INTEGRATED STRATEGIES FOR LOAD DEMAND MANAGEMENT IN THE STATE OF TAMIL NADU

Booma JAYAPALAN[1*], Mahadevan KRISHNAN[2]
[1*]Assistant Professor, [2]Professor Department of EEE, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India.
boomakumar2005@gmail.com

Karunanithi KANDASAMY
Professor / EEE
Siddhartha Institute of Engineering and Technology,
Puttur, Andra Pradhesh, India.

Kannan SUBRAMANIAN
Professor / EEE
Ramco Institute of Technology
Rajapalayam, Tamil Nadu, India.

Abstract: *Electricity is in crisis state of demand in the state of Tamil Nadu. The state is in need of a proper power management planning. This paper aims at recommending and focusing the strategies to meet such load demand, for the period of 30 years, from 2015-2044. Two strategies are proposed namely, increasing generation capacity through Generation Capacity Expansion Planning (GCEP) and by reducing the load demand through Demand Side Management (DSM). Both strategies were analyzed With Pumped Storage System (WPSS) and With No inclusion of Pumped Storage System (WNPSS). Renewable Energy Sources (RES) opted as a future candidates with different penetration levels via Business-As-Usual RES (BAURES), Optimum RES (OPRES), High RES (HRES) as Scenarios in GCEP. In DSM, Load Management Programme (LMP) and Energy Reduction Programme (ERP) were analyzed as Scenarios. For all Scenarios Reliability index Energy Not served (ENS) is a deciding factor. Wien Automatic System Plan-IV (WASP-IV) is utilized for attaining accuracy on calculations and observations, MATLAB is used for instant simulations. Pollutants of Carbon-di-oxide (CO2) and Sulphur-di-Oxide (SO2) emitted from thermal plants, Cumulative Least Present Worth Cost (LPWC) for 30 years were estimated. The best suited GCEP option is identified as OPRES with PSS and DSM is identified as concurrent implementation of LMP and ERP with PSS. Both Suited Strategies were integrated and its effects also investigated.*

Key words: *Demand Side Management, Energy Not Served, Load Management Program, Generation Capacity Expansion Planning, Pollutant Emissions, Flexibility index, Cumulative Least Present Worth Cost.*

1. Introduction

Electricity is a vital source for civilized and modern way of life for many reasons. Due to its multi-dimensional applications, power source has become an inevitable energy source to form and shape the life. As this is the case various factors contribute to the equally vulnerable demand for input of electricity in coming days or years. The advancement of technology has paved way for improvement in the form of human life that electricity is the core element for sustained growth. Education, health, science and technology, Communication and media, production, research and transportation are the key areas which highly depend upon electricity.

Coal, biomass, diesel, hydro power, wind energy, solar energy, nuclear fuels, and even bio-degradable wastes are various constituents of electricity. Quite contrary to conventional mode of electrical energy consumption, electricity derived from these sources decides the environmental patterns. Having discussed the utility factors of electricity, it is now important to explore the crucial alternatives for meeting the rising demand for electrical energy. Industrial applications, expansion activities, implementation of research results all need for feeding required amount of electricity. Thus, the need of the hour is increasing the generation of electricity by installing more and more plants. For this task reliability of supply, installation costs, maintenance and eco-friendliness and environmental constraints are to be viewed as crucial factors. On power distribution side too regulatory and mandatory factors are also to be framed. Hence, an in-depth analysis of existing power systems and the corresponding expansion schemes is to be devised. Such developments and amalgamation of schemes are there in practice. These are found in tools like analog, hybrid and digital modes aided by computers. These tools help the planning engineers to meet the energy planning challenges. If this is the case for the technologists, some questions arise which need to be sorted out with proper justifications.

- How to identify the proper plant locations which deserve enhancement of generation capacity?
- What amount of optimum capacity can be fixed for the generating plants?
- Which, among the possible alternative and / or renewable sources like solar, wind, pumped hydro, gas turbines, steam - would be feasible?
- How can the environmental impact or decay be coped?
- What will be the strategy to balance the energy generation and reduced load management in a concise manner?
- What could be the result in finding out the reliability of the consumer from the point of view of uninterrupted power supply?

Taking these as the challenging factors of power system, this paper aims at devising optimum level of load demand management through coordinated planning strategies. The tasks involved in the analysis are on the lines of providing necessary energy supply and efficient modes of demand reduction. To meet these challenges, factors relate to proper planning of combined resources are need to be required. Simultaneously, reliability is evaluated through its index ENS and the considerable elements of environmental pollutants of CO_2 and SO_2 are taken for crucial analysis. On broader level GCEP encompasses low penetration level, high penetration level, Business As Usual level under RES category. On parallel, Demand side strategies contain Load Management Program (LMP) and Energy Reduction Program (EMP). This study is focused on the power demand of the Tamil Nadu state, a potential industrial state in India. Keeping these index matrices for the study, planning strategies are adapted to the 30 year duration, from 2015 -2044. For the sake of viable analysis for the study, computer-based WASP-IV is utilized.

2. Related Works

In this section, works on the lines of the present paper are analyzed where in the modes of expansion of optimized power systems are discussed. While being so, the emission standards with regard to coal based power generation become a major constraint, which is exhibited in [1]. The list enumerates the world countries based on the emission level from which it can be found that India is far behind the major developing countries like Australia, China, the European Union and the United States. The standards stipulated on emission control are not easily met by India due to various reasons [2]. According to this literature, RES can be applied for various feasible levels and emission control can be standardized on long term planning. To continue the possibility of the proposal, a comparative analysis of earlier practices of power generation, plant-wise generation patterns regarding other levels of trace atmospheric counts are illustrated in [3]. This analysis is found ideal for the Indian conditions related to coal based power generation during the period of 2001-2002 and 2009-2010 [4].

A comprehensive analysis of such feasibility is carried out on power expansion plans from countries like Iran, Oman and Pakistan. WASP-IV and MATLAB are used to undertake the expansion plans of these countries which proved to be worth applying [5-7]. Yet another means of power management found to be ideal for Tamil Nadu climatic conditions is dealt in [8] which relates to climate oriented plan. Much of these findings clearly depict the unreliable process power generation including the unpredictable cost factors. With regarding wind power generation, this paper aims at suggesting high level penetration of wind power plants, much contrast to the conventional ones. Thus, the sole focus of this paper is on the proposal of power generation expansion plan taking the optimal generation capacity mix on par different penetration levels of RES [9].

For the sake of arriving at the clear picture over the reliability of power system prevalent in Tamil Nadu during the year 2015 WASP-IV is applied and the findings are mentioned in [10]. A complete analysis of Demand Side Management (DSM) and Supply side Management (SSM) along with three different Renewable Energy penetration bases are discussed in [11]. This analysis is based on the economic and environmental impacts on the feasibility of the expansion plans. As a viable mode of power expansion plan, customers' involvement regarding photovoltaic electricity generation and their probable management methods are discussed in [12]. When China faced its critical power shortage and devised its own expansion plan, the country came out with a hybrid multi-criteria mode of assessing the Demand Side Management. China chose to construct these plans to meet the restructuring of its industrial decline. A separate case study regarding China's revamping measure on these lines is made in Beijing [13].

3. Outline View of Tamil Nadu Power Sector

The state of Tamil Nadu is a potential landscape among the 29 states in India, with its territorial stretch as the eleventh largest. Tamil Nadu has the population volume to stand as the sixth in the country. Geographically, the state is located down south of the Indian region and is encircled by other states namely Andhra Pradesh, Karnataka, Kerala, and Pondicherry. Due to various factors beyond control, Tamil Nadu undergoes a tough phase of electrical energy distribution. During the last five years, the state has witnessed a highly disproportionate nature of demand and generation of electricity. This has resulted with acute power shortage evoking large scale of power cuts which badly affected the general life.

Both domestic and commercial sectors faced hardships due to this power crisis and the industrial sector is the worst affected ending up with economy decline. Dip in the proportion of demand and generation could not be rectified during this period. In the year 2014, the peak demand was 13771 MW against the installing capacity of 21,794MW. The same sort of difference could be noticed during the year 2015, when the installing capacity had been 23,762MWagainst the peak demand of 13766MW [14]. Nevertheless, there has been a reasonable improvement in the installing capacity but the peak demand was parallel in increase. This is observed when the de-rating of generators are considered critically in addition to the accumulated deriving of 45% of renewable sources in the installed capacities. The state faced the inconsistent flow of wind due to seasonal patterns. So the state could not receive necessary amount of wind and hydro energy during the specified seasons.

Moreover, the decades old thermal plants have not been properly overhauled or conditioned to run effectively or to the best, replaced. The acute nature of power cut effected by the state was recorded by the Central Electricity Authority of India (CEA). This record disclosed that Tamil Nadu implemented the average power shut down for commercial and HT sectors to the amount of 40% [15]. As per the CEA's report for 2012, which contained accurate range of power cut, the capital city Chennai received the shut down for two hours per day. The power shut down in other regions of the state was in the pattern of three hours in the urban and rural areas. However, the commercial and HT sectors received the worst treatment with 10% shut down during the peak hours. Having accounted all these threats, the need for an alternative mode of sustaining the normal power supply is analyzed. Based on the analysis, certain strategies under DSM are observed.

On administrative set-up, Tamil Nadu Generation and Distribution Corporation (TANGEDCO) manage the distribution and management of power supply in the state. TANGEDCO explores all possibilities to implant power generation sources. According to the statistics available, as on December 2015, the total installed capacity of 23, 762 MW is found in Tamil Nadu [16], which Coal plants, Lignite plant, Gas plants, Nuclear plants and Diesel plants share 27.4%, 17.4%, 4.3%, 4.2% and 1.73% respectively. This illustrates that the generation of power from the above mentioned plants account for 55.03% of the net installed capacity while renewable sources contribute the remaining 44.97%. The contribution of wind energy, out of this capacity of 44.97% stands as 31% whereas 9% comes from Hydro plants and the combined contribution of solar energy, waste energy, bio-mass and bio co-generation accounting for 5%. An extensive power generation mix pattern is shown in Figure 1.

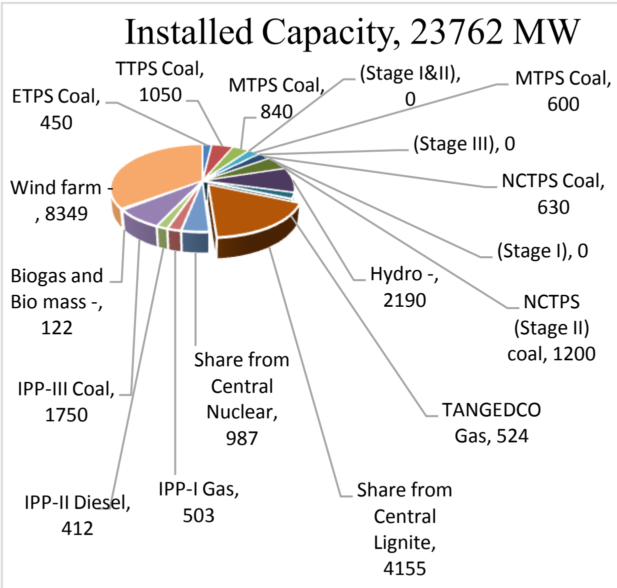

Fig. 1. Installed generation mix of Tamil Nadu in 2015.

While the power shortage occurred due to the failing of source wind, there were administrative inefficiencies in planning and maintenance which added the crisis. The foremost lapse is letting the decades old plants run out of their capability and not being replaced properly. This led to face the production of less capacity of power, making disproportion of demand against production.

The units in Thoothkudi and Ennore, put together six in numbers, are nearly 47 years old which need to be replaced. The Mettur thermal plant was commissioned in 1980 as much as eight units at Neyveli hub of 1960s are in such pathetic condition. Shut off of the ETPS in November 2016 made the condition to the worst level.

4. Implementation in WASP-IV [17]

WASP-1V is one among the efficient software package tools applied in the studies related to GCEP. Thus, an appropriate view is derived on the reliability of Tamil Nadu power system using this WASP-IV, which consists of Seven modules listed below:

Module 1: LOADSY (Load System Description),

Module 2: FIXSYS (Fixed System Description),

Module 3: VARSYS (Variable System Description),

Module 4: CONGEN (Configuration Generator),

Module 5: MERSIM (Merge and Simulate),

Module 6: DYNPRO (Dynamic Programming Optimization),

Module7: REPROBAT (Report Writer of WASP in a Batched Environment).

4.1 Load Demand Data and Energy Growth

The load profile existed during 2015 in the power system of Tamil Nadu is illustrated in Figure2. The an average load, 11,981.84MW in that year, making the average annual load factor for the year to 87.36% out of the net energy demand of 105353.1GWh.

The load demand during the past eleven years (2005-2015) has been derived from SRPC annual report. When time series analysis is applied it is found that the consistent increase of demand shows 5.8% increase in terms of the demand history. And this projection gives the figure of 74,589MW during the 30th year 2044. The load demand data were fed to the WASP-IV through LOADSY.

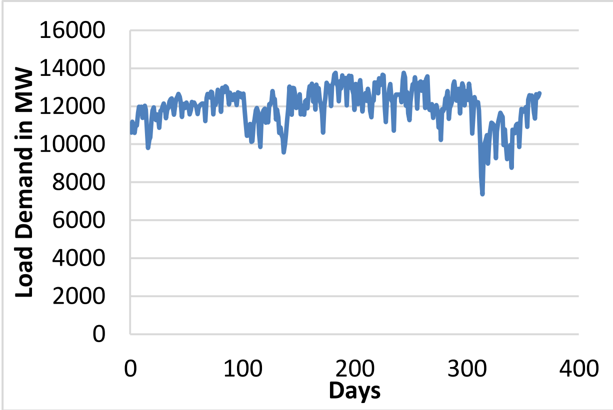

Fig. 2. Daily load demand profile of Tamil Nadu in 2015

Chart Source: Southern Regional Power Committee (SRPC) – Progress report 2015.

The Fifth-order polynomial equation for Load Duration Curve (LDC) input data obtained for the Tamil Nadu Power system's peak demand for the year 2015 is arrived from using curve fitting method in MATLAB, fifth order polynomial equations was developed and coefficients were found. These coefficients were inserted to WASP-IV for estimating energy demand in GWh and 30 years of energy demand has been derived.

4.2 Future Expansion Capacity retirement of Thermal plants

Majority of thermal plants in the state of Tamil Nadu are worn out to the maximum and need to be replaced. To compensate the difference of power Generation Capacity Expansion with RES is viably recommended. Table 1 displays the comparative analysis of worn out thermal plants according to their year of commencement of operation.

Table 1. Retirement of Thermal Plants

Name of the plant	Year							
	2017	2019	2022	2027	2029	2031	2038	2040
ETPS	-450	-	-	--	--	--	-	-
TTPS	-	-420	-210	-	-	-420	-	-
MTPS	-	-	-	-420	-420	-	-	-
NCTPS	-	-	-	-	-	-	-420	-210

5. Energy Planning Analysis

In this section, the proposal regarding

implementation of integrated resource planning for the state of Tamil Nadu is suggested. When it comes to the matter of discussion on integrated resources planning, both supply and demand side management of power system have to be given equal care. As such, there are two possible means of power generation expansion plans for future needs. The first one is supply side action enhancement through increased generation capacity. To make this more user-friendly, environmental factors are also taken into consideration for reaching at various RES levels. The second one is related to decrease the demand by several restricted modes in order to save cost of newer plants installation as well. This can be achieved through Load management and Energy Reduction Programme.

5.1 Supply side management

Under supply side option, in this case, it is suggested to improve the generation capacity by way of applying GCEP. Tamil Nadu has been generating electricity from the maximum level of best available resources. In addition to the conventional energy sources, the state musters its power generation from wind, solar and hydro plants. These are the ideal renewable energy sources most suited for the state's geographical and natural conditions. Further, expansion planning becomes more feasible when these sources are exploited for power generation. Out of these, hydro plants are more viable when pumped storage option is utilized due to its whole reliability and future availability. This is justified with the existing hydro plants such as one at Kadamparai with the installed capacity of 500MW in the year (2017) and the other one at Kundah, 500 MW by the end of year 2022. In addition, Sillahalla project is estimated to generate 2000 MW by the year 2023 followed by Velimalai with an output of 200 MW by the year 2027. Tamil Nadu had the Renewable Energy Sources penetration level to 44.9% during the year 2015. This has emulated more possibilities to explore the penetration levels of various RESs. As such, Business As Usual Renewable Energy Source (BAURES) has 40% penetration level, while Optimum RES (OPRES) has 50% penetration level and High RES (HRES) has 60% penetration level were taken with the ref [18] Subsequently the option of optimum RES lies on the reliability index of Energy Not Served (ENS). In addition, with different penetration levels of RES, emissions from coal based plants in the form of $CO_2$and $SO_2$are analyzed by employing WASP-IV. As for the cost factor, the total projections for installation of plants in connection with various RES are estimated by way of dynamic programming. Since each scenario of these categories has individual merit and constraints.

5.2 Demand Side Management

This involves analyzing Demand Side Management (DSM), by the way of Load Management Program through peak shifting and Energy Reduction Program (ERP). Essential factors which govern the reliability through ENS, meeting the hazards of environmental pollution caused due to CO_2 and SO_2 and Cumulative 30 years of LPWC are taken into account for analysis in this paper. Every situation on the basis of individual scenario is clearly illustrated in the following Table 2.

Table 2. Various Scenarios Considered

Scenario	Supply Side Option - GCEP
1 a / 1 b	BAURES WNPSS / BAURES WPSS
2 a / 2 b	OPRES WNPSS / OPRES WPSS
3 a / 3 b	HRES WNPSS / HRES WPSS
4 a / 4 b	LMP WNPSS / LMP WPSS
5 a / 5 b	ERP WNPSS / ERP WPSS
6 a / 6 b	Concurrent LMP & ERP WNPSS / Concurrent LMP & ERP WPSS

The overall possibility of expansion plans under both With No Pumped Storage System (WNPSS) and With PSS (WPSS) are comparatively analyzed. Having considered all these probable factors for projection, GCEP and DSM strategies are identified and proposed, based on the constraints from generation system Reliability Index ENS.

6. Observation and Findings on GCEP

The analytical estimation and outcome of the proposed GCEP are concisely described in this section. This is applicable for both demand and supply side in the case of power generation and utility scheme. GCEP is derived from the listed scenarios, out of which 1a to 3a and 1b to 3b are made under WASP-IV. This is done to arrive at the ENS, pollutant controlling measures and cost-efficient factors is given in Table 3.

6.1.1 Reliability Index - ENS

From the analysis of the data available with respect to various scenarios, the results and figures show critical variations. In case of 40% BAURES, the value of ENS is found to be 11080.5GWh; in case of 50% OPRES there is 9086.1GWh; and in case of 60% HRES there is 44584.2 GWh in the 30^{th} year of GCEP. Keeping all these data aside, it is found that in the inclined condition of Tamil Nadu, at 50% RES penetration level the generation of energy could be 9086.1GWh. Hence, it is presumed that the generation capacity is attained based on the variation levels of ENS to the given value. When the scenario 1a and 2a are analyzed, it can be seen that there has been a reduction of ENS at 17.99% while in the scenarios 1a and 3a there is an increase of ENS at 302.4%. This hike in ENS can be seen in the case of scenarios 2a and 3a where there is an increase of390.68%. However, there is an ENS decline in the case of scenarios 1band 2b where there is reduction of 32.1%. Again there are cases of increase in ENS in scenarios 1b and 3b, as well as 2b and 3b through 327.9% and 530.4% respectively.

6.1.2 Estimation of Pollutants CO2 and SO2

From the given Table 3 it can be inferred that more than RES, conventional coal oriented power generation plants emit large amount of pollutants. Among the scenarios analyzed in this study, HRES alone emits lesser emission of CO_2 and SO_2 while BAURES and OPRES do not match HRES in terms of emission quantity.

Regarding reliability index in scenarios 3a and 3b, there is a greater amount yet with lesser compared to other scenarios. Still, there is a mixed variation of CO_2 in scenarios 1a -2a, 1a – 3a and 2a -3a. In case of the first one among these three, there is an increase of 0.75% while in case of the second there is a decline with 17.3% and the same kind of reduction could be found in the third case with 17.9%. The volume of SO_2 present in 1b-2b, 1b-3b and 2b-3b scenarios display a contrasting picture with an increased 1.1% in the first case while there is a decrease of 16.2% and 17.1% in other cases respectively. Thus, to make the feasible nature of generation, it is suggested to opt for 50% OPRES as ideally suitable for the state of Tamil Nadu according to present generation mix.

6.1.3 Cumulative Least Present Worth Cost (LPWC)

The proposed models for thermal and nuclear plants contain various parameters on technical and economic phenomena. Each unit incurs a fixed cost allocation based on the implementation of technical structures. Technical parameters include maximum and minimum capacities for each plant, heat rate at minimum capacity and incremental heat rate between minimum and maximum capacity, maintenance mandates such as scheduled outage.

In addition, there are elements like failure probability, emission rates and specific energy use. On economic levels, the cost calculation includes capital investment, variable fuel cost, fuel inventory cost for the initial stage. From the basic analysis, it can be understood that there is a direct proportion of cost increase in terms of increased RES penetration levels. This makes the total cost of the expansion plan and the all plant cost values were taken from [19]. As an important task, the projected and cumulative total cost for the proposed plants for the 30 year period is estimated using WASP-IV. From this cost estimation, it is found that the cost becomes least when there is a combination of generation plants. This is mooted under Dynamic Programming. When it is said cumulative cost, it includes capital investment in the beginning stage, operation and maintenance cost as recurring head, and the dead money form of ENS.

Table 3. Summary of all scenarios on GCEP

Scenarios	Penetration level of RES in %	With No Pumped Storage System (WNPSS)					With Pumped Storage System (WPSS)				
		ENS in GWh	Pollutants KT		Total generation GWh	Cumulative LPWC K$	ENS in GWh	Pollutants KT		Total generation GWh	Cumulative LPWC K$
			CO_2	SO_2				CO_2	SO_2		
BAURES	40	11080.5	279715.5	9210.4	559908	192028144	8652.9	281810.2	9269.1	564245	111024008
OPRES	50	9086.1	281834.6	9273.8	561901	202523648	5873.5	284854.1	9361.4	567986	129843368
HRES	60	44584.2	231161.1	7902.5	526399	243973920	37032	236247.5	8061.3	538998	175165184

Out of all the scenarios referred so far involving GCEP based on WNPSS and WPSS, there is a percentage variation to the decreased value of 42.2% in case of 1a -1b in BAURES. Similarly, for scenarios 2a -2b in OPRES there is decrease in value of 35.9%. In case of scenarios 3a-3b in HRES there is a decrease of 28.2%.

6.2 Observation and Findings on DSM

It is again stressed that all the scenarios discussed in this paper on DSM fall under Energy Reduction Program (ERP) and Load Management Program (LMP). As regards ERP, the process is large scale with need to reduce power consumption by domestic and commercial sectors. This includes restraining heavy usage of electricity during peak hours under LMP.

In order to make these programs more effective, power supply can be scheduled in a way that no person or commercial sector is affected. In addition, promotion of utilizing electrical gadgets and electronic devices consuming less electricity is recommended. Beyond these two, DSM for WNPSS and WPSS under same Hydro capacity throughout the observed period of 30 years are viewed to be viable with respect to feasibility and cost factor.

6.2.1. Reliability Index - ENS

This can be affected by way of Load Management Program. Through this scheme, the monthly load patterns were observed and shift on heavy demand during peak hours can be modified. The following Table 4 illustrates the cumulative summary of all scenarios under both the pumped storage patterns:

Of all the scenarios, when peak shifting method is tried under Load Management Program, the resultant ENS is 30175.8GWh. Hence ERP enhances the possibility of reducing the ENS to 23.2% and when ENS is adopted concurrently the resultant ENS is 24.2%, which is a considerable reduction. Further reduction of ENS, 1.3%, is attained in the comparative ENS of scenarios 5a and 6a. Subsequent comparative reductions could be noticed in scenarios 4b, 5b and 6b. Through this trial observation it is noticed that pumped storage system provides appreciable reduction of ENS. This is due to PSS being utilized as storage system. Further, when these patterns are adopted under storage system, cycle efficiency to the extent of 80% is witnessed in PSS. Only after this, PSS is converted as a generator which is made to run for eight hours a day. For another eight hours PSS is let to pump and store water so that the remaining eight hours will be silent hours. All these factors make PSS as more reliable mode of power generation by adopting ENS.

This observed value is different when ERP is employed, wherein 24.2% reduction is observed at 5% demand rate. Thus, it can be accepted that ERP under WNPSS is reliable and flexible in terms of reduction task.

6.2.2 Estimation of Pollutants CO_2 and SO_2

Pollutants play a hindrance role in the case of generating power through coal. Such pollutants are equally hindrance in case of gas turbines as well. So it is mandatory that these pollution constraints are to be given serious considerations for effective power generation. Globally, CO_2 and SO_2 are considered as more prevailing pollutants in the atmosphere. In this study, much attention is given to account the effect of these pollutants in the process of load demand management programs. So, by applying WASP-IV, necessary remedial measures and steps to face for overcoming the pollution effect are described. For instance, when LMP is applied, the resultant amount of 396782.2 KT of CO_2 and 12681.1KT of SO_2 are arrived.

Table. 4 Summary of all scenarios on DSM

Scenarios	With No Pumped Storage System (WNPSS)				With Pumped Storage System (WPSS)			
	ENS in GWh	Pollutants KT		Cumulative LPWC K$	ENS in GWh	Pollutants KT		Cumulative LPWC K$
		CO_2	SO_2			CO_2	SO_2	
LMP	30175.8	396782.2	12681.1	178197392	29838.9	396857.0	12683.5	175958944
ERP	23167.9	376661.7	12043.6	163346704	22869.8	376692.6	12044.6	161456336
Concurrent LMP & ERP	22863.6	376071.9	12022.7	161865712	22580.5	376081.9	12023.0	160082912

However, when ERP is applied, the scene becomes different with considerable reduction of the pollutants. It is 376661.7KT of CO_2 and 12043.6KT of SO_2 which accounts a 5% reduction compared to the scenarios 4a and 5a, against 5.2% reduction in scenarios 4a and 6a. Yet, it is to be accepted in principle, that pump storage system is not reliable on reducing the pollutants. This is due to the fact that DSM strategies do not support generating electrical energy.

6.2.3 Cumulative Least Present Worth Cost (LPWC)

The total LPWC of 2015 which is 8419134 K$ is increased to a substantial value of 17819732K$ in 2044. Similar reduction could be observed in scenarios 5a and 6a where the total LPWC stood at 8% and 9% reduction than scenario 4a at 30th year. Same is the case with scenarios 5b and 6b. So to say, there has been a remarkable reduction of total cost in 6b when ERP PSS is combined with LMP. Another feature that has to be noted, however, is the convenience of the planners to fix the plan duration. As such, it can be summed up that PSS enabled reduction of ENS cost gives way to better reliability, which, in turn effects the reduction in total cumulative LPWC.

Based on all these findings, it is suggested that concurrent implementation of LMP and ERP with PSS is suited for the Tamil Nadu power systems. In order to manage power demand and power generation methods effectively, the following measures are best suited for Tamil Nadu State:

i. In general, ground water plays a crucial role for irrigation purposes in the state of Tamil Nadu. This necessitates the demand for power utility to derive water for agriculture purposes too. Hence to manage the demand, alternative measures can be devised on efficient water management rather than dependence on electricity.
ii. Conventional lighting systems can be replaced with LED bulbs / energy saving lighting system and CFL.
iii. Frequent and periodical Energy auditing can be implemented in domestic power utility, commercial sectors, household power usage, and corporate offices. Proper power conservative measures can be appraised to these sectors.
iv. In order to reduce Green House Gas (GHG), the State can adopt green tree plantation whereby energy can be conserved, water can be saved and sufficient amount of Oxygen can be preserved. If temperature is maintained at low with by creating micro climate, then the need for more electricity, especially for fans and air-conditioners will be lesser.

6.3 Effects of Integration of Concurrent DSM on different RES Scenarios in GCEP

While viewing the overall impact of DSM at various levels of RES Scenarios under GCEP, it is to be important to review its compatibility towards proposed power system. Based on the above discussed findings and references, the following observations could be inferred: three scenarios under consideration were matched with the reliability of the system, expected generation of energy, global warming due to emission of CO2 and SO2 are found. All these findings contribute to a decrease of 48.12% in ENS reliability index for BAURES, for OPRES it is 77.65 % and that of HRES it is 36.5%. Then the expected energy generation from the RES penetration is reduced 4.6% in the case of BAURES, 4.5% in OPRES and 3.5% in HRES.

In the case of BAURES, the environmental pollution is protected with the reduction of CO2 and SO2 at 8.6% and 7.8% respectively. In OPRES, the reduction of CO2 is 5.2% and that of SO2 is 5.1%. Finally in the case of HRES, there is a 4.3% reduction of CO2 and 3.8% reduction of SO2. While PWC of BAURES increased to 57.8%, OPRES to 39% and 19.7% for HRES. All these observations are derived working on a comparison between WNDSM and WDSM. The following Table 5 illustrates the comprehensive analysis of the findings from the research work proposed in this paper.

7. Conclusion

As such, to land at the most possible level of results both supply and demand side management schemes are integrated at all the penetration levels, BAURES, OPRES & HRES. Again, this is carried out by employing concurrent LMP & ERP. The net results analysis exhibits a promising growth reliability of 5.8% for the entire period of 30 years, when OPRES is implemented under With and With

Table. 5 Comparison of different RES Scenarios on WNDSM and WDSM

With No DSM Strategies (WNDSM)					
Scenarios	ENS in GWh	CO_2 in KT	SO_2 in KT	PWC in K$	Expected Generation in GWh
BAURES	8652.9	281810.2	9269.1	111024008	564245
OPRES	5873.5	284854.1	9361.4	129843368	567986
HRES	37032	236247.5	8061.3	175165184	538998
With Combined DSM Strategies (WDSM)					
Scenarios	ENS in GWh	CO_2 in KT	SO_2 in KT	PWC in K$	Expected Generation in GWh
BAURES	4488.9	257513.0	8529.5	175210464	537874
OPRES	1312.2	270071.5	8879.5	180521520	542157
HRES	23514.2	226171.5	7756.2	20965280	520135

NO PSS bases.Based on this factor, it is estimated that there will be prospect of 50% in OPRES on supply side under both WNPSS and WPSS for the whole phase of 30 years. From the complete analysis and accountings, it is observed that under Supply side management, from the overall scenarios dealt with it is found that there will be a 50% enhanced level of possibilities with GCEP. Moreover, it is found that integration of supply and demand side options show wider prospects of reduction in pollution emissions in the cases of thermal plants. This is mainly possible due to the implementation of DSM strategies. However, it is also noted that due to the inverse effects of cost factors, there has been an increase in LPWC. When reliability factor is considered, it is true that PSS paves way for betterment but has no requisite impact on pollution control.

Thus, a clear view about the proposed power generation, power storage and power distribution schemes viable for the state of Tamil Nadu can be obtained. In case of Demand Side Management, it is noted that, ERP individually gives better reduction in demand. At the same time if LMP and ERP are managed on Concurrent Implementation with PSS basis, better results are noticed. Various ways to reduce energy from the consumer side is also suggested. Further strategies possible under energy reduction program are suggested as expansion activities.

References

1. Pabla, A.S.: *Electrical Power Systems Planning*, Macmillan India Limited, 1998.
2. Geonka, D, and Sarath Guttikunda.: *Coal Kills: An Assessment of Death and Disease Caused by India's Dirtiest Energy Source*, Urban Emissions in partnership with the Conservation Action Trust and Greenpeace India, pp.1-36, 2012.
3. Raghuvanshi, S.P., Chandra, A. and Raghav, A.K.,: *Carbon dioxide emissions from coal based power generation in India*. Energy Conversion and Management, (2006), Vol.47, No.4, Mar 2006, pp.427-441.
4. Mittal, M.L., Sharma, C. and Singh, R.,: *Estimates of Emissions from coal fired Thermal power plants in India*, In: Proceedings from 20th Emissions invertory conference, Tampa, Florida, 2012, pp.1-23.
5. Noshad, B., Goodarzi, M. and Kivan, S.,: *Generation Expansion planning for Iranian power grid aiming at providing reliability by comparing WASP-IV program and proposed Algorithm by Dynamic programming*, Indian Journal of Science and Technology,(2012), Vol. 5, No.7, Jul 2012, pp. 2961-2966.
6. Shinwari, M.F., Latif, M., Ahmed, N., Humayun, H., Qureshi, I.M., Ul Haq, I. and Chohan, Y., : *Optimization model using WASP-IV for Pakistan's power plants generation expansion plan*, Journal of Electrical and Electronics Engineering, (2012), Vol.3, No.2, Nov 2012, pp.39-49.
7. Malik, A.S. and Kuba, C.,: *Power Generation expansion planning including large scale wind integration: A case study of Oman*, Journal of wind energy, (2013), July.2013, pp.1-8.
8. Chattopadhyay, D. and Chattopadhyay, M.,: *Climate aware generation planning: A case study of the Tamil Nadu Power System in India*, The Electricity Journal, (2012) Vol.25, No.6, Jul.2012, pp.62 -78.
9. Karunanithi, K., Kannan, S. and Thangaraj, C.,: *Generation expansion planning for Tamil Nadu: a*

case study, In: Transactions on Electrical Energy System, (2015), Vol.25, No.9, Sep.2015, pp1771-1787.

10. Booma J, Mahadevan K, Karunanithi K and Kannan S.,: *Analyzing Reliability of Tamil Nadu Power grid for the year 2015 using WASP-IV*", Indian Journal of Science and Technology, (2016), Vol. 9, No. 38, Oct.2016, pp.1-10.
11. Karunanithi, K., Saravanan, S., Prabakar, B.R., Kannan, S. and Thangaraj, C.,: *Integration of Demand and Supply side Management strategies in Generation expansion planning*, Renewable and sustainable Energy Reviews, (2017), Vol.73, Jun.2017, pp.966-982.
12. Fernandes, R.C., de Avila Geisler, R., Tenfen, D., Abreu, S.L., Takigawa, F.Y. and Neto, E.A.A.,: *Demand Side Management of Electricity Aiming to minimize cost of Residential consumers*, Journal of Clean Energy Technologies, (2016), Vol. 4, No. 5 Sep.2016, pp.321-324.
13. Dong, J., Huo, H. and Guo, S.,*: Demand side management performance evaluation for commercial enterprises*", Sustainability, (2016), Vol. 8, No. 10, pp.1041.
14. *Southern Regional Power Committee – Bangalore, Progress report – 2015*, (from January to December). [Online]. Available: http://www.srpc.kar.nic.in/html/all uploads.html (assessed online on 10.05.2016).
15. *Central Electricity Authority/ Annual Report – 2015.* Available: http://www.cea.nic.in/ monthly-gen.html (assessed online on 16-03-2016).
16. *Installed capacity (in MW) of power utilities in the states/UTS* located in Southern Region. Available: www.cea.nic.in/reports/monthly /inst_capacity/ jan16.pdf (assessed online on 10-03-2016).
17. International Emissions Trading Association.,: Wien Automatic System Planning (WASP) Package: A Computer Code for Power Generating System Expansion Planning Version WASP-IV with User Interface User's Manual. International Atomic Energy Agency, (2001), pp.13-150, *Austria.*
18. Booma J, Mahadevan K, Karunanithi K and Kannan S.,: *Renewable energy penetration and its impact on reliability – A case study of Tamil Nadu*, Journal of Computational and Theoretical Nanoscience, (2017), Vol.14, No.8, Aug.2017, pp.4036-4044.
19. "*Updated Capital Cost Estimates for utility scale electricity generation plants*", Independent Statistics and Analysis, U.S. Energy Information Administration, U.S. Department of Energy, (2013), April 2013, pp.1-201, Washington, DC.