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A REVISED STUDY ON INDIA-SRILANKA INTERCONNECTION OF TRANSMISSION SYSTEM

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Abstract: India and Sri-lanka are facing a growing gap, between power demand and supply. However, India's power system is very large, and it's North Eastern and Eastern regions have surplus power and the neighboring countries also have significant hydro potential. This surplus energy should be available to support power exports from India to export power to Sri-lanka. The proposed transmission interconnection between Madurai and Tuticorin in Tamil Nadu, India, and Anuradhapura and Puttalam in Sri-lanka optimizes the installed capacity by way of utilizing the diversity in peak demand, sharing spinning reserves and also optimizing the overall generation mix. This paper is focused on different studies conducted in the past and pre-feasibility study for interconnection has been carried with most viable interconnection scheme on the basis of present energy scenario of both countries which is more viable presently. This interconnection scheme appears as a solution problem of energy deficit such that instated of constructing more generating plants separately these two countries can share some part of their resources and generation among them via transmission by proper scheduling of load through load curve.

Keywords: Grid Interconnection, HVDC, BBDC, HVDC Light, super grid, mono-poler and Bi-polar HVDC, Spinnig Reserve.

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INTRODUCTION

Over the last to decades south Asia has been one of the fastest growing regions in the world, with an average annual growth rate of 6% as measured by GDP per capita. The main contributing part of this increase rate is the supportive hand of power sector of that country. The power sector of these countries became a supportive pillar for development.

Yet despite of this impressive macroeconomic growth, the energy sector in the region has not been able to keep pace, and continues to experience chronic problems of shortage of supply and poor quality of services and No South Asian country is able to meet its energy needs entirely from its own domestic resources because each country has its own resources which has some limitations, and due this limitation that particular country is unable to support in the growth as speedily as needed. Hence to secure both countries nearer future and accelerate the speed of development there is a need of new energy resources. The political Representatives as well as business community are recognizing gradually the need of cross-border energy exchange and promote regional energy trade. The region has available energy resources to produce power and it should be a matured option to interconnect the entire regional grid to mitigate the power crisis. India's power system is very large, and its North Eastern and Eastern regions have surplus power and the neighboring countries also have significant hydro potential [1].

This surplus energy should be available to support power export from India to export power to Sri-lanka. The proposed transmission interconnection between the two countries would provide advantages to both the systems in terms of optimizing the installed capacity by way of utilizing the diversity in peak demand, sharing Spinning reserves and also optimizing the overall generation mix.

II. BACKGROUND

The idea of establishing a transmission interconnection between India and Sri-lanka is not new. The idea was first considered in the late 1970's by Professor **Zablonski** in Sri-lanka [1].

Then after in the year 2002 USAID asked NEXANT to revisit the idea because the electrical grid interconnection of these two countries would provide opportunity to enhance system reliability and provide the ability to exchange power among these countries [7].

Currently with the absence of any interconnection, no power exchange between the two countries takes place. The pre-feasibility study conducted by NEXANT in 2002 had various conclusions as follows:

Proposed power exchange would serve as supply/generation option for Sri-lanka. Sri-lanka has developed a generation plan through the year 2014; the proposed transmission interconnection scheme would provide Sri-lanka with an additional option in its planned generation mix.

The transmission systems under development in the two countries would support power exchange between the countries

Based on expected supply/demand scenario, India should be able to supply the required power to Sri-lanka .The alternatives permit power exchange of up to 1,000 MW. Indicative investment requirement for these alternatives ranges from approximately $116 million to $175 million as per NEXANT report of 2002[1].

In 2006, Review has been taken on the pre-feasibility study conducted by NEXANT in the year 2002. To exploit the regional resources an initiative took in 2006 by launching South Asian Association for Regional Cooperation (SAARC) Energy Center in Islamabad. The objective of that is to facilitate and promote energy trading connecting India, Pakistan, Bangladesh, Sri-lanka, Nepal, Maldives and Bhutan to minimize the acute power shortage faced by them [6].

For south Asian energy trade promotion world bank also suggested that, bi-lateral interconnection between India and Sri-lanka will support srilankan power sector in dry season and would be able to provide thermal support as well as srilankan power sector also has capability to support India for some emergency peak power demand.

III. OBJECTIVIES AND SCOPE**2006 by**

The objective study is to examine and assess the possibilities for interconnecting the transmission systems of India and Sri-lanka. The objective of such a transmission interconnection would be to facilitate bilateral power exchange between the two countries.

As the Indian subcontinent is facing a massive challenge with regards to energy security in its member countries, some technical experts proposed concept and design of 'super grid' to carry huge quanta of power across the Indian sub-continent and India Sri-lanka interconnection is also a part that super grid, hence this study would be helpful as a module study for super grid. In this study one consideration made that indo-lanka interconnection would be a way for efficient use of energy resources for electricity generation thus an overview on benefits electricity market among these countries has been taken.

This study is divided into two phases, under first phase of study present condition of electricity sector of both the countries has been studied and in the next phase proposed scheme of interconnection has been lightened with various alternatives.

IV. PRESENT ELECTRICITY SCENARIO

The need of interconnection arises from the deficiency of local bodies to fulfill the required demand. As per the survey conducted in past years, Sri-lanka has deficit of 4.9% supply demand and India has 9% deficit in peak demand. The transmission alternative which will be proposed further in this paper for interconnecting the grid in India and Sri-lanka will depend on existing transmission and generation system in each country. Considering this aspect a brief data related to generation in both countries from year 2007-08 up to 2013-14 is presented in this section (Table I).

From the given data (Table I), India had total installed capacity of 132329MW (132.329GW) in the year 2007-08 with peak demand of 108866 MW. The demand growth in that period was only 5.19%. but then next in the period of 2012-13 the demand growth rises to 9% and peak demand was 135453MW with installed capacity of 199877MW deficit of energy and peak demand was 9.92% and 16.60% respectively for 2007-08 periods and it was 8.71% and 8.98% respectively for period 2012-13.

Currently India has total installed capacity of 255.013GW with peak demand of 195000MW (aprox.) the demand growth rate is 10.4%.the load factor is varying from 59-63% and the system losses are minimized from 27% to 23.65% in this period.

As like India srilankan electricity sector also has changing attribute because for period of 2007-08 installed capacity of Sri-lanka was 2400 MW with peak demand of 1840 and demand growth was 7-8%. The energy generated in this period was 9820Gwh with deficit of 4.49% in supply demand, the system losses of srilankan system was 15.7% in that period.

After that currently (for period of 2013-14) srilanka has installed capacity 3242MW with 11960Gwh energy generated system losses are restricted to 11% and demand growth is 8.5%.

From that brief electricity scenario we conclude that among this two countries none of the country has surplus resource of electricity to support demand growth, both are facing deficit either in peak demand or in supply demand. To overcome these problems each of the country is planning for erection of new generating plants for future years which will require large investment of capital which further adversely affect human, environment etc.

Hence in such condition this interconnection scheme appears as a solution to this problem such that instated of constructing more generating plants separately these two countries can share some part of their resources and generation among them via transmission by proper scheduling of load through load curve.

V. PROPOSED INTERCONNECTION SCHEME

A transmission system interconnection between India and Sri-lanka could provide significant benefits to the economies of the two countries through closer cooperation on power exchanges, enhanced system reliability, improved security and diversity of supply, increased economic efficiency in system operation, reduced environmental impacts, and lower consumer costs[7].

In developing the proposed alternative interconnections, more focus has been made on following considerations:

YEAR	Country/region	INSTALLED CAPACITY	PEAK DEMAND	ENERGY GENERATED	DEMAND GROWTH	SYSTEM LOSSES	LOAD FACTOR	PER CAPITA CONSUMPTION
2007-08	INDIA	132329MW	108866MW	670654Gwh	5.19%	27.20%	59-60%	819Kwh
	SRILANKA	2400 MW	1840 MW	9820 Gwh (HYDRO-40% THERMAL-60%)	7-8%	15.7%	53%	
2010-11	INDIA	199877MW	122287MW	922451Gwh	5.25%	23.87%	62.9%	----
	SRILANKA	2820MW	1963MW	10714Gwh (HYDRO-42% THERMAL-58%)	7-8%	13.5%	62%	450Kwh
2012-13	INDIA	199877MW	135453MW	963722Gwh	9%	23.65%	-----	884Kwh
	SRILANKA	3334MW	2146MW	11800Gwh (HYDRO-46% THERMAL-54%)	7-8.5%	11%	62.8%	515Kwh
2013-14	INDIA	255013MW	Near about195000MW	967150Gwh	10.4%	23.65%	63-65%	917Kwh
	SRILANKA	3262MW	---	11960Gwh	8.5%	11%	63%	---

Table I. Electric energy scenario (from 2007-08 to 2013-14)

Existing and planned generating capacity in each country

Existing and planned transmission systems in each country

Time frame for development; and

Technical and operational factors.

All this factors are studied in the reports and other papers which are presented as reference for this paper hence actual work on this factors are not presented here.

From this brief electricity scenario conclusions has been made as follows:

As Sri-lanka had planned for addition of 1774 MW thermal plant plus 184 MW renewable plants up to 2020 and up to that period total 547.7 MW capacity units are going to retire, which means addition of near about 1410 MW capacity unit in srilankan power sector.

So instead of investing large capital on such huge capacity addition sharing is better option because it is profitable for both countries.

As all regions in India are connected to national grid recently, country has one grid one frequency system. Thus large support can be provided through any part of country to fulfill energy demand.

For Sri-lanka to get access to a South Asian Regional Electricity Grid, the only feasible connection is with India through a HVDC marine cable. This interconnection would be different from any other electricity interconnections planned in the South Asia Region. As interconnection is beneficial for Sri-lanka through all the way, it is also benificial for India also because this interconnection would aid to fulfill emergency peak demand in country especially in south region which facing 9% deficit in peak demand currently.

In this section, the range of possibilities for transmission interconnection between India and Sri-lanka based on technical and economical requirements is reviewed.

A. TECHNICAL PARAMETER CO-ORDINATON

For any system interconnection it is always feasible to match the technical parameters of the systems going to interconnect.

Table ii gives the detail of technical parameter co-ordination in which coordination between frequency has been shown which suggest that the frequency of both the countries are nearly same and their permissible deviation not has lot difference. The transmission voltage levels of both countries are also show with their medium of communication.

As in alternative proposed the HVDC interconnection is more emphasized technology hence asynchronous ties between these two regions also possible where some parameter co-ordination does not matter.

COUNTRY	PERMISSIBLE FREQUENCY BAND (Hz)	PERMISSIBLE DEVIATION	TRANSMISSION VOLTAGE LEVEL(kV)	PERMISSIBLE DEVIATION	COMMUNICATION SYSTEM
INDIA	49.95-50.05 Hz	(-1.6%+0.6%)	765,400,230,220, 132, 110,100,66	735-800 kV 420-360 KV 245-200 KV 145-120 kV	WIDEBAND,VAST,GSM,PLCC
SRI-LANKA	49.95-50.05 Hz	(+/-1%)	220,132	(+/- 5%)	PSTN,PLTS,PLC

TABLE II. TECHNICAL PARAMETER CO-ORDINATION

B.CONFIGURATION ALTERNATIVES

There are four basic alternative transmission interconnection configurations that would provide for bilateral power exchanges between India and Sri-lanka. These alternatives have a number of variations centered on the use of alternating current (AC) and/or direct current (DC) transmission technologies.

The substations that would be involved in the proposed interconnection are Madurai and Tuticorin in Tamil Nadu, India, and Anuradhapura and Puttalam in Sri-lanka.

The alternative transmission technologies are high-voltage DC (HVDC) and high-voltage AC (HVAC) with back-to-back DC. HVDC technology has two variations—bipolar and monopole.

The four basic alternatives are:

- MAI-HVDC—Madurai-Anuradhapura interconnection using HVDC
- TPI-HVDC—Tuticorin-Puttalam interconnection using HVDC
- MPI-HVDC—Madurai-Puttalam interconnection using HVDC
- MAI-BBDC—Madurai-Anuradhapura interconnection using HVAC with BBDC

Fig5.1. Map showing alternatives for interconnection

The map shown in fig5.1 give the concept of actual path of interconnection of transmission line alternatives as per the key findings through survey there are no technical barriers to a transmission interconnection between India and Sri-lanka,

ALTERNATIVE	INVESTMENT (MILLION RUPEES)
MAI-HVDC	10270/9467
TPI-HVDC	9469/10827
MPI-HVDC	8538/9652
MAI-BBDC	8662

TABLE III. COST ESTIMATION (in 2002)

The initial economic assessments forecast an investment range of 10270 million rupees to 10827 million rupees (as per pre-feasibility in 2002) for the various alternatives [1]. As per present condition target project (i.e. 500WM monopole-stage I) cost for a powergrid-ceb joint venture to be profitable is 372.4 musd (excluding customs duty and taxes), which at present is estimated to be 554 musd(33794 million rupees)[7]. Tuticorin-Puttalam HVDC and Madurai-Anuradhapura back-to-back dc alternatives are the most expensive options and offer no additional technical advantage over the others.

Among these alternatives the Madurai - Anuradhapura HVDC interconnection is considered as most reliable and economical alternative hence the scheme is proposed to connect a grid from Madurai in southern India to Anuradhapura in central Sri-lanka, through the pal strait. The link will be of 400kV HVDC which will transfer 1000 MW power. The line would have an initial transfer

Capacity of 500 MW and later another 500 MW would be added [6].

The length of line would be 360 km with 120km submarine cable. Since this interconnection is through water way, thus HVDC light technology is most reliable and feasible for grid interconnection. it is also beneficial from the point of view of super grid.

C. MAI-HVDC

As discussed above Madurai - Anuradhapura HVDC interconnection is considered as most reliable and economical alternative hence the scheme is proposed to connect a grid from Madurai in southern India to Anuradhapura in central Sri-lanka, through the pal strait. The link will be of 400kV HVDC which will transfer 1000 MW power. The line would have an initial transfer capacity of 500 MW and later another 500 MW would be added. The length of line would be 360 km with 120km submarine cable. fig 5.1 have a single line route structure which is divided in to three parts, in first part the converter station of Indian side is placed at Madurai and 130 KM overhead line is spread up to panaikulam; in second part submarine cable from panaikulam to thiruketis-waram of length 120KM would be spread; In third part one more land route is from Thiruketis to Anuradhapura of length 110KM.

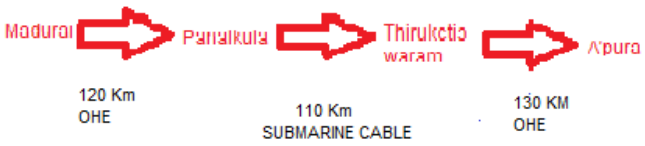

Fig5.2. Transmission line route

The transmission technology would be used have various options ahead as follows:

1.500MW Mono pole – stage I

500MW – stage II

2. 2x500MW – Stage I

3. 2x250MW Bi-pole – Stage I

2x250MW – Stage II

At a conceptual level, a monopole connection may be viewed as consisting of one path of power flow carrying total amount of power and a bipolar connection may be viewed as consisting of two parallel paths of power flow, each path carrying half of the total power.Fig5.3

and Fig5.4 gives brief idea of interconnection on conceptual level where first preference is given to option 1 i.e.1×500 MW monopole line.

Fig5.3 shows the single line diagram of mono-polar HVDC interconnection where one terminal on each side is grounded i.e. return path is provided through ground. Only two converter transformers one on each side is required.

Fig5.4 shows the single line diagram of bi-polar HVDC interconnection where four converter transformers two for each pole are required.

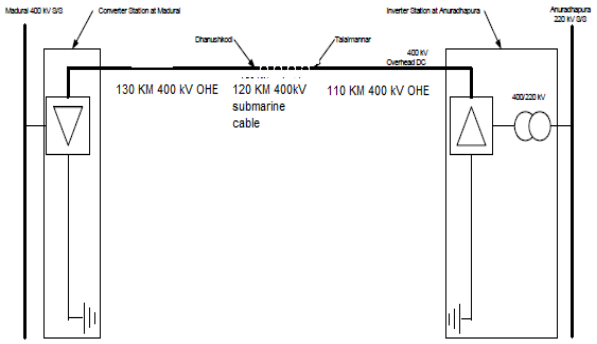

Fig 5.3 Monopole HVDC interconnection single line diagram

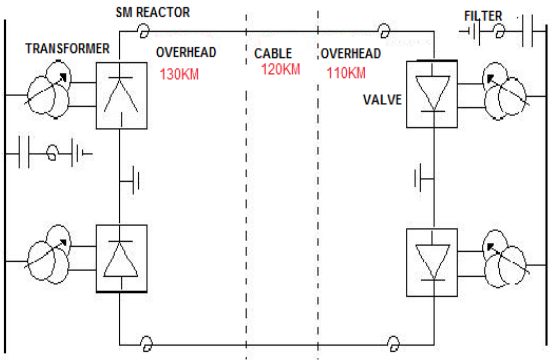

Fig 5.4 Bi-polar HVDC interconnection single line diagram

As the HVDC light technology is preferred the switches of valves are made up of IGBT device. The filter arrangements are also shown on both sides of converter stations. As the HVDC light

technology is preferred the switches of valves are made up of IGBT device. The filter arrangements are also shown on both sides of converter stations.

To achieve project viability in present condition the project must be structured as a 1x500 MW monopole interconnection.

Presently, a MOU on Feasibility Study for India- Sri-lanka Electricity Grid Interconnection was signed among GOSL, GOI, CEB and Power Grid Corporation of India Limited (PGCIL) on 9th June 2010. Executing Agencies, CEB and PGCIL are jointly carrying out the feasibility study. The expected period of complete installation will be 3-4 years.

VI. CONCLUSION

Benefits of proposed cross-border interconnection and others:

After the study assessment of this interconnection some major benefits of India srilanka cross border interconnection are concluded as follows:

Opportunity for srilanka to enter into India Power Exchange for energy trading

Access to electricity from cheaper sources of power generation in the South Asia Region, Reduction in operational cost through better resource management, Meeting growing power demand with imported power.

Improved load profile - valley filling and reliability and security of both systems.

It offers potential for export of anticipated surplus base load power from India.

Emergency peak load requirement of India can be fulfill.Creates opportunities for joint investments

Improves supply profile (base / peaking)

It Leads toward diversified trading potential, while improving power system performance by timely and appropriate generation and transmission capacity additions and distribution system improvements.

It offers opportunity to share surplus of power over the south Asia if concept of super grid comes to reality.

It stands as an example for energy conservation through power exchange.

Under this study the energy scenario of both countries for past few years(2007-2013) has been studied according to that we can concluded that present state is perfect for power exchange, for benefits of both sides.

This study also concludes that among four alternatives presented Madurai-Anuradhapur line (360km) is a better option.

Below this alternative three more technical options are also presented of technical interconnections in which three options of technical out of which 1×500mw mono-pole options has suggested as a viable option. Presently, no bilateral power exchange exists between India and Sri-lanka.

Proposed power exchange would serve as supply/generation option for Sri-lanka and peak demand fulfillment option for India.

The studies conducted in past has four alternatives for interconnection some of which are much expensive. The investment requirements for the alternative interconnections are moderate and should not present a significant barrier to the development of an interconnection.

Among that alternatives Madurai- Anuradhapura 400 kV, 500mw mono-pole interconnection is most feasible in present conditions, as per present condition target project(i.e. 500wm monopole-stage I) cost for a powergrid-ceb joint venture to be profitable is 372.4 musd (excluding customs duty and taxes), which at present is estimated to be 554 musd(33794 million rupees). This investment is very less as compared to investment in other options hence, it provide lower cost electricity behind every kwh.

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