Interconnection of Regional Grids of ASEAN, SAARC/BIMSTEC and GCC Regions

The Pan Asia Grid Interconnection Project (PAGIP)

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Abstract

Globally, the experiences have proven that interconnection of smaller power systems to form a large power pool or regional grid is beneficial to all participants in terms of efficiency, economy, reliability and resilience. In this paper, an attempt has been made to enumerate the various gains that are there for the taking in case of interconnecting regions in general and the GCC, SAARC/BIMSTEC and ASEAN region in particular. Further in the paper an attempt has been made to identify all activities and tasks to be completed to ascertain the feasibility of interconnecting the regions. It does appear from the data and facts analysed that such an interconnection between these three regions will be very beneficial to all the Nations in the Pan Asia Grid. The narration has been kept simple for easy understanding by all.

Background

Post-independence, India developed state-wide power systems in 1950s and 1960s. Later India started interconnecting the state grids with the adjacent states for sharing surplus power or importing to meet shortages. These interconnections were initially operated in radial mode which were not very efficient. Following the model of power pools in Europe and America, India also setup five regional grids in the 1980s. Later these regional grids were interconnected to form a national grid. Today, India operates one of the largest power systems in the world covering 3 million Sq Km with connected generation resources aggregating over 350 GW and about 270 million electricity customers serving a billion plus population. After we interconnected all the regions and created a national grid, there have been no grid failures in the past 6 years. This experience underscores the rationale for larger interconnected power systems. India also has power exchanges operating; and the uniform market price is discovered for the entire country on the power exchanges. This can be interpreted to mean that the national resources are being utilized optimally and demand met in an equitable manner because of the national grid.

In general, owing to peak and non-peak hours in every power system, the additional capacity to be reserved for peak hour demand can be reduced considerably in an interconnected system as that capacity can be drawn from another area where peak may experience at different hours. If a power plant or transmission line in a power system fails, the capacity can be provided instantly from the adjacent power systems if they are interconnected. Similarly, in case of disasters, both natural and man-made, the chances of grid failure are much less in a large power pool.

Regional Grids in South Asia, Southeast Asia and Middle East

Two decades ago, the United States Agency for International Development (USAID) mooted the idea of interconnection of electricity grids in South Asia and Southeast Asia and supported the feasibility studies for interconnections and prepared masterplans for SAARC Grid and ASEAN Grid. In South Asia, the Indian grid is already connected to the grids of Nepal, Bhutan and Bangladesh. Interconnection with Sri Lanka is also proposed through undersea cables which is likely to happen in the near future. These interconnections have benefitted all the nations in the region. Bhutan can sell its clean hydropower; Bangladesh has been able to import a part of their electricity demand from India. Similarly, there is a master plan for interconnection of the grids of ten ASEAN countries in the Southeast Asia and many interconnection lines have already been built. These regional interconnections have led to economic development and contributed to improving access to electricity for millions of people in these regions.

Almost during the same time, the countries in the Arabian Gulf region made the master plan for a common grid for the Gulf Cooperation Countries (GCC). An interconnector was built connecting the Kuwait, Saudi Arabia, Bahrain, Qatar, UAE and Oman. This interconnector has been in operation for the last ten years. Gulf Cooperation Countries Interconnection Authority (GCCIA) is operating and maintaining these interconnector systems and also running a power market. Before establishing the interconnector, the cost-benefit analysis of the interconnector was very thoroughly analysed. It was found that the interconnector will provide enough benefits in terms of sharing of generation capacity and operating reserves to justify its cost. In addition to this, the countries have also benefited through the power trading taking place through these interconnections. Thus, one can see that the technical benefits of the Gulf interconnector is enough to justify the investments. One important feature of the GCC region is that the Saudi grid operates at 60 Hz and the rest of the nations, operate at 50 Hz. Interconnecting these regions hence required an HVDC station. The HVDC station also helps in frequency and voltage control by automatically responding to changes in these parameters on either side of this region. Thus, one can infer that difference in operating frequency need not be a hurdle for building interconnections. The Bahrain grid is connected to the interconnector by a sub-sea cable. This has performed satisfactorily after initial teething problems.

ASEAN established the electricity interconnecting arrangements within the region through the ASEAN Power Grid (APG) under the ASEAN Vision 2020 adopted in the Second ASEAN Informal Summit in Kuala Lumpur on 15 December 1997. HAPUA (Heads of ASEAN Power Utilities/Authorities), as SEB (Specialised Energy Body), is tasked to ensure regional energy security by promoting the efficient utilisation and sharing of resources. The construction of the APG is first done on cross-border bilateral terms, then expanded to a sub-regional basis and finally to a total integrated regional system. It is expected to enhance electricity trade across borders which would provide benefits to meet the rising electricity demand and improve access to energy services in the region.

Rationale for Interconnection of Regional Grids in ASEAN, SAARC and GCC Nations

Figure 1

The relevance of interconnection of regional grids has gained attention in the era of increasing share of variable renewable energy (VRE) resources on the grids. Integration of intermittent VRE, especially solar and wind, is efficiently handled in a larger balancing area that offers better forecasting of VRE generation and opportunities for intra-day and hour-ahead mitigation measures for managing the variability of VRE resources. Larger power systems could also offer large quantities of demand flexibility and dispatchable generation resources at lower cost. Interconnected grids could also offer the opportunity to replace their own costly generation by a relatively cheaper imported power. Bangladesh can be quoted as an example for such a benefit. Nepal, which has so far, been a net-energy importer from India, can use the same transmission lines to export its surplus power when new plants are commissioned in Nepal. Even in power deficit and surplus scenarios, due to demand profile diversity, opportunities of mutually beneficial energy trade exist. These variations are not only due to difference in time zones, but also due to seasonal differences and also difference in weekends and festivals in each interconnected country.

The Gulf region did not have much fuel diversity at the time of establishment of the interconnector but now there will be fuel diversity in GCC nations as Saudi Arabia, Oman and UAE plans to build GW scale solar plants.

Between the eastern parts of ASEAN Grid to the western end of the GCC Grid, there is a 5-hour time zone difference which can be leveraged efficiently in the interconnected operations. As solar generation diminishes and evening peak starts in ASEAN region, solar generation will be at its peak in ASEAN and GCC regions. Later when evening peak load increases in western parts of India and GCC region, the base load plants in ASEAN grid could support. Also, the morning peak in ASEAN can be supported by based load plants in the SAARC/BIMSTEC region. This manner of interconnected operations helps not only in integration of renewables, but also efficient operation of base load plants in all the regions. The hydro generation in SAARC and ASEAN could also improve the power quality in GCC grid when there will be tens of gigawatts of solar generation in GCC nations. The interconnection could also have the potential to reduce fossil fuel consumption in these regions through sourcing the clean solar, wind and hydel power.

The figure 1 shows the likely places where the interconnectors needs to be built to interconnect the three region. There are two options as far as achieving interconnection is concerned. A separate interconnector can be built or the nation grid of a nation can be used for regional power transfer. To decide on the suitable choice, detailed analysis is required and it is felt that a mix of the two option may be the optimal choice.

For connecting GCC region to the SAARC/BIMSTEC region, there are two options as shown in Figure 1. We can have a line from SAARC region say from Afghanistan to Kuwait connecting the intervening nations also. However, it will require connecting, Afghanistan and Pakistan to India and through India to other SAARC/BIMSTEC nations. On the other side of Afghanistan and Pakistan if GCC region is to be connected, the interconnector will pass through Iran, Iraq and other nations before reaching Kuwait.

On the other hand, a subsea cable connecting the Gujarat coast in India in SAARC/ BIMSTEC region to Oman can be considered. This has got its own challenges as the distance is about 1300 Kms and the depth is at least 3000 meters. At the same time there is a HVDC undersea able, 1600 meters below sea level in Italy though it is a 420 Kms long cable. The longest electrical subsea cable is 580 Kms long and connects Norway with Netherlands. The depth is much less but it is in service since 2008. The viability of the India – Oman subsea cable can be looked into as perhaps the technology is now available.

Similarly, for connecting the ASEAN region with the SAARC/BIMSTEC region, some of the options can easily be envisaged. One option is connecting Manipur in India to Thailand via Myanmar. Another option is connecting Indian Eastern and/or North eastern grid to Thailand and beyond through Bangladesh and/or Myanmar. The image 1a and 1b below shows the likely points of interconnection.

Image 1a

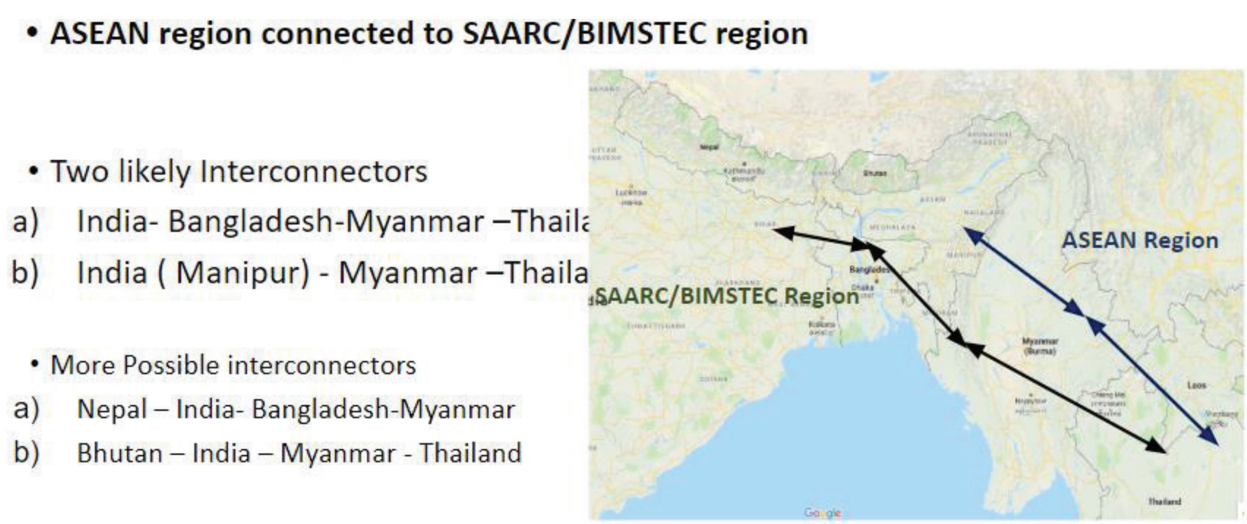


Image 1b

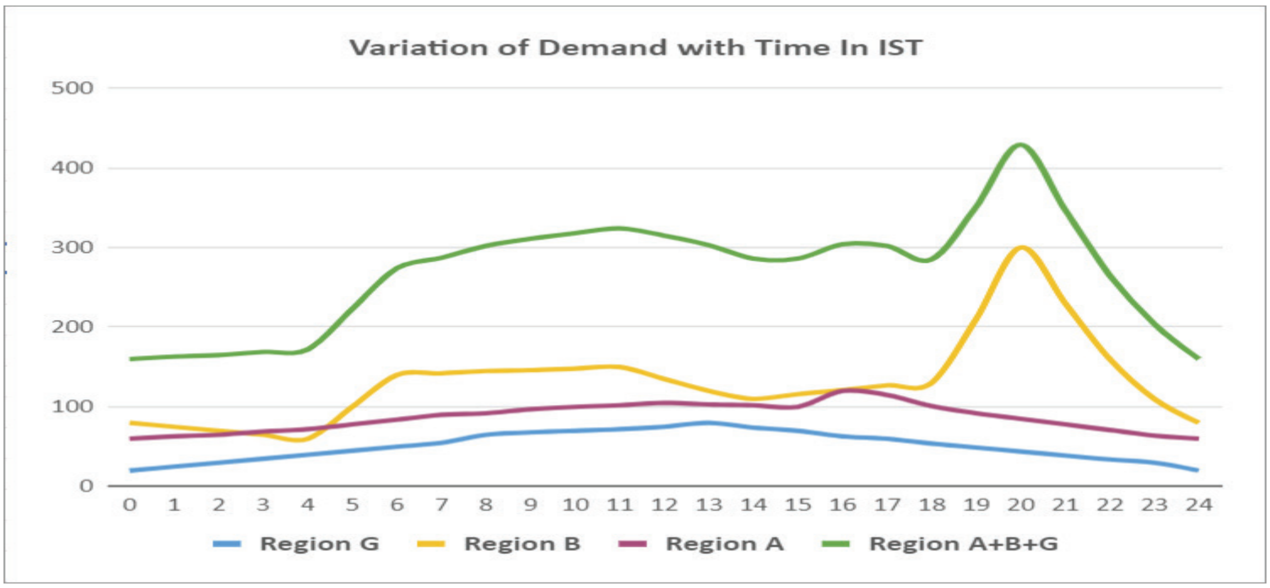
Benefits of interconnecting GCC, SAARC/BIMSTEC and ASEAN region

The Graph 1 below shows the demand curves of three regions and the combined demand curve of the interconnected region. As can be see, the combined Peak Demand of the interconnected region is less than the same of the individual demand curves. This reduction in the peak demand leads to reduction of required capacity addition as the installed capacity can be utilized across the regions though various power market mechanisms.

The same can also be seen in the Table No 1

Note: The demand curve is based on the following assumptions and adjustments

1) The figures are assumed and do not actually represent the actual demand curve of any region or nation.
2) The demand curves of Region A and C have been shifted to align them with a common standard time of region C. Thus the times mentioned is not that of the individual regions but of the Region B.
3) It is assumed that there is no grid congestion and the adequate transfer capacity if available for flow of electricity throughout the three regions.
4) All system losses are assumed to be negligible.
5) All units are in MW or GW as the case may be



Graph-1 Individual and combined regional demand curves

Region	Peak Demand Equal to Required capacity (GW)	Minimum Demand (GW)	Approximate Average Demand (GW)	Approximate Reduction in Installed capacity requirement due to Interconnection* Percentage Reduction
G	80	20	50	16 = 80 – [(400/500) *80)] 20%
B	300	60	160	60 20%
A	120	60	90	24 20%
Interconnected Region G+A+B	400	160	300	100 20%
Algebraic sum of three regions	500	140	300	100 20%

Table – 1 All Figures in GW

Remarks –

1) Regional figures are assumed figures and do not represent any actual region.
2) * Reduction assumed to be proportional to Average Demand

Benefits to the Nations of the Interconnected Regions

Certain conclusions can be drawn from the above table and the graph.

A) The required installed capacity of the interconnected region is less than the algebraic sum of the required capacity of the individual regions without interconnection. If grid congestion is present, this benefit will be reduced but will definitely be there in any case.

B) The percentage reduction in installed capacity requirements is same for all the three regions with no transmission constraints, and losses assumed as zero. This figure may vary if come capacity addition at particular nodes is required to maintain the voltage profile or for any other system security requirement.

C) The reduction of capacity in GW terms is proportional to the capacity required in that region assuming that the capacity requirement is equal to the peak demand.

D) It can be seen that the load curve has been flattened. The peak demand of the combined system is less than and algebraic sum of the individual regions. Similarly, the Off Peak demand of the combined system is more than and algebraic sum of the individual regions. In can be mathematically proven that the deviations of the demand are reduced in case of the combined system.

ECONOMIC BENEFITS

A) The cost of Interconnecting the regions, is much less than the cost of addition the required capacity, both yielding the same ultimate result. The money can then be utilized for other developmental activities.

B) In the figures and the table across, on can see that the generation deficient condition existing in region A has been removed by this interconnection. Under deficit generation situations, load shedding is resorted to which adversely impacts the economy. This allow the industries to grow and also other sectors like agricultural, commercial and domestic are impacted in a positive manner. All this leads to increase in GDP, which benefits all inhabitants of that region.

C) The surplus generation in the Regions G and B, can be sold to the Region A which was power deficit. Thus the idle generation capacity is utilized and it also lead to economic gain to the seller region, with a positive impact on their economy due to addition earning from power export.

D) A vibrant power market can be established in the interconnected region. A properly designed power market, can lead to the maximization of the benefits of Interconnecting the three regions.

E) One aspect of economic gain which is not immediately apparent from the above, is the gain due to replacement of costlier power by cheaper power. Due to variation inherent in the load curves, the generation capacity on bar and the generation level keeps on changing. The difference in the load curves gives and opportunity of replacing costlier generation by imported cheaper generation, leading to economic benefits to both the regions. This leads to the generation of producer and consumer surpluses which is an indicator of economic benefit.

F) Conservation of natural resources like coal, oil and gas as the generation from these sources at partly replaced by generation from renewable sources.

G) The interconnected, if utilized with proper planning and coordination can also reduce the frequent shut down and re start of generating stations. This will improve the heat rate, auxiliary consumption and also extend the life of the generating units.

TECHNICAL BENEFITS

A) The impact of tripping of a large generating unit on the power system is minimised. For example, if there is a 500 MW unit connected to a 5000 MW grid, it’s outage will lead to a loss of 10% of the generating capacity. However, is the same is a part of larger system say 20000 MW, its outage will lead to a loss of only 2.5% of the generating capacity. Thus the impact of the power system will be accordingly being less.

B) The above logic is also applicable in case of loss of demand due to load throw off. The larger is the system, less is the adverse impact as in case of generator tripping as mentioned above.

C) Sharing of operating reserves, also leads to a benefit. Generation deficient regions are compelled to operate their grids with little or no operating reserves due to various other reasons. Interconnecting the regions leads to sharing of operating reserves and lead to benefits in a manner very similar to the impact on capacity requirement. Thus there can be adequate operating reserve in a generation deficit region if it is interconnected to a generation surplus region. The primary, secondary and tertiary reserve that has to be maintained has an economic impact also. Interconnecting regions will reduce the cost of maintaining these reserves.

D) The system operator has many more options for maintaining system parameters in a large interconnected region which large number of demand and injection points spread throughout the combined region.

INTEGRATION OF RENEWABLE SOURCES OF POWER

A) The large interconnected system will promote integration of renewable sources in all the regions. The inherent variability of certain renewable sources will be catered to as mentioned in case of generator tripping of load throw off. This will be more frequent almost continuous but less severe.

B) Due to the difference in time zones, the variation of solar generation in the three region will lead to the availability of solar power in the individual regions for a longer period of time as can be seen in figure 3. This will also lead to mitigation of the adverse impact of solar generation due to its variation in the very short term (within a minute) which is hard to predict and quantify.

C) Solar and wind generation prediction methodologies have improved significantly in the past few years. Still the prediction is not quite compared to capacity of a fossil fuel plant to adhere to it’s given schedule. For the reasons explained earlier, these variations will be better addressed in a large interconnected grid. This is also true to a lesser extent in case of a run of river hydro.

D) The large interconnected system will lead to better utilization of hydro sources with reservoirs and pumped storage pants. With proper planning, these resources can be utilized when the generation deficit exists in the interconnected region or to replace the costlier generation.

E) In a small system, the variation in climatic condition and weather is limited. However, in a very large, geographically spread out system, these may be significant. This can be utilized to utilize the renewable sources in a much more efficient manner. For example, the run of river hydro generation in one part can be utilized to operate a pumped storage plant in another part. Thus the cost of generation from the pumped storage plant is minimised when the run of river hydro power is utilized even when low demand which exists in the run of river hydro region.

ENVIRONMENTAL BENEFITS

The combined interconnected regions will lead to better integration of renewable energy sources. They will also replace the costly generation as explained earlier. This will lead to many environmental impacts.

A) Reduction of release of greenhouse gases. This will reduce global warming.

B) Reduction of pollution due to cutting down on usage of fossil fuel

C) Reduction in carbon footprints.

The benefits of interconnection these regions will be the same as that enumerated above. However, the benefits have to be quantified or at least estimated. This will then have to be compared to the cost of the building the interconnections. For this the various alternative locations for building interconnectors have to be considered. One needs to decide the likely points of connection, kind of connection (AC or DC), capacity of the interconnections etc. The whole process may require a period of eight to ten years before the interconnection is commissioned. Hence the one needs to plan based on the likely scenario from 2028 onwards.

In view of the above the following sequence of activities may need to be competed.

Activities and tasks to be completed

A) Garner support and disseminate the concept by interacting with all key stakeholders in the three regions. This will include the ministry, power sector utilities, regulators, system planner, etc. and also key experts.
B) To study power sectors, the three regions and their constituent nations for analysing and forecasting key parameters like demand, generation, nation grid augmentation plan, energy export and or import plan, generation potential and other relevant. The cost of generation and the strength of the grid is also to be ascertained in consultation with the key stakeholders of the region and the constituent nations
C) The savings in capacity addition and the operation reserve sharing to be ascertained for based on the demand, generation forecasts, fuel mix etc. for a period of 20 years starting 2030
D) To study and forecast the interregional flows (Or Trades) expected on these interconnectors for a period of 20 years starting 2030.
E) The reduction is carbon emission, integration of renewable sources and saving of natural resources to be quantified.
F) To work out the desired capacity of various interconnections required based on the above information.
G) The alternate routes for interconnection may be studied. considering all factors like cost, system condition and other social, economic and political aspects.
H) To study and estimate the costs of building these interconnectors and the payback period based on the outcome in a) and b) above.
I) Recommend suitable incorporation of smart grid technology in the interconnected region Grid.
J) To analyse and recommend a feasible mode of establishing a vibrant power market between these regions. Power exchange is one option, banking is another. Other options like long, short and medium term PPA etc also need to be consider and suitable recommended.
K) To suggest the required regulatory, policy and legal requirements including a dispute resolution mechanism, Unscheduled interchange settlement mechanism and all other commercial terms and conditions including tariff, charges and penalties.
L) A draft of a recommended agreement to be signed by all the parties is to be prepared.

Execution of the tasks and activities

A) It is suggested that the project will be executed and structured as below
   a) A suitable entity should run the project secretariat with a strong team of technical people. They should also have presence in all the three regions of GCC, BIMSTEC/SAARC and ASEAN. They should have a proven track record of executing large transmission related project of this or similar nature.

b) A high level Project advisory body will be formed including representatives from GCCIA, BIMSTEC, ASEAN secretariats the Project Secretariat. This high level body will supervise the project and also resolve any issue that may arise.
c) The Project Secretariat will be responsible for proper execution of the project.
d) It is necessary to have adequate funds to execute the project. Developmental agencies in the Region may be approached to secure adequate funding.
e) A Technical committee with two to three members each from all the three regions will execute the technical tasks of the project. Secretary of the committee will be from the Project Secretariat.

f) A Finance committee with two members each from all the three regions will execute the financial tasks of the project. Secretary of the committee will be from the Project Secretariat.

g) A Regulatory and Commercial committee to be formed sometime after the technical and finance committee is formed to execute the relevant tasks of the project. Secretary of the committee will be from the Project Secretariat.

h) Other than the head office of the Project Secretariat, there regional office to be established in the three regions. This will help in overcoming language and other such barriers. A national representative may also be established at some of the nations if the requirement is felt for the same. This will also help the project to more inclusive of the various nations and the Regions.
i) The project secretariat and the members of the committee will ensure stakeholder consultation in all the Regions as a continues process.
j) Each of the committee will come out with a comprehensive report after completions of all tasks entrusted to them.
k) The project secretariat will come out with the Final Report combining the individual committee reports, feedback from key stakeholders etc.

Next Steps

Initial deliberations between different stakeholders have been initiated on the feasibility of potential interconnections between India and Myanmar as well as India and Oman. However, no feasibility studies have been taken conducted yet. If the buy-in of all stakeholders on this idea of an interconnected grid between these three regions can be achieved, then the concept can be further taken ahead by conducting first a Pre-Feasibility Study and based on the same, a detailed feasibility study for the potential interconnections needs to be conducted. Once the feasibility study is over and a Detailed Project Report (DPR) is prepared, the actual erection of the interconnectors can start.

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