Determine the tariff for generation, supply, transmission and wheeling of electricity, wholesale, bulk or retail sale within the State Issue licenses for intra-State transmission (ISTS), distribution and trading Promote co-generation and generation of electricity from renewal sources of energy
Central Transmission Utility (CTU)	• Transmission of electricity through ISTS network • Planning & co-ordination related to ISTS with all the agencies • Provide non-discriminatory open access of ISTS to any licensee or generating company or bulk customer as per the provisions of Electricity Act 2003. • CTU shall be the nodal agency for ISTS connectivity of Long term Access (LTA) & Medium Term Open Access (MTOA) • CTU shall not engage in the business of trading / generating electricity
State Transmission	• Undertake transmission of electricity through intra-State

Organization	Contemplated Roles and Responsibilities
Utility (STU)	transmission system; • Co-ordination for planning & development of intra-state transmission network. • Provide non-discriminatory Open Access to its transmission network by licensees, generating companies and bulk customers of the state on payment of transmission charges • Operate the SLDC till the State Government notify any company or authority or corporation for this purpose
Regional Power Committees (RPC)	• Undertake Operational Analysis in the region • Co-ordinate with STU & CTU to facilitate planning of Intra &Interstate transmission system • Outage planning & co-ordination in the region • System Protection studies for the region • Certification of system availability factor for the purpose of payment of transmission charges • Preparation of Regional Energy Account, UI account, Reactive energy account and congestion charge account based on the data given by RLDC.
National Load Dispatch Centre (NLDC)	• Monitoring & operation of National Grid • Co-ordination for restoration of synchronous National grid • Co-ordination for trans-national exchange of power • Supervision over RLDCs • Supervision & control over inter-regional links • Scheduling & Dispatch of electricity over inter-regional links • Co-ordination with RLDCs for inter-regional energy accounting and exchange of power • NLDC shall be the nodal agency for collective transactions
Regional Load Dispatch Centre (RLDC)	• Optimum scheduling & dispatch within the region in accordance with the contracts entered by the licensee or the generating companies operating in the region • Keeps account of energy transmitted through regional grid

Organization	Contemplated Roles and Responsibilities
	• Supervision & control over Inter-state Transmission System (ISTS) • RLDC of the region where point of drawl of electricity is situated shall be the nodal agency for the Short Term Open Access (STOA) transactions. • Operation of ancillary services • Operation of regional UI pool account, regional reactive energy account and Congestion Charge Account, provided that such functions will be undertaken by any entity (or entities) other than RLDCs if the Commission so directs.
Regional Load Dispatch Centre (RLDC)	• Apex body for grid operation in the state • Optimum scheduling & dispatch within the region in accordance with the contracts entered by the licensee or the generating companies operating in the state • Keeps account of energy transmitted through state grid • Supervision & control over Intra-state Transmission System • Responsible for real time grid operation in the state • Complying the directions of RLDC and execute such directions through STU, licensees, generating companies of the state • Issue concurrence or no-objection for STOA & collective transactions of state utility or intra-state entity

4.5 Maldives

The Republic of Maldives is a geographically dispersed low lying archipelago of 1,192 coral islands, situated on the 1,600 km long Laccadives - Chagos submarine ridge in the central Indian Ocean, 750 km South West of Sri Lanka. Out of 1,192 islands, 194 are inhabited [19] and 105 are tourist resorts. National population is 350,759 [20]; of which one-third resides in capital island Malé.

Electricity sector has 99.2% diesel generation and 0.8% renewable generation. As on date, around 2 MW of solar power projects have been installed in the country as pilot initiatives.

The gist of the power sector in Maldives is as follows:

a. Ministry of Energy, Environment and Water (MEEW), Ministry of Finance, Ministry of Economic Development and Ministry of Trade and Industries are involved in Electricity Sector activities.

b. Maldives Energy Authority (MEA) is an independent regulatory body affiliated to the Ministry of Energy, Environment and Water and operates under guidance of a Governing Board appointed by the President. MEA is also responsible to set standards for improving the quality of electricity supply and conduct awareness program and resolving conflicts between electricity providers and consumers.

c. State Electric Company Limited (STELCO) is government-owned and is the largest electricity utility coordinating generation and distributions functions.

d. Island Development Committees (IDCs), Private Companies and Non-Governmental Organizations (NGOs) are also involved in providing electricity.

It is to be noted that the interconnection of Maldives with rest of SAARC countries would not be economically viable given the present demand structure.

4.6 Nepal

Federal Democratic Republic of Nepal is a landlocked country, situated between China and Member State India. Owing to its location in Himalayan region characterized by mountains and perennial rivers, Nepal has immense hydro potential which has not been tapped yet. The current total installed generation capacity is much lesser than the peak demand. As most of the generation is run-of-river based, the power deficit is higher during dry season. Inadequate power infrastructure has led to high losses and high tariffs. Hydropower Development Policy, 2001 was notified for promoting hydel power development. A 400 kV transmission link to India has been planned. Ministry of Energy is the line Ministry with primary jurisdiction over the power sector. Electricity Act 1992, Electricity Regulations 1993 are the principal legislations for governing power sector. Salient features of the Act are provisions to encourage private sector involvement and status of Nepal Electricity Authority (NEA) was changed from that of a sole monopoly player to that of a licensee with the responsibility of buying the privately generated power. Electricity sector of Nepal is vertically integrated with NEA, a public sector utility, responsible for electricity generation, transmission and distribution throughout Nepal. Tariff Fixation Commission is the regulatory agency set up to review and approve tariff. Relevant important bodies are:

a. Water and Energy Commission Secretariat (WECS): Assist Ministry in formulation of policies and planning of projects in the water resources and energy sectors.

b. Nepal Electricity Authority (NEA): A public sector utility responsible for electricity generation, transmission and distribution throughout Nepal. It is also responsible for energy exchanges with India and act as a single buyer of electricity from private independent power producers.

- Majority of Generation, Transmission & Distribution of Nepal Power Sector is under NEA.
- The primary objective of NEA is to generate, transmit and distribute adequate, reliable and affordable power by planning, constructing, operating and maintaining all generation, transmission and distribution facilities in Nepal's power system both interconnected and isolated.
- It has to recommend, determine and realize tariff structure for electricity consumption with prior approval of Government of Nepal.
- Recommend to Government of Nepal, long and short- term plans and policies in the power sector.
- As part of internal unbundling, NEA is organized as
    - Generation Directorate
    - Transmission Directorate
    - Distribution & Consumer Services Directorate
    - Planning, Monitoring and Information Technology Directorate
    - Engineering Services Directorate
- Under Transmission Directorate, System Operation Department functions as Load Dispatch Centre
- Under Planning, Monitoring and Information Technology Directorate is Power Trade Department which is responsible for trading of electric power in both domestic and cross border market.

c. Department of Electricity Development (DOED): Assisting in implementation of overall government policies related to power/electricity sector.

d. Alternative Energy Promotion Centre (AEPC): Under the Ministry of Science, Technology and Environment with the objective of developing and promoting renewable/alternative energy technologies in Nepal.

4.7 Pakistan

The Islamic Republic of Pakistan is situated bordering the Arabian Sea, between India in the east and Iran and Afghanistan in the west. Pakistan is the second largest power sector amongst the SAARC Member States. Power generation mix consists of hydro, thermal (furnace oil, gas, coal) and nuclear. Demand far exceeds the generation capability in Pakistan and as a result frequent outages plague the electricity sector. Major efforts are being focused on adding generation capacity avoiding any delays. Currently, Pakistan is importing power from Iran. It is also part of CASA-1000 project which enables import of power from Central Asia. Involvement of private sector in renewable energy is promoted through provisions of Alternative Energy Development Board (AEDB) Act, 2010. Ministry of Water and Power

(MWP) is a federal government entity and is primarily responsible for the activities in power sub-sector of the energy sector. Ministry of Petroleum and Natural Resources (MPNR) is other ministry involved in energy sector. Regulation of Generation, Transmission and Distribution of Electric Power Act 1997 along with all amendments also referred to as NEPRA Act No. XL of 1997 is the principal legislation governing power sector. National Electric Power Regulatory Authority (NEPRA) is key regulatory body responsible for issuing licenses, tariff determination and preparing and enforcing Grid Codes [21] and standards. Alternative Energy Development Board (AEDB), Pakistan Atomic Energy Commission (PAEC), Private Power and Infrastructure Board (PPIB) are involved in promotion and development of different activities in power sector. Despite efforts to make electricity sector competitive, vertically integrated utilities dominate in the system.

The major autonomous bodies are;

a. Water and Power Development Authority [22] (WAPDA): It is responsible for operation and maintenance of existing hydro power generation and development of new hydro power plants operating in public sector.

b. Pakistan Electric Power Company (PEPCO): PEPCO is vested with the responsibility of thermal power generation, transmission, distribution and billing. It is responsible for the management of all the affairs of corporatized ten Distribution Companies (DISCOs), four Generation Companies (GENCOs) and a National Transmission Dispatch Company [23] (NTDC).

c. National Transmission and Dispatch Company (NTDC) is under PEPCO and is responsible for managing power transmission business all over the country at 500 kV and 220 kV levels under public sector. At present, NTDC is acting as single buyer, transmission network operator and system operator.

d. K-Electric [24] (Previously Karachi Electric Supply Company-KESC): Currently, it is the only vertically integrated utility and is responsible for power generation, transmission and distribution for the greater metropolis of Karachi.

e. National Electric Power Regulatory Authority [25] (NEPRA): It has been established for the regulation of electrical power generation, transmission and distribution in Pakistan. Its main responsibilities are:

  - Issue licenses for generation, transmission and distribution of electric power.
  - Establish and enforce Standards to ensure quality and safety of operation and supply of electric power to consumers.
  - Approve investment and power acquisition programs of the utility companies.
  - Determine Tariffs for generation, transmission and distribution of electric power.

f. Alternative Energy Development Board [26] (AEDB): It is to assist and facilitate development of alternative or renewable energy in order to achieve sustainable economic growth with transfer of technology for development of an indigenous technological base through a diversified energy generation.

g. Pakistan Atomic Energy Commission [27] (PAEC): It is a semi-autonomous and a scientific research institution, concerned with research and development of nuclear power, promotion of nuclear science, energy conservation and the peaceful usage of nuclear technology.

h. The Private Power and Infrastructure Board [28] (PPIB): It was created in 1994 to promote private sector participation in the power sector of Pakistan. PPIB facilitates investors in establishing private power projects and related infrastructure, executes Implementation Agreement (IA) with Project Sponsors and issues sovereign guarantees on behalf of government.

4.8 Sri Lanka [29]

Democratic Socialist Republic of Sri Lanka is an island country having maritime borders with India to the northwest and Maldives to the Southwest. Hydro power, Coal based and liquid fuels based generation are the dominant sources of electricity. Solar and wind power are still in early stages of deployment. Currently, there is no significant surplus or deficit in power sector. Ministry of Power and Energy is the line ministry for Electricity Sector. Sri Lanka Sustainable Energy Authority was established under the Sri Lanka Sustainable Energy Authority Act, No. 35 of 2007 as an apex institution to drive Sri Lanka towards a new level of sustainability in energy generation and usage, through increasing indigenous energy and improving energy efficiency within the country. Public Utilities Commission of Sri Lanka (PUCSL) is the key economic, safety and technical regulator of the electricity industry. Ceylon Electricity Board Act No. 17 of 1969, Public Utilities Commission of Sri Lanka (PUCSL) Act, 2002, Sri Lanka Sustainable Energy Authority Act, No. 35 of 2007 and Sri Lanka Electricity Act, No. 20 of 2009 are the regulations governing electricity sector. Ceylon Electricity Board, a government-owned corporation controls all major functions of generation, transmission and distribution. Lanka Electricity Co. (Pvt.) Ltd. (LECO), a private limited liability Company is the only other electricity company and is involved exclusively in distribution. As per Act of 2009, generation license for more than 25 MW is given only to those companies for which government has majority shareholding. Therefore, electricity sector continues to be a monopoly in Sri Lanka.

The important bodies in power sector are as follows:

a. Ministry of Power and Energy is the line ministry for Electricity Sector. Under the Ministry of Power and Energy are the following institutions:

   - Ceylon Electricity Board (CEB): Ceylon Electricity Board is a body corporate established in 1969 under the Act of Parliament No. 17 of 1969. It is empowered to generate electrical energy, transmit the same and distribute it to reach all categories of consumers and to collect the revenue.

- Lanka Electricity Company: Lanka Electricity Co. (Pvt.) Ltd. (LECO) is a private limited liability Company registered under the Companies Act No.17 of Sri Lanka for distribution of electricity. Present shareholders of LECO are CEB, UDA, Government Treasury and four local authorities (LA).
- Sri Lanka Sustainable Energy Authority: Established under the Sri Lanka Sustainable Energy Authority Act, No. 35 of 2007 as an apex institution to drive Sri Lanka towards a new level of sustainability in energy generation and usage, through increasing indigenous energy and improving energy efficiency within the country.

b. Public Utilities Commission of Sri Lanka (PUCSL): The government established the Public Utilities Commission of Sri Lanka (PUCSL) in 2002 as a regulator for the energy, petroleum and water sectors, under the PUCSL Act 2002.Public Utilities Commission of Sri Lanka became the economic, safety and technical regulator of the electricity industry with the enactment of Sri Lanka Electricity Act, 2009.

c. The Ceylon Electricity Board (CEB) is the largest electricity company in Sri Lanka. With a market share of nearly 100%, it controls all major functions of electricity generation, transmission, distribution and retailing in Sri Lanka.

5.0 Legal and Regulatory Framework

5.1 Electricity Act Document

The apex legal document in each of the Member States is given in Table 5.1.

Table 5.1: Apex Legal Document for the SAARC Member States

Member State	Apex Legal Document
Afghanistan	Not Available* (NA)
Bangladesh	Electricity Act 2003 (Amendments 2005 and 2010)
Bhutan	Electricity Act of Bhutan, 2001
India	Electricity Act, 2003
Maldives	NA
Nepal	Electricity Act 1992
Pakistan	NEPRA Act No. XL of 1997
Sri Lanka	Electricity Act 2009

* Not Available (NA) – Does not exist.

5.2 Grid Code Documents

The Grid Code documents corresponding to each of the Member State are highlighted in Table 5.2.

Table 5.2: Grid Code Documents for the SAARC Member States

Member State	Grid Code Document
Afghanistan	NA
Bangladesh	Grid Code, 2012
Bhutan	Grid Code 2008 (Reprint 2011)
India	Grid Code 2010 (Amendment 2014)
Maldives	NA
Nepal	Grid code 2005 (Draft),
Pakistan	Grid Code, 2005

Member State	Grid Code Document
Sri Lanka	Grid Code, 2014

5.3 Regulatory Framework

All the SAARC Member States except for Afghanistan have established an independent sector Regulator and these are given in Table 5.3.

Table 5.3: Electricity Sector Regulators of SAARC Member States

Member State	Electricity Sector Regulator
Afghanistan	NA
Bangladesh	Bangladesh Energy Regulatory Commission (BERC)
Bhutan	Bhutan Electricity Authority (BEA)
India	Central Electricity Regulatory Commission (CERC), State Electricity Regulatory Commissions (SERC) for each state
Maldives	Maldives Energy Authority
Nepal	Department of Electricity Development
Pakistan	National Electric Power Regulatory Authority (NEPRA)
Sri Lanka	Public Utilities Commission (PUC)

5.4 Appellate Authority

The Appellate Authority is identified in Bhutan, India, Pakistan and Sri Lanka and only India has a sector specific Appellate Authority. The details are presented in Table 5.4.

Table 5.4: Appellate Authorities for the SAARC Member States

Member State	Appellate Authority
Afghanistan	NA
Bangladesh	NA
Bhutan	Concerned Minister or Court of Law
India	Appellate Tribunal for Electricity

Member State	Appellate Authority
Maldives	NA
Nepal	NA
Pakistan	Provincial High Courts and Supreme Court of Pakistan
Sri Lanka	Court of Appeal of Sri Lanka

5.5 Monitoring of Prices in the Electricity Market

In India, the Central Electricity Regulatory Commission (CERC) has constituted a Market Monitoring Cell (MMC) which tracks and monitors the prices prevailing in all segments of the Electricity Market i.e. bilateral trades, trades in the Power Exchange and the real time prices as Unscheduled Interchange (UI). Except for India, other Grid Codes do not contain provisions relevant to competitive power market.

5.6 Value of Lost Load (VOLL)

The value of lost load (VOLL) is not available for any of the SAARC Member States.

5.7 Infrastructure for Inter Control Centre and Control Centre to Substations Communication

The mode of communication among the Control Centers and between Control Centre and Substations is given in Table 5.5.

Table 5.5: Modes of Communication for the SAARC Member States

Member State	Communication Systems
Afghanistan	NA
Bangladesh	PSTN and PLCC
Bhutan	PSTN, PLCC and OPGW
India	Wideband (Microwave & Fiber Optic), VSAT, GSM, PLCC
Maldives	NA
Nepal	PSTN,PLCC and Optical Fiber
Pakistan	Telephone, Fax, PLC, OPGW
Sri Lanka	Microwave, PSTN, PLTS, PLC

5.8 Technical Issues

5.8.1 Normal Operating Frequency

The normal operating frequency of all Member States is 50 Hz. Permissible frequency deviation is given in Table 5.6.

Table 5.6: Normal Operating Frequency for SAARC Member States

Member State	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 – 51.5 Hz
Pakistan	49.5 – 50.5 Hz
Sri Lanka	49.5 – 50.5 Hz

5.8.2 Transmission Voltage Levels and Permissible Deviations

The transmission voltage levels for SAARC Member States are given in Table 5.7

Table 5.7: Transmission Voltage Levels and Permissible Deviations

Member State	HVAC Transmission Voltage Levels (kV)	Permissible Deviation
Afghanistan	220, 110	NA
Bangladesh	400, 230, 132	+/- 5%
Bhutan	400, 220, 132, 66	+/- 5%
India	765, 400, 220, 132, 110, 66	800 – 728; 420 – 380; 245 – 198; 145 – 122; 121 – 99; 72 – 60;
Maldives	11kV is the distribution voltage. Maximum distribution voltage is 33 kV	+/- 10%

Member State	HVAC Transmission Voltage Levels (kV)	Permissible Deviation
Nepal	132, 66	+/- 10%
Pakistan	500, 220, 132, 66	+/- 10%
Sri Lanka	220, 132	+/- 10%; +/- 5%

6.0 Comparison of Grid Codes of the SAARC Member States

The Grid Codes of all SAARC Member States (as of today, Grid Codes do not exist for Afghanistan and Maldives) are referred to understand technical and commercial issues concerning cross border trading in existing Grid Codes. To start with, a brief description about the Grid Codes [30] is presented below:

Bangladesh: Grid Code was approved by Bangladesh Energy Regulatory Commission (BERC) in 2012 in exercise of the powers conferred by section 59 of the BERC Act 2003. Power Grid Company of Bangladesh (PGCB), the transmission licensee, became responsible for managing and updating/servicing the Grid Code. In this context, PGCB was also made responsible to establish and manage the Grid Code Review Panel in accordance with provisions of Section 3.4 of the Grid Code. The Panel will consist of the following:

a. A Chairman who is an officer of the Licensee not below the rank of Director;

b. A Technical Member (Secretary) who is an officer of the Licensee not below the rank of Deputy General Manager;

c. A Member from BPDB (to represent Generation), two members from Distribution Utilities (for tenure of two years on rotation basis);

d. A member from REB (to also represent the PBSs);

e. A member from IPPs/ Private Generators (for tenure of one year each on rotation basis to be notified by the Licensee, to represent all the IPPs/ Private Generators in Bangladesh); and

f. A member to represent Buyer

The rules to be followed by the Panel in conducting its business shall be formulated by the Panel itself and shall be approved by the BERC. The Panel will meet at least once in three months. All the opinions and request for amendments from Grid Users are discussed and PGCB shall prepare a report on the revisions it feels necessary and submit it to BERC for approval.

Grid Code of Bangladesh is organized into the following sections:

a. Management of the Bangladesh Grid Code;

b. Transmission System Planning;

c. Connection Conditions;

d. Outage Planning;

e. Schedule and Dispatch;

f. Frequency and Voltage Management;

g. Contingency Planning;

h. Cross Boundary Safety;

i. Operational Event/Accident Reporting;
j. Protection;
k. Metering;
l. Communication and Data Acquisition;
m. Tests;
n. Numbering and Nomenclature;
o. Data Registration;
p. Performance Standard for Transmission; and
q. Financial Standard for Transmission

Bhutan: Grid Code Regulation 2008 was issued by Bhutan Electricity Authority (BEA) under Section 89 of the Electricity Act of Bhutan, 2001. BEA is responsible for managing and amending the Grid Code according to the prescribed procedure issued by the BEA. The Grid Code Regulation document is organized into the following sections:

a. Role and Responsibilities;
b. Planning Code;
c. Connection Conditions;
d. Operations and Operational Planning;
e. Scheduling and Dispatch Code; and
f. Management of Grid Code Regulation

India: The Indian Electricity Grid Code (IEGC) is a regulation made by the Central Electricity Regulatory Commission (CERC) in exercise of powers under Sections 79 and 178 of the Electricity Act 2003. CERC is vested with responsibility of reviewing and modifying the IEGC. Principal IEGC regulations were enforced in 2002 with major amendments in 2012 and 2014. CERC consists of a Chairperson and three other members who are appointed by the Federal Government. Chairperson of Central Electricity Authority (CEA) will be the ex-officio member. As specified in the Act, the IEGC is prepared having regard to CEA's "Grid Standards for Operation and Maintenance of Transmission Lines". Following have been supplemented to the IEGC:

a. Transmission Planning Criteria and Guidelines issued by the CEA;
b. CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-state Transmission and related matters) Regulations, 2009;
c. CEA (Installation and Operation of Meters) Regulations, 2006; and
d. CEA (Technical Standards for connectivity to the Grid) Regulations, 2007.

IEGC document is organized into the following sections:

a. Role of Various Organizations and their Linkages;
b. Planning Code for inter-State transmission;
c. Connection Code;
d. Operating Code;
e. Scheduling and Dispatch Code; and
f. Miscellaneous

Further, each of the States in India has its own State Grid Cod describing the operation of electricity sector within its own domain. Each State Grid Code addresses generation, transmission and distribution aspect of the power system. In each case, the transmission perspective of State Grid Code is based on the Indian Electricity Grid Code and therefore is not likely to cause any dispute/ambiguity in implementation of regulations.

Nepal: The NEA Grid Code, 2005 prepared by Nepal Electricity Authority (NEA) is an internal document and till to-date lacks the authority of the law. Hence, full compliance by non-NEA Grid Users is not mandate. Until the Nepal Grid Code gets enacted, NEA shall abide by the NEA Grid Code in its entirety and endeavor to bring non-NEA parties into the purview of this Grid Code.

Grid Code Management Committee (GCMC) established by NEA Management is responsible for implementation and review of the NEA Grid Code. It shall recommend necessary amendments to NEA Management for approval. GCMC consists of the following:

a. General Manager of Transmission and System Operation of the NEA as the chairperson;
b. Director of System Operation Department of the NEA as member secretary;
c. A member from the Ministry of Water Resources; and
d. One director/departmental head of each of the following organizations within NEA
    - Grid Operation Department;
    - Grid Constructor;
    - System Planning Department;
    - Generation and Technical Services Department under Distribution and Consumer Services.
    - Also, representatives of IPPs, High Voltage Consumers and private distributors shall be invited to the GCMC meeting as and when required.

The GCMC shall meet at least three times in a year. NEA Grid Code document is organized into the following chapters:

a. Grid Code Management;
b. Grid Planning;

c. Performance Standards for Grid;
d. Grid Connection Requirements;
e. Grid Operation and Management;
f. Scheduling and Dispatch;
g. System Test;
h. Grid Metering;
i. Exemptions and Transitory Provisions; and
j. Reports

Pakistan: The Grid Code of Pakistan has been prepared by National Transmission and Dispatch Company (NTDC) under Article 16 of NTDC license and approved by National Electric Power Regulatory Authority (NEPRA) pursuant to Section 35 of NEPRA Act, 1997. NTDC shall establish and maintain the review panel which shall be a standing body and shall undertake the functions detailed in Section 3.3 of the Grid Code. The functions include the following:

a. Review all suggestions for amendments;
b. Submit all the agreed recommendations to NEPRA for approval; and
c. Resolve any matters of dispute between NTDC and its users/code participants.

Pakistan Grid Code is comprised of the following chapters:

a. Code Management;
b. Data Registration Code;
c. Operation Code;
d. Connection Code;
e. Planning Code;
f. Protection and Metering Code;
g. Scheduling and Dispatch Code; and
h. Code Definitions

Pakistan Grid Code has been twice supplement to regulate on-grid wind power plants in April 2010 and on-grid Solar PV Power Plants in June 2014

Sri Lanka: The Grid Code of Sri Lanka has been formulated in pursuant to the provisions of Clause 17 (f) and 3.1 (c) of the Sri Lanka Electricity Act, No. 20 of 2009. The Public Utilities Commission of Sri Lanka (PUCSL) approves and amends the Grid Code as and when necessary. The Grid Code Enforcement and Review Panel (GCERP), established by the PUSCL is mandated to review and revision of the Grid Code. Review of the Grid Code shall be carried out periodically and as and when required. The GCERP shall consist of the following nine members:

a. 2 members representing the Transmission Business and Bulk Supply Operation Business of the Transmission Licensee respectively;
b. A member representing the Distribution Licensees who shall also be a member of the Distribution Code Enforcement and Review Panel (DCERP) as well;
c. 2 members representing the state-owned generators;
d. A member representing privately owned generators of installed capacities exceeding 100 MW;
e. A member representing privately owned generators of installed capacities less than 100 MW;
f. A member representing the bulk supply customers served by the Transmission System; and
g. Director (Licensing) of PUCSL shall function as the Secretary to the panel.

The panel should meet at least once a month. The Grid Code document is organized into the following sections:

a. Grid Planning Code;
b. Grid Connection Code;
c. Grid Operations Code;
d. Generation Dispatch Code;
e. Grid Metering Code;
f. Planning and Operating Standards; and
g. Information and Data Exchange

Comparison of the Grid Codes of all Member States, where exist, is provided in the following section for ease of understanding and for effective analysis:

6.1 Planning Code

In this section, a comparative analysis of the Planning Codes of all Member States, where exist, is presented.

6.1.1 Introduction

Table 6.1: Introduction to Planning Code of the Grid Codes of SAARC Member States

Member State	Grid Code Section
Bangladesh	4.1

Member State	Grid Code Section
Bhutan	4.1
India	3.1
Nepal	-
Pakistan	PC 1
Sri Lanka	2.1

a. Transmission Licensee i.e. grid operator is responsible for all transmission planning activities in Bhutan, Bangladesh, India, Pakistan and Sri Lanka. However, in Nepal, grid owner is responsible for all activities relating to transmission planning.

b. **Transmission Planning Process**

- Bangladesh: A System Planner is assigned by the government to prepare and submit a long-term (preferably 20 years) Power System Master Plan to the commission for Transmission and Generation expansion. The Power System Master Plan shall be updated periodically, preferably every 5 years and used as an input to the National Plan.
- Bhutan: The System Operator shall prepare aggregated medium term (5 years) and long-term (10 years) load forecasts for the overall system. System Operator shall also prepare a medium term expansion plan for the generation capacity. Ministry of Economic Affairs shall develop and periodically update the overall Power System Master Plan which includes developments for the Transmission System including export transmission facilities. Based on the Power System Master Plan, other reports/criteria/guidelines issued by the ministry and data submitted from transmission users, the Transmission licensee shall carry out grid planning studies and prepare a transmission plan which shall be submitted to BEA for approval. The completion of these works, in the required time frame, shall be ensured by the Transmission Licensee
- India: Central Electricity Authority (CEA) will formulate the perspective transmission plan once in five years and continuously update to take care of the revisions in load projections and generation scenarios. The load projections would also be carried out by the CEA with the formulations of Electric Power Survey (EPS). At present 18^{th} EPS is in operation. The generation planning aspect is deliberated in the State Grid Codes.
- Nepal: The System Planning Department (SPD) of NEA is responsible for Grid Planning. Based on data collected from distribution utilities and other NEA grid users, the SPD shall prepare every year a demand forecast for the following 15 year

period and to meet this demand, it shall also prepare a least cost generation expansion plan. Based on the demand and generation expansion plan, SPD shall conduct an annual review of the performance of the grid with a planning horizon of five years. Consolidating all these studies, the SPD shall review the Power System Master Plan every year.

- Pakistan: NTDC shall establish a planning process and submit a Transmission System Expansion Plan (TSEP) to NEPRA each year as part of the "Annual System Reliability Assessment and Improvement Report". The NTDC plan may be prepared for next 1, 3, 5 and 10 years into the future. The plan shall contain a long-term load forecast (at least for twenty years) and identify the required transmission system reinforcements/upgrading/expansion projects. All code participants shall provide necessary data to facilitate the planning process.
- Sri Lanka: Transmission Licensee will prepare a transmission development plan for a period of ten years and update the plan at least once in two years.

c. In India, Transmission licensee (CTU) shall provide the non-discriminatory open access for all inter-state transmission lines and STU for intra transmission lines. In addition, other transmission licensees in India shall also provide open access. No such regulations regarding open access are given in other Grid Codes.

6.1.2 Scope

Table 6.2: Applicability of Planning Code of Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	4.3
Bhutan	4.3
India	3.3
Nepal	3.2
Pakistan	PC 1.1
Sri Lanka	2.2

Planning Code applies to:

Bangladesh: Planning code applies to transmission licensees and distribution licensees.

Bhutan: Planning code applies to Transmission Licensee, Generation Licensees and the Distribution Licensees connected to and/or using and involved in developing the Transmission System.

India: Planning code is applicable to Central Transmission Utility (CTU), other Transmission licensees, Inter-State Generating Station (ISGS), connected to and/or using and involved in developing the Inter-State Transmission System (ISTS). It is also applicable to Generating Companies, IPPs, State Electricity Boards/State Transmission Utility (SEBs/STUs) and licensees with respect to generation and/or transmission of energy to/from the ISTS.

Nepal: Planning code is applicable to System Planning Department (SPD), NEA; Grid Owner; System Operator; Generators; Distributors; Any other non NEA entity with a User System connected to the Grid.

Pakistan: Planning code applies to Transmission licensee (NTDC), Generation and distribution licensee, Transmission-connected consumers and externally connected parties.

Sri Lanka: Planning code is applicable to Transmission Licensee, Transmission System Users, prospective Users, and parties who are authorized to carry out distribution/supply activities and are connected to the Grid.

6.1.3 Planning Criteria

Table 6.3: Planning Criteria of Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	4.4
Bhutan	4.6
India	3.5, CEA Transmission Planning Criteria
Nepal	3.6
Pakistan	PC 2.2
Sri Lanka	2.5

a. Criteria to be considered while undertaking transmission planning are given in respective Grid Codes for all Member States except India. In India, it is separately provided in Transmission Planning Criteria notified by CEA in January 2013 while it is briefly explained in the Grid Code.

b. Contingency Criteria**:** For all the Member States, (N-1) contingency is applicable. However, 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. India has also introduced N-1-1 stability criterion for critical elements of the grid which proves their code as more stringent.

c. Grid Codes of Sri Lanka, Bhutan and India specify that transmission system should be capable of withstanding loss of most severe single system in-feed (India and Bhutan) or loss of one generator (Sri Lanka) whereas the other Grid Codes have not specified the regulations regarding loss of in-feed or generator.

d. Except India, Grid Codes of all other SAARC Member States specify the same voltage variation limits for both planning and operation stages. For India, CEA's manual on transmission planning criteria specifies a planning margin to be considered during planning stage.

6.1.4 Transient Stability Limits

Transient stability limits as specified in Grid Codes of different Member States are as follows:

a. Bangladesh: Grid planning studies should be carried out such that system is maintained stable during a temporary fault clearance by three-phase trip within 100 ms and followed by successful re-closure within 300 ms. Grid Code also specifies that from stability perspective, the maximum fault clearance times shall be 100 ms for 400 kV and 160 ms for 220 and 132 kV faults.

b. Bhutan: Grid Code only specifies that transient stability should be considered in planning studies; it does not mention any specific limits.

c. India: Transmission planning should be such that the grid shall be able to survive the following:

- A permanent three phase to ground fault on 765 kV or 400 kV cleared in 100 ms.
- A permanent three phase to ground fault on 220 kV or 132 kV cleared in 160 ms.
- A permanent single phase to ground fault on a 765 or 400 kV and accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3- pole opening (100 ms) of the faulted line shall be considered.
- A fault in HVDC convertor station, resulting in permanent outage of one of the poles of HVDC Bi-pole.
- An outage of single largest generating unit or a critical generating unit.
- A temporary single phase to ground fault on a 765 kV in a scenario where a 'N-1' contingency already has happened in the system. Accordingly, single pole opening (100 ms) of the faulted phase and successful re-closure (dead time 1 second) shall be considered.

d. Nepal: Like Bhutan, Nepalese Grid Code only specifies that transient stability should be considered in planning studies and does not mention any specific limits.

e. Pakistan: Grid code specifies that planning process should consider that system be capable of surviving a permanent three phase to ground fault on 500 kV or 220 kV with a fault clearance of 100 ms.

f. Planning of Cross-Border Interconnection: Grid Code of Bhutan specifies that planning of the Transmission System for export of power from the generating stations to neighboring countries shall be discussed and reviewed with the concerned agencies of the neighboring countries. Grid Codes of other SAARC Member States do not specify any provisions for planning cross-border interconnection.

g. In India, Transmission licensee (CTU) shall perform the reactive power compensation studies for ISTS; similar studies are not required to be performed as per other Grid Codes.

6.2 Connection Code

In this section, a comparative analysis of the Connection Codes corresponding to all Member States, where Grid Code exist, is presented.

6.2.1 Introduction

Table 6.4: Connection Codes of the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	5.1
Bhutan	5.1
India	4.1
Nepal	-
Pakistan	CC 1
Sri Lanka	3.1

In all Grid Codes, it is mentioned that Connection Code applies to all users who are already connected and those seeking new/modification (in existing) connection.

6.2.2 Procedure for Connection

Table 6.5: Procedure for Connection in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	5.8
Bhutan	5.4

Member State	Grid Code Section
India	4.4
Nepal	5.4
Pakistan	CC 3
Sri Lanka	3.12

Any potential user seeking to establish new or modified arrangement of connection to or for use of the Transmission System shall submit an application in standard format to i) CTU in India; ii) Transmission licensee in Bhutan, Bangladesh, Pakistan and Sri Lanka; and iii) Grid Owner in Nepal.

6.2.3 Connection Agreement

Table 6.6: Connection Agreement of the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	5.1
Bhutan	5.5
India	4.5
Nepal	5.4
Pakistan	CC 4.2
Sri Lanka	3.12.8

A Connection agreement shall be signed by the applicant in accordance with the CERC Regulations, 2009 for India and in accordance with the Grid Code for other Member States.

6.2.4 Important Technical Requirements for Connectivity to the Grid

Table 6.7: Technical Requirements of the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	5.50
Bhutan	5.13
India	4.6

Member State	Grid Code Section
Nepal	5.10
Pakistan	OC 4.9.1, OC 6.3
Sri Lanka	3.7

a. With reference to Bhutan Grid Code, the Distribution Licensee shall not depend upon the Transmission System for reactive compensation support. In Bangladesh, the users who are connected to transmission system should not depend on transmission system for reactive support. In Pakistan, Grid Code specifies that DISCOs (distribution companies) shall maintain a power factor of a minimum of 95% by providing reactive compensation at 132 kV and below voltage levels. Pursuant to the Indian Grid Code, STUs and users should not depend on ISTS for reactive power support.

b. Transmission licensee is responsible for data communication (such as flow, voltage and status of switches/transformer taps etc.) through SCADA in Bhutan, Bangladesh, Pakistan and Sri Lanka. Grid Owner and RLDC are responsible in case of Nepal and India respectively.

c. In all Member States except for India, Transmission Licensee and users shall be responsible for safety in accordance with Grid code. In India, Transmission Licensee and Users shall be responsible for safety in accordance with CEA (Technical Standards for connectivity to the Grid) Regulations, 2007, CEA (Safety Requirements for construction, operation and maintenance of electrical and electric lines) Regulations, 2008.

Grid Code of India exclusively specifies that all utilities shall have in place, a cyber-security framework to identify the critical cyber assets and protect them so as to support reliable operation of the grid, whereas Grid Codes of other countries do not specify such regulations.

6.2.5 International/Cross Border Connection

Table 6.8: Cross Border Connection in Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	5.9
Bhutan	5.14
India	4.7
Nepal	-
Pakistan	-
Sri Lanka	-

In Bhutan, the procedure for cross border connection to the Transmission System and the execution of agreement for the same shall be done by the agency who has been assigned this responsibility by the Ministry. In Bangladesh, the same procedure shall be done by the Licensee in consultation with the Commission and the Line Ministry. According to Indian Grid Code, the procedure for cross border connection to ISTS and the execution of agreement for the same shall be determined by Transmission Licensee (CTU) in consultation with CEA and Ministry of Power (MOP). Whereas Grid Code of Pakistan, Sri Lanka and Nepal do not specify any regulation for cross border connection.

6.2.6 Schedule of Assets of Regional Grid

Table 6.9: Schedule of Assets in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	5.3
Bhutan	5.15
India	4.8
Nepal	-
Pakistan	
Sri Lanka	-

According to Bhutan Grid Code, all Transmission Licensees shall submit annually to the Authority, by 31st March each year, a schedule of transmission assets which would constitute the Transmission System as on 31st December of the previous year. According to Indian Grid Code, CTU and other transmission licensees granted license by CERC shall submit annually to CERC by 30th September each year a schedule of transmission assets which constitute the Regional Grid as on 31st March of that year indicating ownership on which RLDC has operational control and responsibility. In Sri Lanka, Transmission Licensee shall establish a Plant and Equipment database whereas no such regulations are specified in Pakistan and Bangladesh Grid Codes.

6.2.7 Connectivity Standards Applicable to the Wind and Other Generating Stations Using Inverters

Table 6.10: Connectivity Standards in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	-

Member State	Grid Code Section
India	CEA (Technical Standards for Connectivity to the Grid)Amendment Regulations, 2013
Nepal	-
Pakistan	Addendum No. 1
Sri Lanka	3.11

Except India and Sri Lanka, Grid Codes of other SAARC Member States do not specify the connectivity standards/requirements to be complied with by wind and other generating stations using inverters. Sri Lanka Grid Code specifies requirements only for wind generators whereas India Grid Code specifies requirements applicable to both wind and other generating stations using inverters. These requirements are given below:

a. Both India and Sri Lanka Grid Codes specify that the harmonic current injections from a generating station shall not exceed the limits specified in IEEE Standard 519.

b. Grid Code of India specifies that the generating station shall not inject DC current greater than 0.5% of the full rated output at the interconnection point. However, Sri Lanka Grid Code doesn't specify about DC injection.

c. The generating station in India shall not introduce flicker beyond the limits specified in IEC 61000 and in Sri Lanka, shall comply with IEC 61400-21 standard and P28 Engineering recommendations of UK.

d. India Grid Code specifies that the measurement of harmonic content, DC injection and flicker shall be done at least once in a year in presence of the parties concerned and the indicative date for the same shall be mentioned in the connection agreement whereas Sri Lanka Grid Code does not specify similar condition.

e. Indian Grid Code specifies that the generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading whereas Sri Lanka Grid Code only mentions that reactive power control capability shall be provided.

f. The generating units shall be capable of operating in the frequency range of 47.5 Hz to 52 Hz (India)/47.5 Hz to 52.5 Hz (Sri Lanka) and shall be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz.

g. CEA guidelines of India specifies that wind generating stations connected at 66 kV and above shall have

- Low Voltage Ride-Through Capability (LVRT). Provided that during voltage dip, units shall generate active power proportional to the retained voltage and shall maximize supply of reactive current till the time voltage starts recovering.

- Facility to control active power injection in accordance with a set point which shall be capable of being revised in accordance with the directions of appropriate LDC. Reduction in generation shall be done, as far as possible, by sharing it among all the units on pro-rata to their capacity and not by shutting down few units.

The Sri Lanka Grid Code only mentions that active power regulation capability shall be provided.

6.3 Operation Code

In this section, a comparative analysis of the Operation Codes of various Member States is presented.

6.3.1 Operating Philosophy

Table 6.11: Operating Philosophy in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	6
India	5.1
Nepal	-
Pakistan	OC 1.1
Sri Lanka	4.1

In Bhutan, Pakistan, Nepal and Sri Lanka, system operator is responsible for the operation of power system. In Bangladesh, NLDC is responsible. In India, overall operation of the National/ inter-regional grid shall be supervised by the NLDC while the RLDC would supervise the Inter-State transactions. In India, all licensees, generating station/company and any other person connected with the power system operation shall comply with the directions issued by the respective RLDC /SLDC.

6.3.2 System Security Aspects

Table 6.12: System Security in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	6.6
Bhutan	6.6
India	5.2

Member State	Grid Code Section
Nepal	-
Pakistan	OC 4, OC 4.8.1
Sri Lanka	4.17

a. In case of Bhutan and India, it is stated in the Grid Code that no part of the grid shall be deliberately isolated from rest of the National/Regional grid, except under an emergency or when such isolation is specifically instructed by system operator or RLDC respectively. The restoration process shall be supervised by the System Operator (Bhutan) or RLDC (India), as per operating procedures separately formulated by NLDC/RLDC in India and by system operator in Bhutan. Bangladesh Grid Code specifies that no cross boundary circuits or Generating Unit of a Generator shall be removed from service without specific release from the NLDC. Sri Lanka Grid Code specifies that the Transmission Licensee shall ensure that switching operations are carried out only by Authorized Persons, under the direction of Systems Control Centre (SCC). In extreme emergencies where there is a threat to human life or to system equipment, switching operations may be carried out without being directed by SCC. Immediately after carrying out any switching operations, all related information shall be reported to the SCC by the relevant officers. In Pakistan, any operational changes can be made only under the instructions of System Operator.

b. All thermal generating units of 200 MW and above (in India) and all hydro units of 10 MW and above (in Bhutan, Nepal and India), shall have their governors in operation at all times. Pakistan Grid Code specifies that all thermal and reservoir based generators of capacity above 100 MW shall provide free governor control action within the frequency sensitive band of 49.8-50.2 Hz. Droop settings in the range of 3% to 6% are specified for India and Sri Lanka, 3% to 10% for Bhutan whereas no such specification is given in other Grid Codes. Governor dead band of ±0.03 Hz and ±0.05 Hz for India and Sri Lanka respectively is specified whereas no such specification is given in other Grid Codes.

c. Reserves/Load Following Capability/Supplementary Control of Generation

- Grid Codes of all Member States except India specify that adequate operating reserves (Spinning/Contingency/Stand-by) shall be made available for use during contingency conditions and large demand variation conditions. Reserves are also included in the day-ahead dispatch schedule of the respective SAARC Member States.
- Grid Code of India does not explicitly mention about operating reserves but it specifies that all thermal generating units of 200 MW and above and all hydro units of 10 MW and above operating at or up to 100% of their Maximum Continuous Rating (MCR) shall be capable of instantaneously picking up to 105% and 110% of

their MCR, respectively, when frequency falls suddenly. Any generating unit in India not complying with the above requirements shall be kept in operation only after obtaining the permission of RLDC. Only Bhutan Grid Code mentions a similar such regulation for generating units among other Member States.

- Grid Codes of India and Bhutan specify that supplementary control for increasing or decreasing the output for all generating units, irrespective of their type and size, would be one 1% per minute or as per manufacturer's limits. However, if frequency falls below 49.7Hz, all partly loaded generating units shall pick up additional load at a faster rate, according to their capability. The Grid Codes of Bangladesh and Nepal specify that when the frequency rises above 51.0 Hz or falls below 49.0 Hz for Bangladesh/above 50.5 Hz or below 49.5 Hz for Nepal, the Generating units which were responsible for seeing frequency of the system shall decrease or increase respectively their Generating Output at a rate of 2% per 0.1 Hz for departure of frequency until the frequency is restored within the normal range. Grid Codes of Sri Lanka and Pakistan make no such specifications.

d. Ramping rates: All Grid Codes specify that while preparing generation schedules, the concerned entity should consider the ramping-up/ramping-down limits of the generators.

e. According to the Grid Codes of India, Bhutan, Bangladesh and Sri Lanka, all generating units shall have an automatic voltage regulator (AVR) in service. Indian Grid Code also specifies that a properly tuned Power System Stabilizer (PSS) should be in service whereas other Grid Codes don't specify such a condition.

f. Operating Frequency Range

- 49 Hz to 51 Hz in Bangladesh
- 49.5 Hz to 50.5 Hz in Bhutan
- 49.9 Hz to 50.05 Hz in India
- 49.5 Hz to 50.5 Hz in Nepal
- 49.8 Hz to 50.2 Hz for Pakistan
- 49.5 Hz to 50.5 Hz in Sri Lanka

g. All distribution licensees shall provide automatic under-frequency and *df / dt* relays for load shedding in India and under-frequency relays for load shedding in Pakistan.

h. In India, all Users, STU/SLDC, CTU/RLDC & NLDC, and in Bhutan, transmission licensee shall facilitate identification, installation and commissioning of System Protection Schemes (SPS) (including inter-tripping and run-back) in the power system. Grid Codes of other countries don't specify about Special Protection Schemes.

i. Procedures shall be developed to recover from partial/total collapse of the grid in accordance with CEA Regulations (Grid Standards) and in accordance with the requirements given under section 5.8 in Indian Grid Code, Section OC 8 in Pakistan Grid Code and accordance with section 6.12 in Bhutan Grid Code.

j. All users under the operation control of system operator (in Bhutan and Pakistan) and RLDC (in India) shall send information/data including disturbance recorder/sequential event recorder output.

k. All users, system operators, transmission licensees shall take all possible measures to ensure that the grid voltage always remains within specified values.

Table 6.13: Permissible Voltage Limits under Normal and Emergency Conditions

Condition	Permissible Voltage Limits
Normal Conditions	+/- 5% in Nepal, Bhutan, and Bangladesh +8% and -5% for 500 kV and 220 kV in Pakistan +/- 5% for 132 KV, +/-10% for 220 kV in Sri Lanka +/- 5% for 400 kV, 765 KV; +/- 10% for 220 kV & below in India
Emergency Conditions	+/- 10% in Nepal, Bhutan, and Bangladesh +/-10% for 500 kV and 220 kV in Pakistan +/- 10% for 132 KV, +/-10% for 220 kV in Sri Lanka +/- 5% for 400 kV, 765 KV; +/- 10% for 220 kV & below in India

l. In India, the Grid Code specifies that system operator shall make all efforts to evacuate the available Solar and Wind power and treat them as a must-run station except in a scenario where doing so will be against grid security or safety considerations. Other Grid Codes do not specify such requirements.

6.3.3 Demand Estimation for Operational Purposes

Table 6.14: Demand Estimation in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	6.3
Bhutan	6.8
India	5.3
Nepal	-
Pakistan	OC 2.2

Member State	Grid Code Section
Sri Lanka	4.5

a. In India, SLDCs are responsible for demand estimation (MW, MVAr and MWh) for daily/weekly/monthly/yearly basis and in Bhutan Distribution licensee is responsible for the same. Transmission licensee is responsible for the same in Pakistan, Bangladesh and Sri Lanka.

b. In India, SLDCs shall take into account the Wind Energy forecasting to meet the active and reactive power requirement. Same is not mentioned in other Grid Codes.

6.3.4 Demand Management

Table 6.15: Demand Management in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	8.4
Bhutan	6.9
India	5.4, CERC (Measures to relieve congestion in real time operation) Regulations, 2009
Nepal	6.5.2, 6.8.2
Pakistan	OC 3.1, OC 3.4.5
Sri Lanka	4.18

a. SLDCs in India, System Operator and Distribution Licensees in Bhutan, System Operator and Distribution licensees in Pakistan, System operator in Nepal, Transmission licensee in Sri Lanka and NLDC in Bangladesh should make provisions to reduce their demand in the event of insufficient generating capacity or supply from external interconnections.

b. Grid Code of India specifies that the SLDCs/SEB/Distribution licensee shall initiate action to restrict drawl of its control area within scheduled value when the frequency falls to 49.7 Hz and shall ensure requisite load shedding is carried out to prevent over drawl when frequency is 49.5 Hz and below. Also, when frequency is above 49.7 Hz and below 50.1 Hz, each control area shall ensure the over drawl/under injection during a time block (15 minute blocks) shall not exceed 12% of scheduled value or 150 MW, whichever is lower. Grid Codes of all other Member States mention that during frequency level problems, the concerned entity shall give instructions to distribution licensees to decrease their drawl by a certain quantum. Also, Pakistan Grid Code specifies that when system frequency falls to 49.4 Hz or below, load shedding must be carried out to bring the frequency back to at least 49.8 Hz.

c. Load Shedding/Dropping Schemes:

- According to India Grid Code, SLDCs through their respective State Electricity Boards/Distribution Licensees shall formulate and implement state-of-the-art demand management schemes for automatic demand management like rotational load shedding, demand response, etc. and the interruptible loads shall be categorized into four non-overlapping groups, for scheduled load shedding, for unscheduled load shedding, for shedding through under frequency/df/dt relays and for shedding through System Protection Schemes (SPS).
- Nepal Grid Code specifies that the distributor/HV Consumer shall split the demand into discrete MW blocks for automatic load dropping and the number of such blocks shall be specified by system operator. Two groups of digital under frequency relays shall be provided- Group A for frequency level < 49.0 Hz and Group B for frequency level < 48.0 Hz. Under frequency settings shall be provided by system operator. Grid Owner of Nepal shall install under frequency relays to cover about 50% of the System peak demand on feeders spread all over the distribution network to provide a reasonably uniform disconnection in the Distribution System.
- Bhutan Grid Code specifies that if required by system operator then the distribution licensees shall provide automatic under-frequency load shedding facilities in their respective systems and details of arrangements of demand into discrete blocks to system operator.
- Pakistan Grid Code specifies that facility to disconnect demand during low frequencies is given at all transmission connection points and System Operator shall provide automatic load shedding groups and the amount of load to be shed
- Sri Lanka Grid Code specifies that an automatic under-frequency load shedding program will be implemented by the Transmission Licensee to control the system demand. Distribution licensees shall provide details to transmission licensee identifying feeders at each grid substation as essential and non-essential loads with feeders having non-essential loads being further categorized in the order of priority.

d. In India, regulations applicable during scenarios of congestion in the inter-control area transmission lines have been laid down. For each inter-control area transmission line, CTU shall declare the corresponding Total Transfer Capability (TTC), Available Transfer Capability and Transmission Reliability Margin (TRM). If the flow in an inter-control area transmission line exceeds its ATC, then NLDC/RLDC shall give a warning to involved entities and if it exceeds TTC, then applies congestion charges over and above the Unscheduled Interchange (UI) charges to the defaulting entities. There are no such regulations concerning congestion charge mechanisms for relieving congestion during real time operation in other SAARC Member States.

e. The measures taken to reduce the drawl from the Transmission System shall not be withdrawn as long as the frequency/voltage remains at a low level or congestion continues unless specifically permitted by the System Operator (Pakistan, Nepal & Bhutan) and RLDC/SLDC (India). The same is not mentioned in Bangladesh Grid Code.

6.3.5 Periodic Reports

Table 6.16: Periodic Reports Requirement in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	6.14
India	5.5
Nepal	-
Pakistan	-
Sri Lanka	4.17

a. Weekly and Monthly reports covering performance of the national / integrated grid in previous week shall be prepared by NLDC, in India. In Bhutan, a quarterly report shall be issued by the System Operator which covers the performance of the Transmission System for the previous quarter.

b. Daily, Weekly and Quarterly reports covering the performance of the regional grid shall be prepared by each RLDC (India) based on the inputs received from SLDCs/Users.

6.3.6 Operational Liaison

Table 6.17: Operation Liaison in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	6.13
India	5.6
Nepal	-
Pakistan	OC 6.1.1
Sri Lanka	4.2

Operational liaison (to facilitate quick transfer of information to operational staff) is briefed in India, Pakistan and Bhutan Grid Codes.

6.3.7 Outage Planning

Table 6.18: Outage Planning in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	6
Bhutan	6.11
India	5.7
Nepal	-
Pakistan	OC 4.1.3
Sri Lanka	4.11

a. In India, annual outage plan shall be prepared in advance for the financial year by the Regional Power Committee [31] (RPC: There are five Regional Power Committees covering Northern, Western, Southern, Eastern and North Eastern) Secretariat in consultation with NLDC and RLDC and reviewed during the year on quarterly and Monthly basis. This will be done after carrying out necessary system studies and, if necessary, the outage programs shall be rescheduled. All Users, CTU, STU etc. shall follow these annual outage plans. In Bhutan, system operator shall be responsible for analyzing the outage plans given by all Licensees, and finalization of the outage plan for the following calendar year. In Nepal, Users/generators will interact with system operator to plan for outages of grid / generators. In Bangladesh, the Transmission Licensee shall produce a yearly transmission outage program for the period July to June. In Sri Lanka, the transmission licensee shall establish a transmission outage program with a three year window; Year 3 will be indicative with tentative dates, year 2 will be rolling over to the Year 3 program, and the Year 1 will be the committed outage plan. In Pakistan, System Operator shall finalize the outage plan for the following year based on the discussions with generation and distribution licensees and other transmission consumers.

b. Pakistan Grid Code specifies that adjustments to outage schedule are allowed but there is no commitment on others to adjust their outage plan. NLDC/RLDC (in India) and system operator (in Nepal) are authorized to defer the planned outage in case of any of the following, taking into account the statutory requirements:

- Grid disturbances
- System isolation

- Partial Black out in a state
- Any other event in the system that may have an adverse impact on the system security by the proposed outage.

6.3.8 Recovery Procedures

Table 6.19: Recovery Procedure in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	6.12
India	5.8
Nepal	-
Pakistan	OC 8

The RLDC (in India), system operator (in Bhutan and Pakistan) and Transmission Licensee (in Bangladesh and Sri Lanka) 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.

6.3.9 Event Information

Table 6.20: Event Information in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	6.15
India	5.9
Nepal	-
Pakistan	OC 7.3.1
Sri Lanka	4.23

Event information details are mentioned in India, Pakistan and Bhutan Grid Code and same is not mentioned in other Grid Codes.

6.4 Schedule & Dispatch Code

In this section, a comparative analysis of Schedule and Dispatch Codes of all Member States, where Gird Code exist, is presented.

6.4.1 Objective

Table 6.21: Objective of Schedule and Dispatch Codes in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	7.2
Bhutan	7.2
India	6.2
Nepal	7.1
Pakistan	SDC 1.1
Sri Lanka	5.3

In Bhutan, this Code is applicable to the System Operator, Generation Licensees, Distribution Licensees and Large Consumers and in Nepal, it is applicable to the System Operator; Grid Owner; Generators; Distributors; and any other non NEA entity with a User System connected to the Grid. In India, this code shall be applicable to NLDC, RLDC/SLDCs, ISGS, Distribution licensees / SEBs / STUs / regional entities, Power Exchanges, wind and solar generating stations and other concerned persons in the National and Regional grid. Pursuant to Sri Lanka Grid Code, it applies to the Transmission Licensee, Generation Licensees, Distribution Licensees, Transmission Customers and Embedded generators where as in Bangladesh it applies to NLDC, Generator and Distribution Licensee. As per Pakistan Grid Code, it applies to centrally dispatching generation units, system operator, transmission consumers and other NTDC Code Participants.

6.4.2 Demarcation of Responsibilities

Table 6.22: Demarcation of Responsibilities the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	7.4
Bhutan	7.4
India	6.4

Member State	Grid Code Section
Nepal	7.3
Pakistan	SDC 1.1
Sri Lanka	5.6

a. In India, the regional grids shall be operated as loose power pools with decentralized scheduling and dispatch, in which the States shall have operational autonomy. In other Member States, centralized scheduling and dispatch is being followed.

b. In India, if regional entities deviate from the drawl schedule, within the limit specified by the CERC in Deviation Settlement Regulations as long as such deviations do not cause system parameters to deteriorate beyond permissible limits and/or do not lead to unacceptable line loading, however, such deviations from net drawl schedule shall be priced through the Deviation Settlement Mechanism (DSM). DSM rates are also applicable for generator when deviations occur with respect to scheduled values. Other Grid Codes have no provisions which are similar to DSM mechanism. India has progressively moved to a stricter regime in respect of deviations from schedules and penalties have also been increased. Even under-drawl is considered a deviation.

c. In all Grid Codes, Generators are responsible to provide their capability for the day-ahead schedules. In India, Pakistan and Sri Lanka, the current day revisions are also allowed. IEGC specifies that generation be scheduled for 15 minute time blocks, for Pakistan it is half hourly basis whereas for all other Member States it is on hourly basis.

d. According to Indian Grid Code, any bilateral agreements between buyer and seller for scheduled interchanges on long-term, medium – term basis shall also specify the interchange schedule, which shall be duly filed with CTU and CTU, shall inform RLDC and SLDC, as the case may be about these agreements in accordance with CERC Regulations, 2009. All other regional entities should abide by the concept of frequency-linked load dispatch and pricing of deviations from schedule. Similar regulation is not included in other Grid Codes.

e. Pakistan and India Grid Codes exclusively specify that for generators working with different fuels, availability shall be declared with respect to each fuel type.

f. In India, the hydro generating stations shall be free to deviate from the given schedule without causing grid constraint and a compensation for difference between the actual net energy supply by the hydro generating station and the scheduled energy (ex-bus) over day shall be made by the concerned Regional Load Dispatch Centre in the day ahead schedule for the 4th day (day plus 3). In Bhutan, when the frequency is higher than 50.5 Hz, and spilling of water is not envisaged, the System Operator shall reschedule the dispatch schedule of generating stations. Similarly, in the event of frequency falling below 49.5 Hz the System Operator may consider revision in dispatch schedule after examining the overall inflow position and scheduled dispatch of other generating stations.

g. In India, NLDC shall be responsible for scheduling and dispatch of electricity over inter-regional links in accordance with the Grid Code. NLDC shall also be responsible for coordination for trans-national exchange of power. In Bhutan, Bangladesh, Pakistan and Nepal, the system operator is responsible for the same whereas in Sri Lanka it is the Transmission licensee.

h. Indian Grid Code specifies that generators can deviate from the schedules within the limits specified in CERC DSM regulations. Whereas Pakistan Grid Code specifies that system operator may give notice to generators to increase their output during a settlement period.

6.4.3 Scheduling and Dispatch Procedure for Long-Term Access, Medium-Term and Short-Term Access

Table 6.23: Scheduling & Dispatch Procedure in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	7.3
Bhutan	7.5
India	6.5, CERC (Open Access in inter- State Transmission) Regulations, 2008
Nepal	7.5
Pakistan	SDC 14.3
Sri Lanka	-

a. In India, by 8 am every day, the ISGS shall advise the concerned RLDC, the station-wise ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 00:00 hrs to 24:00 hrs of the following day. Where as in Bhutan the time frame is 9 am, in Pakistan it is 10 am and before 12 noon in Nepal, Bangladesh and Sri Lanka.

b. According to Indian Grid Code, all renewable energy power plants, except for biomass power plants, and non-fossil fuel based cogeneration plants whose tariff is determined by the CERC, shall be treated as ‘MUST RUN’ power plants and shall not be subjected to ‘merit order dispatch’ principles. The same is not present in Bhutan and Nepal as both are dominated by hydro power exclusively.

c. In the event of bottleneck in evacuation of power due to any constraint, outage, failure or limitation in the Transmission System, associated switchyard and substations owned by the Transmission Licensee, sudden demand change by the Distribution Licensees or Large Consumers, the System Operator shall revise the schedules and advise the NLDC in Bhutan. Whereas in India, RLDC shall revise the schedules which shall become effective from the 4th time block.

d. According to Indian Grid Code, revision of declared capability by the ISGS(s) having two part tariff with capacity charge and energy charge (except hydro stations) and requisition by beneficiary(ies) for the remaining period of the day shall also be permitted with advance notice. Where as in Bhutan, revision of declared capability by the Generating stations (exporting power to Indian Transmission System) for sudden increase or decrease in inflows for the remaining period of the day shall be allowed with advance notice. The concerned generator may advise the System Operator in Bhutan of such revision who shall then forward the information to NLDC in Bhutan.

e. According to Indian Grid Code, in case of forced outage of a unit for a Short Term bilateral transaction, where a generator of capacity of 100 MW and above is seller, the generator shall immediately intimate the same along with the requisition for revision of schedule and estimated time of restoration of the unit, to SLDC/RLDC as the case may be.

f. According to Indian Grid Code, When for the reason of transmission constraints e.g. congestion or in the interest of grid security, it becomes necessary to curtail power flow on a transmission corridor, the transactions already scheduled may be curtailed by the Regional Load Dispatch Centre. The short-term customer shall be curtailed first followed by the medium term customers, which shall be followed by the long-term customers and amongst the customers of a particular category, curtailment shall be carried out on pro rata basis.

g. The day ahead generation schedules will be informed to the respective generators not less than seven hours before the beginning of each day in Bangladesh, by 6 pm (1800 hrs) in India and Bhutan, by 4 pm (1600 hrs) in Nepal, by 5 pm (1700 hrs) in Pakistan and 3 pm (1500 hrs) in Sri Lanka.

h. RLDC (in India) and system operator (in Nepal) shall document all the information regarding schedules and drawl.

i. **Scheduling of Collective Transactions**: Provisions for buyers and sellers of power to participate in power trade through a power exchange has been made only in the Grid Code of India. Regional Entities in India can participate by availing of short-term open access to inter-control area transmission facilities. Other state utilities/intra-state entities shall obtain “Standing Clearance/No Objection Certificate” from their respective SLDCs for participating through Power Exchange. NLDC shall, by 11:00 hrs on the previous day, provide the power exchange a list interfaces / control areas / regional transmission systems on which unconstrained flows are required and the power exchange shall furnish the same by 13:00 hrs along with the information of total drawl and injection in each of the regions. Based on this information, NLDC shall check for congestion and inform the same along with available limit for scheduling collective transactions to the Power Exchange by 14:00 hrs. After ensuring that the scheduled collective transactions are within the limits, Power Exchange shall submit the same to NLDC by 15:00 hrs. NLDC shall send the details to different RLDCs for final checking and accommodating in their schedules. RLDCs shall confirm on the same by 17:00 hrs and NLDC shall inform the power exchanges about the acceptance by 17:30 hrs. RLDCs shall schedule the Collective Transaction at the respective periphery of the Regional Entities and individual transactions for State Utilities/intra-State Entities shall be scheduled by the respective SLDCs based on the detailed breakup of each point of injection and each point of drawl within the State provided by the power exchanges.

j. As per India Grid Code, the Power Exchange shall ensure that the necessary infrastructure for data exchange/communication with NLDC/RLDCs and SLDCs is put in place prior to commencement of the operation and shall be responsible for the day to day maintenance of the same. Power Exchange shall be responsible for Settlement of Energy Charges, Price Discovery and Settlement arising due to Congestion, with its participants.

k. **Sharing of Transmission Losses:** Regulation for sharing of transmission losses amongst the designated transmission customers has been laid down in India. Grid Codes of other Member States have not specified any regulations concerning sharing of losses. Central Electricity Regulatory Commission (Sharing of Inter State Transmission Charges and Losses) Regulations, 2010 and its amendments contain the procedures and mechanism to be followed. An Implementing Agency (IA), approved by CERC, shall compute loss allocation factors using the Hybrid method and losses shall be apportioned to the DICs (Designated ISTS Customers) by suitably adjusting their scheduled MWs. The Intra-State transmission system losses shall be taken care of in the Schedules by respective SLDCs.

6.4.4 Reactive Power and Voltage Control

Table 6.24: Reactive Power & Voltage Control in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	8.5
Bhutan	7.6
India	6.6

Member State	Grid Code Section
Nepal	-
Pakistan	SDC 2.4.2.5
Sri Lanka	-

a. In India Grid Code, reactive energy drawl at the rate of 10 paisa/ kVArh (with an increase of 0.5 paisa/ kVArh per year) is mentioned and same is not mentioned in other Grid Codes.

b. In general, the Distribution Licensees (in Bhutan) and Regional Entities except Generating Stations (in India) shall endeavor to minimize the reactive power drawl at an interchange point when the voltage at that point is below 95% of rated, and shall not return reactive power when the voltage is above 105%. ICT taps at the respective drawl points may be changed to control the reactive power interchange as per Distribution Licensee's (in Bhutan) and Regional Entities except Generating Station's (in India) request but only at reasonable intervals. In Pakistan, system operator can instruct generators to provide reactive power support for voltage control.

c. In India, hydro generating units of capacity 50 MW and above shall be capable of operation in synchronous condenser mode. The quantum of absorption/injection of reactive power shall be instructed by the appropriate load dispatch center.

d. Switching in/out of all 400 kV Bus and Line Reactors throughout the grid and Tap changing on all 400/220 kV ICTs shall also be done as per RLDCs instructions only in India whereas in Bhutan, the Bus and Line Reactors at all voltage levels and tap changing of all ICTs up to 66/33 kV level shall be done as per instructions of System Operator.

6.5 Metering Code

In this section, a comparative analysis of the Metering Codes of various countries is presented.

6.5.1 Applicability of Regulations

Table 6.25: Applicability of Regulations in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13
Bhutan	Annexure 3
India	3

Member State	Grid Code Section
Nepal	9.2
Pakistan	PMC 2.1 (f)
Sri Lanka	6.2

a. 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 Member States, however, the same is not explicitly mentioned in their Grid Codes.

b. In India, the meters are classified into three categories: Interface, Consumer, Energy accounting and audit meters. Where as in Pakistan, revenue meters are used for the purposes of billing, engineering studies and planning. In Bangladesh, the meters are classified as Generation, Transmission and Distribution connected Meters. In Nepal, the meters are classified as Energy Meters and Bi-directional Meters. Bhutan Grid Code only specifies energy meters.

6.5.2 Standards

Table 6.26: Standards in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.3.3,13.4.3,13.6.5,13.6.6
Bhutan	5.6
India	5
Nepal	9.5
Pakistan	PMC 2.1 (f)
Sri Lanka	3.4.7

The meters in India shall comply with Bureau of Indian Standards (BIS). If relevant BIS are not available, it shall follow the relevant IEC Standard. Pakistan, Sri Lanka, Nepal and Bangladesh follow IEC standards. Bhutan and Bangladesh follow their own country specific meter standards.

6.5.3 Ownership of Meters

Table 6.27: Ownership of Meters in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.3.2,13.4.2 ,13.6.2
Bhutan	Annexure 3.3
India	6
Nepal	9.4
Pakistan	PMC.2.1(d)
Sri Lanka	6.5.4

In all the Member States, where Grid Code exist, the meters provided in transmission system are owned and maintained by Transmission licensees. In India, the meters used for real time monitoring are interface meters and energy accounting meters are for billing purposes. In all Member States except for Pakistan, billing is processed by system operators. In Pakistan, billing is processed by Central Power Purchasing Agency (Guaranteed) – the single buyer, based on the data provide by the system operator.

6.5.4 Locations of Meters

Table 6.28: Location of Meters in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	Annexure 3.3
India	7
Nepal	9.3.5
Pakistan	PMC 2.1.(b)
Sri Lanka	6.5.5

In all Member States, the meters shall be located at outgoing feeders of generation substation (common connection point). Metering for transmission lines in India is done at both ends of the line between substations of two different licensees.

6.5.5 Operation, Testing and Maintenance of Meters

Table 6.29: Operation, Testing and Maintenance in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.6.3, 13.6.4
Bhutan	Annexure 3.4 5.13.8 (vi)
India	10
Nepal	9.7
Pakistan	-
Sri Lanka	6.8

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

6.5.6 Meter Reading and Recording

Table 6.30: Meter Reading and Recording in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.3.5 , 13.4.4, 13.6.7,13.6.8
Bhutan	7.4.9, Annexure 3.9
India	14
Nepal	9.6
Pakistan	PMC.2.1(i)
Sri Lanka	6.7.3 ,6.7.4

a. All Member States have the provision to transfer the meter readings which are connected at transmission connection point to remote location through data communication channels.

b. Grid Code of India specifies that the Inter-State Transmission licensee, the CTU, shall install special energy meters on all inter connections between the regional entities and other identified points for recording of active and reactive power exchanges. The State Grid Codes specify the same for intra-state transmission licensee, the STU. The meters shall be of static type. Weekly readings of the meters located between two control areas/ regional entities shall be forwarded to the RLDC for computation of net drawl / injection who will then forward it to RPC Secretariat for issuing the Unscheduled Interchange account.

Bhutan Grid Code specifies that energy meters shall be installed on all interconnections with the Distribution Licensees and with generators and other identified points for recording of actual bilateral energy exchange and reactive energy drawls. The System Operator shall be responsible for computation of actual energy export/import of each generating stations and at each distribution point. Meters are installed and owned by the licensees in whose premises the meter is installed.

Bangladesh Grid Code specifies that at each metering point associated with determination of energy exported or imported the Transmission Licensee shall install, own and maintain a metering system.

NEA Grid Code specifies that Bi-directional meters shall be installed at all the connection points between Grid and Distributor/Generator to measure active and reactive energy exchange.

Pakistan Grid Code specifies that metering facility shall be provided at the Point of Connections between Code Participants and NTDC to record energy and Maximum power (active and Reactive power both) supplied to or delivered from the Transmission system of NTDC for the purposes of billing, engineering studies and planning. NTDC shall install these energy meters.

c. In case of meter failure, the data is taken from backup meters in countries like India, Nepal, Sri Lanka, Bhutan and Bangladesh. The same is not explicitly mentioned in Pakistan Grid Code.

6.5.7 Meter Failure or Discrepancies

Table 6.31: Meter Failure or Discrepancies in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	Annexure 3.5
India	15
Nepal	9.6.2
Pakistan	PMC.2.1(j)
Sri Lanka	6.8.3

The procedures for Meter failure or discrepancies are specified in all the Member States' Grid Codes except for Bangladesh.

6.5.8 Testing and Calibration

Table 6.32: Testing and Calibration in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.3.4, 13.6.10
Bhutan	Annexure 3.10
India	18
Nepal	9.5.4
Pakistan	PMC.2.1(m)
Sri Lanka	6.8.2, 6.5.4

All the Member States have specified the testing and calibration procedures in their respective Codes.

6.5.9 Accuracy Class of Meters

Table 6.33: Accuracy Class of Meters in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.3.3, 13.4.3, 13.6.5, 13.6.6
Bhutan	Annexure 3.10& 3.7
India	8
Nepal	9.5.1 to 9.5.3
Pakistan	PMC.2.1(g)
Sri Lanka	6.6.1

All the Member States have specified the meter accuracy level as +/- 0.2%.

6.5.10 Access to Meter

Table 6.34 Access to Meter in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	13.3.3, 13.4.3, 13.6.5, 13.6.6
Bhutan	Annexure 5.13.13
India	10
Nepal	9.7.1.3, 9.7.1.4
Pakistan	PMC.2.1(k)
Sri Lanka	6.4.2

All the Grid Codes specify that 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.

6.6 Protection Code

In this section, a comparative analysis of the Protection Codes of various Member States is presented.

6.6.1 Organizations Responsible For System Protection

Table 6.35: Relevant Organizations in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	12.4
Bhutan	6.7.3.2
India	2.4, 5.2
Nepal	5.7
Pakistan	PMC 2.2
Sri Lanka	2.12

a. Regional Power Committee (RPC) and its subcommittee called Protection Coordination Sub-Committee are responsible for undertaking protection studies, coordinate with users for determination and approval of relay settings and finalize a protection coordination plan in India, where as National Transmission and Dispatch Company (NTDC) for

Pakistan, the transmission licensee for Bangladesh and Sri Lanka, Grid Owner for Nepal and System Coordination Committee (SCC) for Bhutan. All the Grid Codes specify that the users shall furnish the required data for protection coordination.

b. The design, installation and maintenance of protection system is carried out by, NTDC and Users in Pakistan, Users and Transmission Licensee for Bhutan, Bangladesh and Sri Lanka, Users and Grid Owner for Nepal, Users, STU/SLDC, CTU/RLDC and NLDC in India.

6.6.2 General Guidelines

Table 6.36: General Guidelines in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	12.10.1
Bhutan	6.7.3.3
India	IEGC 5.2, Technical Standards for Connectivity to Grid, CEA Regulations, 2007
Nepal	5.7.1.2, 6.4.2.7
Pakistan	PMC 2.2 (C)
Sri Lanka	3.5

a. All the Grid Codes except the Grid Code regulation of Bhutan specify that:

- Every element of the power system shall be protected by a standard protection system having the required reliability, selectivity, speed, discrimination and sensitivity.
- An additional protection as back up protection besides the main protection shall be provided.
- The user shall protect his system from faults within his site and from those originating in the grid.
- Protection system shall reliably detect faults and various abnormal conditions within the protection zone and appropriate means to isolate them.
- Circuit Breaker fail protection or Local Breaker Back up protection shall be provided.

b. Grid Codes of India and Bhutan specify that System Protection Schemes (SPS) for operating the system closer to its limits, protection from voltage collapse, cascade tripping and tripping of important corridors shall be provided. Grid Codes of other countries have no specification about such special protection schemes.

6.6.3 Generator and Substation Protection

Table 6.37: Generator and Substation Protection in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	12.10.1, 12.6,12.7
Bhutan	-
India	Technical Standards for Connectivity to Grid, CEA Regulations, 2007
Nepal	5.7.2, 5.7.3.2
Pakistan	PMC 2.2 (C),(D),(E)
Sri Lanka	3.9.10

a. India, Pakistan and Bangladesh Grid Codes explicitly specify that Bus Bar protection shall be provided.

b. All Grid Codes with the exception of Bhutan specify that generators should be protected from faults within the premises and in the grid.

c. India Grid Code specifies that all generators above 100 MW of capacity shall have two independent sets of main protection schemes and a backup protection scheme. Other Grid Codes specify that generators be provided a main and back up protection scheme. Clearance period will be as per connection agreement.

d. Grid Codes of India, Pakistan and Bangladesh specify that each transmission line shall be provided with two sets of distance protection schemes and a backup scheme whereas Nepal NEA Grid Code specifies that a minimum of one distance protection scheme and a backup scheme shall be provided. Sri Lanka and Bhutan Grid Codes do not specify anything about line protection.

6.6.4 Disturbance Recording and Event Logging Facilities

Table 6.38: Disturbance Recording Facilities in the Grid Codes of the SAARC Member States

Member State	Grid Code Section
Bangladesh	-
Bhutan	-

Member State	Grid Code Section
India	Technical Standards for Connectivity to Grid, CEA Regulations, 2007.
Nepal	5.7.3.4
Pakistan	PMC 2.2 (G)
Sri Lanka	-

Both India and Pakistan Grid Codes specify that at all transmission connection sites, disturbance recording and event logging facilities along with time synchronization facility for global common time reference shall be provided. NEA Grid Code of Nepal specifies that the distance protection relays shall have in-built facilities for fault locator, event recorder and disturbance recorder. No such specification are given in other Grid Codes.

7.0 Summarized Analysis

Consolidated analyses of the Grid Codes of all the SAARC Member States, where Grid Code exist i.e. Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka, are summarized below:

a. The Grid Codes of all Member States except for Nepal are legal documents. These Grid Codes are backed by authority of the law of the respective country and require full compliance from the grid users. However, NEA Grid Code of Nepal is still a draft document and hence, full compliance by non-NEA Grid Users is not mandatory by law.

b. The Planning Code of the Grid Codes of all Member States except for India specifies the entities responsible for Generation and Transmission Expansion Planning and the philosophy and criteria for the same. However, the Planning Code of the Indian Grid Code specifies only about Inter-State Transmission System Planning. The plan for Generation Capacity addition in India is provided in the National Electricity Plan, prepared once every five years. Demand forecast is computed through by Electric Power Survey (EPS). Both these documents would be prepared by CEA. Generation planning and distribution system operation is part of the State Grid Codes.

c. The transmission licensees of Pakistan, Sri Lanka and Nepal are responsible for preparing both Generation and Transmission Plans, whereas System Planner in coordination with the transmission licensee is responsible in case of Bangladesh. Similarly, System Operator, a subsidiary of the transmission licensee, is responsible for generation and transmission planning in Bhutan. In India, CEA is responsible for generation planning and the transmission licensees (CTU, STUs) in coordination with CEA, RPCs, etc. are responsible for transmission planning.

d. In case of India, the transmission planning criteria, as developed by CEA, specifies security and reliability limits to be considered at planning stage which are more stringent than the operational security and reliability limits. A planning margin is specified for voltage limits, thermal loading limits of lines and transformers, reactive capabilities of generators, fault levels etc. Grid Codes of other SAARC Member States do not specify conditions on planning margin and only specifies operational security limits as planning criteria.

e. In India, the CERC Regulations 2009 (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter- state Transmission and related matters) state that the nodal agencies shall take steps to provide as much information to the public at regular intervals through various means of communications, including internet, so that information is disseminated widely and in such form and manner which is easily accessible to the public. However, Grid Codes of other SAARC Member States specify that the confidentiality of the user information made available to the licensee shall be maintained.

f. The Grid Codes of all the SAARC Member States specify that the system shall remain within security limits even after the outage of single circuit/transformer/other facilities at transmission voltage level ('N-1' Criterion). Indian Grid Code also specifies that 'N-1' contingency criterion is applicable for HVDC Back-to-Back Station or HVDC Bi-Pole line. The Grid Code of India also specifies that 'N-1' criterion shall be considered assuming an already planned outage of another circuit in another corridor and not emanating from the same substation.

g. The Grid Code of India specifies the transient stability criteria to be satisfied by the system. It provides detailed description of the disturbances to be considered for the stability study and the maximum fault clearance times. Among other Member States, only Bangladesh and Pakistan specify that system shall survive a permanent three phase to ground fault on the 400 kV (Bangladesh) or 500/220 kV (Pakistan) with a fault clearance time of 100 ms. Incidentally, this fault clearance time is in agreement with that followed in India. 'N-1-1' stability criterion is exclusively specified in Grid Code of India for critical elements.

h. The Grid Codes of India and Sri Lanka stipulates that the grid system shall survive the loss of a single generator. The Grid Codes of other Member States do not specify such a criterion.

i. With the exception of the Grid Code of Bhutan which states that plans for power export with respect to transmission facilities shall be included in the Power System Regional Plan, other Grid Codes do not specify any provisions concerning the planning of cross-border interconnections.

j. Connection to the transmission grid is at voltage levels 132 kV, 230 kV or 400 kV for Bangladesh; 132 kV, 220 kV or 400 kV for Bhutan; 132 kV, 220 kV, 230 kV, 400 kV or 765 kV for India; 132 kV or 220 kV for Nepal; 220 kV or 500 kV for Pakistan and 132 kV or 220 kV for Sri Lanka. Therefore, 400 kV, AC cross-border interconnections are possible between India-Bangladesh, India-Bhutan and between India and other Member States only at 220 kV AC interconnections are feasible. However, in view of the system security aspects, HVDC back-to-back connections are preferred between India and Bangladesh, India and Pakistan. Also Mono-polar or Bi-polar HVDC line between Indian and Sri Lanka is the feasible option for interconnections.

k. The Grid Code of India specifies that all utilities shall have in place, a cyber-security framework to identify the critical cyber assets and protect them so as to support reliable operation of the grid; whereas Grid Codes of other Member States do not specify any such regulations.

l. The Grid Codes of Bangladesh, Bhutan and India specify that the procedures for cross border connection to the transmission system shall be done by the transmission licensee/authorized agency. Other Grid Codes do not specify the cross border connection provisions.

m. Grid Codes of India, Pakistan and Sri Lanka include regulation on connection requirements for Wind generators. Both India and Sri Lanka Grid Codes specify that the harmonic current injections from a generating station shall not exceed the limits specified in IEEE Standard 519; the generating station in India shall not introduce flicker beyond the limits specified in IEC 61000 and in Sri Lanka, shall comply with IEC 61400-21 standard and P28 Engineering recommendations of UK. As per Pakistan Grid Code, Power quality parameters shall be governed by latest IEC Standards prevailing at the time of Financial Closing. Grid Codes of India, Pakistan (power factor 0.95 lagging to 0.95 leading at the point of interconnection) and Sri Lanka specify that Wind generators shall have dynamic reactive power support capability. For Wind Power Plants, Grid Codes of India and Sri Lanka specify the Low Voltage Ride Through and Active Power Regulation capability; ability to operate in the frequency band (47.5 Hz to 52 Hz for India, 47.5 Hz to 52.5 Hz for Sri Lanka). Pakistan Grid Code, as well, regulates the Wind Power Plants with respect to Low Voltage Ride Through, exemption from frequency regulation and control, Power Quality, Power Generation Capability Forecasting and upper limit of the total grid connected Wind power equal to 5% of the total installed capacity.

n. Indian Grid Code specifies the connection requirements for generating stations using inverters (e.g. Solar). It specifies the generating station shall not inject DC current greater than 0.5% of the full rated output at the interconnection point. As per Indian and Pakistan Grid Code, each Solar Power Plant shall provide dynamic reactive power support at the interconnection point. Further the Grid Code of Pakistan establishes regulation for PV Solar Power Plants pertaining to Data Requirements, Synchronization/De-Synchronization, Ramp Rate, Power Quality Requirements, Power Generation Capability Forecasting and Low Voltage Ride Through.

o. In India, owing to its transmission system spread over a vast geographical area, the responsibility of Transmission System Operation is decentralized with, NLDC which is responsible for Inter-regional transmission system, RLDCs responsible for Inter-State Transmission System and SLDCs and Sub-LDCs responsible for Intra-state transmission system. In other SAARC Member States, the transmission grid operation is vested with a single entity authorized by law.

p. The Grid Code of India specifies that generators of rating above 200 MW (Thermal) or 10 MW (Hydro) are mandated to have governors in operation. Bhutan Grid Code specifies the same for Hydro units above 10 MW and Pakistan Grid Code specifies similar regulation for Thermal units (above 100 MW) and reservoir-based units. Grid Codes of Bangladesh, Sri Lanka and Nepal only specify that generators shall have a governor in operation.

q. The Grid Code of India specifies that governors can be operated in Restricted Mode whereas other Grid Codes specify a free governor mode of operation.

r. The Grid Codes of all Member States except India specify that adequate operating reserves (Spinning/Contingency/Stand-by) shall be made available for use during contingency conditions and large demand variation conditions. Grid Code of India does not explicitly mention about operating reserves but it specifies that all Thermal generating units of 200 MW and above and all Hydro units of 10 MW and above operating at or up to 100% of their Maximum Continuous Rating (MCR) shall be capable of instantaneously picking up to 105% and 110% of their MCR, respectively.

s. The Grid Code of India states that the SLDCs shall take into account the Wind Energy forecasting to meet the active and reactive power requirement. Other Grid Codes do not specify any provisions for considering Wind forecast in preparing schedules.

t. The Grid Code of India specifies that the system operator of India shall treat Wind and Solar plants as 'MUST RUN' generation plants and shall make all efforts to evacuate the available Solar and Wind power. Other Grid Codes have not laid any such provisions for scheduling of Wind and Solar power plants.

u. Indian Grid Code specifies that the regional grids of India are operated as loose power pools with decentralized scheduling and dispatch, in which the States (Control areas) shall have operational autonomy. The control areas are responsible for maintaining their real-time drawl/injection close to the scheduled value. A Deviation Settlement Mechanism is specified for calculation of charges on the Unscheduled Interchanges (UI). Grid Codes of other Member States have not specified any such settlement mechanisms.

v. All Grid Codes, except for India, specify that the generators shall be centrally dispatched by the respective system operator. In India, the Inter-State Generating Stations (ISGS) are dispatched by concerned RLDC and Intra-State Generating Stations are dispatched by concerned SLDC. In India, generation dispatch schedules are prepared for fifteen minute time blocks, in Pakistan for half hour time blocks and in all other SAARC Member States, hourly time blocks are being followed.

w. Daily time for informing the generation schedules to the respective generators vary with each of the Member State. For Bangladesh, it is not less than seven hours before the beginning of each day, by 6 pm (1800 hrs) in case of India and Bhutan, by 4 pm (1600 hrs) for Nepal, by 5 pm (1700 hrs) for Pakistan and 3 pm (1500 hrs) for Sri Lanka.

x. The Grid Code of India has laid down procedures for scheduling collective transactions i.e. buyers and sellers of power to participate in power trade through Power Exchange(s). Other Grid Codes have neither specified any procedures for operating power exchanges nor any such exchange exist other than India.

y. The Grid Code of India specifies that non-discriminatory Open Access to the transmission grid shall be provided to any generating company or licensee or consumer on payment of charges. Procedures and regulations for calculation of transmission charges for open access users have also been laid down. Electricity regulations in other

Member States do not have provisions for Open Access where electricity sector is managed through a single buyer market. Mechanism for sharing of transmission losses has also been laid down in case of India; in other Grid Codes such a mechanism is not provide.

z. The Grid Code of India has laid down procedures to be followed during different scenarios of congestion in the transmission corridors. A Congestion Charges Mechanism has also been provided for relieving the congestion in transmission lines. No such mechanism for dealing with congestion scenarios is specified in any other Grid Codes.

aa. India Grid Code specifies that all generators above 100 MW of capacity shall have two independent sets of main protection schemes and one backup protection scheme. The Grid Codes of other Member States specify that generators be provided a main and a back-up protection scheme. Grid Codes of India, Pakistan and Bangladesh specify that each transmission line shall be provided with two sets of distance protection schemes and a backup scheme whereas Nepal NEA Grid Code specifies that a minimum of one distance protection scheme and a backup scheme shall be provided. Sri Lanka and Bhutan Grid Codes do not specify anything about line protection. Bhutan Grid Code does not include Protection Code as a section.

bb. Both India and Pakistan Grid Codes specify that at all transmission connection sites, disturbance recording and event logging facilities along with time synchronization facility for global common time reference shall be provided. NEA Grid Code of Nepal specifies that the distance protection relays shall have in-built facilities for fault locator, event recorder and disturbance recorder. No such specification has been given in any other Grid Codes.

Based on the gap analysis performed for SAARC Member States and international practices, the guidelines for cross border trading for Member States are presented in section “The Way Forward”.

8.0 The Way Forward

In the perspective of cross border power trading, power system functions such as planning, connection, protection, operation and metering need to be well defined in the regulatory instrument i.e. Grid Code; relevant processes should ensure efficiency, transparency and standardization. The ultimate grid regulations harmonized with relevance to cross border trading would not replace the existing national Grid Codes for non-cross border issues but would harmonize the processes and standards concerning cross border trade. Based on the international practices for cross border trade and considering the existing transactions in South Asian region, it is suggested that the approach for the development of Regional Interconnection Code may follow the following sequence:

a. Preparation of cross border interconnection code jointly by the relevant authorities of each of the Member States who are authorized for the cross border trade;

b. Adoption and implementation of the cross border interconnection code by all the Member States involved in the cross border trade.

As part of this assignment, it is intended to develop the framework guidelines for each component of the interconnection code which can ultimately serve as the basis for preparing the cross border interconnection code, comprising of the following:

a. Planning guidelines

b. Connection Guidelines

c. Operational Guidelines

d. Capacity Allocation & Congestion management for day-ahead, intra-day and long term operations

e. Scheduling and Dispatch Guidelines

f. Guidelines of Market Rules for Balancing

The summary of each of the identified areas are described below.

8.1 Planning Guidelines

In line with the overall intent of the Article 7 of the SAARC Framework Agreement for Energy Cooperation (Electricity) as regard to planning of cross border interconnections, Regional Plan is vital and required to be prepared for each of the cross border links between the Member States. The Regional Plan can be for bi-lateral transactions or multilateral transactions but can eventually cover the entire SAARC region. It is intended that the Regional Plan shall cover a horizon of next 10 to 20 years.

Based on the existing feasibilities, cross border interconnections anticipated within the SAARC Region are provided in the Table 8.1.

Table 8.1: Potential Cross Border Inter-connections among the SAARC Member States

Interconnection	Member States
AC interconnection: 400 kV and Above	• Between India & Bhutan, India & Nepal, India & Bangladesh • Between Pakistan & Afghanistan

Interconnection	Member States
AC Interconnection of 220kV and below (on radial mode)	• Between India & Bhutan, India & Nepal, India & Bangladesh • Between Pakistan & Afghanistan
HVDC back to back and Bi-pole	• Between India & Bangladesh • Between India & Pakistan
HVDC with underground cable Transmission	• Between India & Sri Lanka • Between Sri Lanka & Maldives (at a later date with due considerations on economics)

Further, for preparation of Regional Plan, the following may be considered as planning guidelines:

a. Macro level transmission planning for cross border trading considering 400 kV and above network in connected countries for next 10 or 20 years.

b. This shall include present and future import and export agreements between the Member States.

c. The Regional Plan (both generation and Transmission) also shall include feasibility studies for future years with various possible scenarios.

d. The planned cross border link shall satisfy N-1 contingency for HVDC links and N-1-1 for AC interconnection.

8.2 Connectivity Guidelines

The proposed connectivity guidelines would consider the following aspects:

a. Guidelines shall detail the connection of Generator (exclusively available for Cross Border Trade).

b. Network connectivity and protection issues shall be dealt in detail (protection scheme which is the most stringent of two or more than two Member States would be adopted for the interconnection).

c. Communication Framework and Exchange of Data among the countries shall be dealt.

The connectivity guidelines would be in line with the overall intent of the Article 8, Article 9 and Article 10 of the Framework Agreement.

Considering the above, the following technical requirement would be included as part of the draft Connectivity Code:

a. Frequency, Voltage Requirements

b. Short Circuit Current Requirements

c. Reactive Power Requirements

d. Responsibility & Ownership

e. Protection and Control
f. Transmission pricing framework
g. Information Exchange through SCADA
h. Safely regulations
i. Cyber Security

8.3 Operational Guidelines

In order to enable secure and reliable operation of the interconnected grid, the operational guidelines would cover the following aspects:

a. Outage Planning (Annually/Monthly/Weekly)
b. Operational Security Analysis
c. Frequency control and handling of Reserves
d. Emergency operational procedures

In addition to above, the following operational security aspects would also be covered in the Operation Code:

a. Definition of power system states
b. Frequency control management
c. Voltage & reactive power management
d. Short circuit management
e. Power flow management
f. Contingency analysis and handling
g. Data Exchange (Scheduled & Real Time)
h. Protection system
i. Stability management

8.4 Guidelines for Capacity Allocation and Congestion Management

The purpose of providing these guidelines is to enable non-discriminatory access to the respective transmission grids for purpose of cross border trade in line with the overall intent of the Article 12 of Framework Agreement. The following issues shall be considered while making guidelines for cross border Capacity Allocation and Congestion management for day-ahead and intra-day operations:

a. Each Member State shall provide ATC and TTC for specific cross border transmission paths for long term and short term trading.
b. Capacity calculation methodology considering reliability margin, contingency, local system changes etc.
c. Coordinated curtailments on long term allocations
d. Forward capacity allocations for day ahead and intra-day operations

e. 60 to 70% of the trading capacity shall be from long-term contracts and remaining from short term.

f. All countries shall facilitate the network for cross border trading and shall not be constrained by any type congestions

g. Congestion relieving mechanisms

In line with the above, the Capacity Allocation and Congestion Management Code would contain the following:

a. Procedure for calculation of TTC, ATC along with reliability margins

b. Mechanism for forward capacity allocation.

c. Congestion relieving mechanism

8.5 Guidelines for Scheduling and Dispatch

The following aspects shall be considered while making guidelines for scheduling and dispatch procedures as well as draft scheduling and dispatch code for cross border flows:

a. Establishment of scheduling processes

b. Provision of information to other country system operators

c. Outage Coordination Process

d. Different tariff shall be determined for further deviations

e. Responsibility and/or applicable entities

f. Day ahead scheduling procedure

g. Intra-day scheduling/revision procedure

h. Sharing of information on schedules with other trading countries

i. Standardized Scheduling intervals (15 min, 1 hour, etc.) for cross border trade

Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AEDB	Alternative Energy Development Board (Pakistan)
AEPC	Alternative Energy Promotion Centre (Nepal)
APSCL	Ashuganj Power Station Company Limited (Bangladesh)
APTEL	Appellate Tribunal for Electricity (India)
ATE	Appellate Tribunal for Electricity (India)
AVR	Automatic Voltage Regulator
BBMB	Bhakra Beas Management Board (India)
BEA	Bhutan Electricity Authority
BEE	Bureau of Energy Efficiency (India)
BERC	Bangladesh Energy Regulatory Commission
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
BIS	Bureau of Indian Standards
BPC	Bhutan Power Corporation Limited
BPDB	Bangladesh Power Development Board
CASA-1000	Central Asia – South Asia 1,000 MW Transmission Line Project
CEA	Central Electricity Authority (India)
CEB	Ceylon Electricity Board (Sri Lanka)
CERC	Central Electricity Regulatory Commission (India)
CTU	Central Transmission Utility (India)
DABS	Da Afghanistan Breshna Sherkat (Afghanistan)
DCERP	Distribution Code Enforcement and Review Panel
DESCO	Dhaka Electric Supply Company Limited (Bangladesh)
DISCOs	Distribution Companies
DGPC	Druk Green Power Corporation Limited (Bhutan)
DHMS	Department of Hydro-Met Services (Bhutan)
DHPS	Department of Hydropower and Power Systems (Bhutan)
DoED	Department of Electricity Development (Nepal)

DPDC	Dhaka Power Distribution Company (Bangladesh)
DRE	Department of Renewable Energy (Bhutan)
DSM	Deviation Settlement Mechanism
DVC	Damodar Valley Corporation (India)
EC	European Commission
EGCB	Electricity Generation Company of Bangladesh
ENTSO-E	European Network of TSOs for Electricity
EPS	Electric Power Survey
GCERP	Grid Code Enforcement and Review Panel
GCMC	Grid Code Management Committee
GENCOs	Generation Companies
HVDC	High Voltage Direct Current
IA	Implementation Agreement
ICE	Inter-Ministerial Commission for Energy (Afghanistan)
IDCs	Island Development Committees (Maldives)
IEEE	Institution of Electrical and Electronics Engineers
IEC	International Electro-technical Commission
IEGC	Indian Electricity Grid Code
IPPs	Independent Power Producers
IPS/UPS	Integrated Power System/Unified Power System of Russia
ISGS	Inter-State Generating Stations
ISTS	Inter-State Transmission System (India)
K-Electric	K-Electric Limited formerly known as KESC
KESC	Karachi Electric Supply Company
LA	Local Authorities (Sri Lanka)
LECO	Lanka Electricity Co. (Pvt.) Ltd.
LTA	Long Term Access
LVRT	Low Voltage Ride -Through Capability
MCR	Maximum Continuous Rating
MEA	Maldives Energy Authority
MEEW	Ministry of Energy, Environment and Water (Maldives)

MEW	Ministry of Energy and Water (Afghanistan)
MMC	Market Monitoring Cell
MNRE	Ministry of New and Renewable Energy (India)
MPEMR	Ministry of Power, Energy and Mineral Resources (Bangladesh)
MPNR	Ministry of Petroleum and Natural Resources (Pakistan)
MTOA	Medium Term Open Access
MWP	Ministry of Water and Power (Pakistan)
NEA	Nepal Electricity Authority
NEEPCO	North Eastern Electric Power Corporation Limited (India)
NEPRA	National Electric Power Regulatory Authority (Pakistan)
NEPS	North East Power System (Afghanistan)
NGO	Non-Governmental Organization
NHPC	National Hydroelectric Power Corporation Limited (India)
NLDC	National Load Dispatch Centre (Bhutan)
NTDC	National Transmission and Dispatch Company (Pakistan)
NTPC	National Thermal Power Corporation Limited (India)
NWPGC	North West Zone Power Generation Company (Bangladesh)
PAEC	Pakistan Atomic Energy Commission
PEPCO	Pakistan Electric Power Company
PFC	Power Finance Corporation Limited (India)
PGCB	Power Grid Company of Bangladesh
POSOCO	Power System Operation Corporation Limited (India)
PPIB	Private Power and Infrastructure Board (Pakistan)
Power Grid	Power Grid Corporation of India
PPAs	Power Purchase Agreements
PSS	Power System Stabilizer
PUCSL	Public Utilities Commission of Sri Lanka
REB	Rural Electrification Board (Bangladesh)
REC	Rural Electrification Corporation (India)
RLDC	Regional Load Dispatch Centre (India)
RPC	Regional Power Committee

SASEC	South Asia Sub-regional Economic Cooperation Program (brings together Bangladesh, Bhutan, India, the Maldives, Nepal, and Sri Lanka)
SCADA	Supervisory Control and Data Acquisition
SCC	Systems Control Centre
SEPS	South East Power System (Afghanistan)
SERC	State Electricity Regulation Commission (India)
SLDC	State Load Dispatch Centre (India)
SPD	System Planning Department
SPS	System Protection Schemes
STELCO	State Electric Company Limited (Maldives)
STOA	Short Term Open Access
STU	State Transmission Utility (India)
TRM	Transmission Reliability Margin
TSEP	Transmission System Expansion Plan
TSO	Transmission System Operator
TTC	Total Transfer Capability
UCPTE	Union for the Co-ordination of Production and Transmission of Electricity
UDA	Urban Development Authority (Sri Lanka)
UI	Unscheduled Interchange
VOLL	Value of Lost Load
WAPDA	Water and Power Development Authority (Pakistan)
WECS	Water and Energy Commission Secretariat (Nepal)
WZPDC	West Zone Power Distribution Company (Bangladesh)

Data Tables

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