Chapter 104
Reliability Evaluation of Tamil Nadu Power Grid for the Year 2012

K. Karunanithi, S. Kannan and C. Thangaraj

Abstract Reliability is a key aspect of power system planning. The objective of this study is to calculate the reliability indices, Loss of Load Probability (LOLP) and Energy Not Served (ENS) for Tamil Nadu, an Indian State, for the year 2012 using a state-of the art computer model, the Wien Automatic System Planning (WASP-IV) package. During the year 2012, the peak load of the state was approximately 12,000 MW. The peak load shortage of approximately 3,500–4,000 MW though the installed capacity is 17,936 MW. Tamil Nadu faced severe power cuts and break downs. The additional capacity required to get the standard LOLP of 0.1, i.e., one day in ten years, one day in one year and one day in one month are calculated. The results of the computer model analysis shows an additional capacity requirement to meet the proposed LOLP varies between 4,054 and 5,723 MW.

Keywords Power grid · Loss of load probability (LOLP) · Wien automatic system planning (WASP-IV) package

104.1 Introduction

Power is one of the critical inputs necessary for the sustained growth of any economy. Its demand has been continuously growing in industrialized and urbanized regions due to varied reason. Moreover, there is no convenient method to store electric energy in large quantities and hence it is compulsory to maintain a

K. Karunanithi (✉) · S. Kannan
Kalasalingam University, Krishnankoil, Virudhunagar 626126, Tamil Nadu, India
e-mail: kkkarunanithi@yahoo.com

S. Kannan
e-mail: kannaneeeps@gmail.com

C. Thangaraj
Anna University of Technology, Chennai, India
e-mail: thangaraj.vc@gmail.com

C. Kamalakannan et al. (eds.), *Power Electronics and Renewable Energy Systems*,
Lecture Notes in Electrical Engineering 326, DOI 10.1007/978-81-322-2119-7_104

continuous and almost instantaneous balance between production and consumption of electricity. Some additional generation capacity is kept as reserve margin to satisfy the variations in demand. If the supply system is not able to meet the demand, load shedding is unavoidable. The increased installed capacity can reduce the power shortage. However, overinvestment and high operating costs may lead to increased energy cost and may reflect in the bill paid by the consumer. On the other hand, underinvestment and low generation margins may lead to unavailability of power and poor reliability to consumers.

Southern region of India has the highest peak shortage of 14.5 % and energy shortage of 10.5 Million Units (MU) [1]. Tamil Nadu is one of the states in southern region. Over the last few years, Tamil Nadu has been facing massive power deficits due to varied reasons. As a result, the state is now facing huge power cuts. This power shortage affects the industries, leading to loss in efficiency, production and loss of income. In order to substitute the power during the power cuts, most of the domestic consumers are using the Uninterrupted Power Supply (UPS) system, commercial consumers are using mini Diesel/Kerosene generators and industrial consumers are using large diesel generators. Hence the estimation of reliability indices in terms of LOLP and EENS is of critical importance.

The performance of various plants in Tamil Nadu was analyzed for the period 2004–2008 and the potential for wind, solar and biomass was discussed in [2]. The incorporation and impact of Wind Energy Conversion System (WECS) in Generation Expansion Planning (GEP) using WASP-III was analyzed in [3]. The different version of WASP model was used in (i) Iranian power grid (ii) Pakistan's Power Plants and (iii) Oman power grid [4–6].

In this paper, WASP-IV package [7] has been used to analyse the reliability in terms of LOLP and ENS of Tamil Nadu Power Grid. The reliability study is carried out for the year 2012. The rest of the paper is organized as follows: Sect. 2 describes the overview of Tamil Nadu power scenario and Sect. 3 describes implementation of the problem in WASP-IV. Section 4 provides results and discussion and Sect. 5 concludes.

104.2 Power Sector in Tamil Nadu-An Overview

Tamil Nadu, the eleventh largest state in India, covers 130,058 m^2 (50,216 sq. miles) and has a coastline of about 910 km (600 miles). In terms of population, it is the seventh most populous state with a population of about 72 million, nearly 6 % of India's population (census 2011). Tamil Nadu has the highest level of urbanization in India, which accounts for 9.6 % of India's urban population. The state has the distinction of having two monsoon seasons: south-west monsoon from June to September and the north-east monsoon from October to December. This distinctive feature has helped Tamil Nadu to become a favored wind power destination because the monsoon winds contribute to the bulk of the annual wind power generation. Tamil Nadu has an installed capacity of 6,700 MW of wind power. The total installed generation capacity of Tamil Nadu in the year 2012 was 17,936 MW [8]. Table 104.1 shows technology and the existing installed capacity of the state in the year 2012.

At present, about one-third of the installed capacity of renewable sources in India exists in Tamil Nadu alone. Out of 17,936 MW installed capacity, thermal contributes 45.6 % and renewable powers contribute 54.4 % (Wind 37.35 %, Biomass 4.85 % and Hydro 12.2 %). The generation mix in the year 2012 is shown in Fig. 104.1.

Though the installed capacity 17,936 MW was sufficiently higher than the peak demand of 12,000 MW, the system was not able to fulfill the demand due to the following reasons:

(i) Scheduled or unscheduled maintenance of generating units and its auxiliaries
(ii) Uncertainty in availability of wind power and hydro power
(iii) Units are working less than their rated capacity due to aging, i.e., many units crossed their lifetime.

In order to overcome the power shortage, the TANGEDCO adopts the following countermeasures [8]

- Forty percent (40 %) cut on base demand and energy for high-tension (HT) industrial and commercial consumers.
- HT industrial and commercial consumers can draw less than 10 % of power from the grid during evening peak hours.

Table 104.1 Installed generation capacity (MW) in Tamil Nadu

S. no.	Name of the plant	Type of fuel	No. of units	Cap./unit (MW)	Cap. (MW)	FOR (%)	Maint. sche. (days/year)
1	Ennore	Coal	3	150	450	3	30
2	Tuticorin	Coal	4	210	840	7	26
3	Mettur	Coal	5	210	1050	10	21
4	Nr. Chennai	Coal	3	210	630	10	34
5	Biomass	–	3	290	870	25	30
6	Wind farm	–	100	67	6700	81.4	10
7	TANGEDCO	Gas	5	103	515	3	20
8	IPP	Gas	10	118	1180	3	20
9	Kalpakkam	Nuclear	2	165	330	3	25
10	Others	Diesel	10	65	650	10	30
11	Share from Central	Lignite	5	506	2530	10	30
12	Hydro	–	33	–	2191	–	–
Total					17,936	–	–

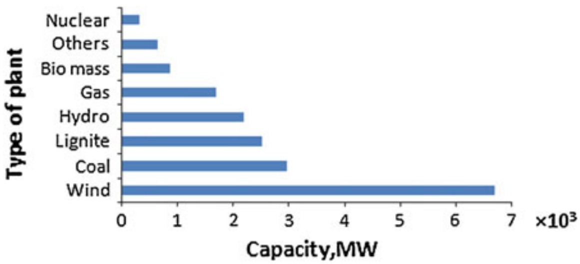

Fig. 104.1 Generation mix of Tamil Nadu in the year 2012

- Introduction of power holiday to all the HT, low tension (LT) and low-tension current transformer (LTCT) industries for one day between Monday and Saturday on staggered basis.
- All HT industries are required to declare Sunday as a weekly holiday.
- All HT industries can procure power through both inter-state and intra-state open access.
- A nine-hour (six hours during day time and three hours during night) three-phase supply for agricultural services.
- For domestic consumers daily two-hour load shedding (i.e., partial loads disconnected) in the state capital Chennai and its suburbs, and four hours in urban and rural feeders in other areas.

104.3 Implementation in WASP-IV

WASP-IV is one of the popular application software package used for Generation Expansion Planning (GEP) studies. WASP-IV calculates reliability indices LOLP and ENS for every year of planning study. In this study, WASP-IV is used to evaluate the Tamil Nadu power in terms of reliability indices and additional capacity required to achieve the same.

104.3.1 Load Data

The detailed load data for Tamil Nadu for every month of the year 2012 is available in [9]. The number of periods (seasons) per year considered as four. Peak load ratio for each season is the ratio of each seasonal peak load divided by peak load of that year. The load duration curve for the year 2012 is shown in Fig. 104.2.

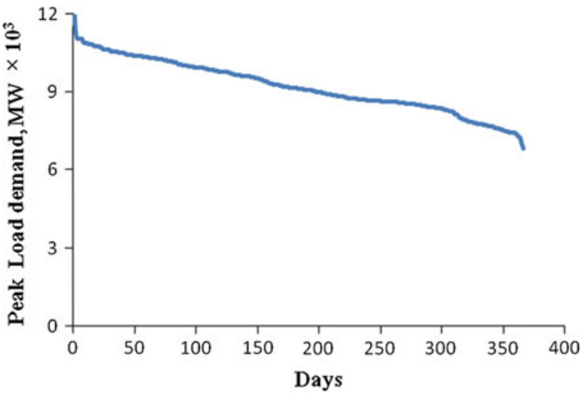

Fig. 104.2 Load duration *curve* of Tamil Nadu for the year 2012

104.3.2 Wind Plant Modeling in WASP

There are several ways to model wind plant in WASP [6] and all have some kind of approximation. In the present study, a wind turbine is modeled as a thermal plant with high FOR (81.4 %).

104.4 Results and Discussions

The minimum demand was 8,052 MW and maximum demand was 12,000 MW in the year 2012. The load factor was 81.51 %. The energy demand in the year 2012 was 85,687.4 GWh and shown in Table 104.2.

The season wise energy generations are as shown in Tables 104.3, 104.4, 104.5 and 104.6. During the first period of study, the energy demand was 20,395.9 GWh and generated energy was only 18,523.5 GWh, the energy shortage was 1,890.9 GWh. The LOLP in this period was 93.52 %. The higher value of LOLP was due to inadequacy of power generation. During the second period, the energy demand was 21,084.3 GWh and generation was 19,323.4 GWh. The energy deficit in this period was 1,760.9 GWh. The LOLP was 76.25 %, which is less than the previous period. During the third period, the highest energy demand occurred as 23,549.8 GWh among the four periods and energy generated was 20,983.3 GWh. The energy shortage was 2,566.6 GWh. The LOLP was still higher as 93.39 %. During the fourth period, the energy demand was 20,657.4 GWh and generation

Table 104.2 Max. and min. load demand, energy demand, load factor in 2012

Year	Max. demand (MW)	Min. demand (MW)	Total energy demand (GWh)	Load factor (%)
2012	12000	8052	85687.4	81.51

Table 104.3 Summary of all four periods

S. No.	Periods	Capacity (MW)	Gen. (GWh)	Peak load (MW)	Energy demand (GWh)	ENS (GWh)	LOLP (%)
1	1	15978.6	18523.5	10800.0	20395.9	1870.9	93.5215
2	2	15995.0	19323.4	11160.0	21084.3	1760.9	76.2566
3	3	16214.4	20983.3	11760.0	23549.8	2566.6	93.3904
4	4	15995.0	19982.5	12000.0	20657.4	674.9	34.0460
Total			78,812.7	–	85,687.4	6873.3	–

Table 104.4 Energy generation of year 2012-Period 1

S. No.	Name of the plant	No. of units	Peak cap. (MW)	Total cap. (MW)	Energy (GWh)	Cap. factor (%)
1	HYRDO	33	194.8	233.6	500.0	10.4
2	ENN	3	150	450	956.1	97.0
3	TUTI	5	210	1050	2093	91.0
4	METT	4	210	840	1683.4	91.5
5	NR.C	3	210	630	1262.4	91.5
6	BIO	3	290	870	957.6	50.3
7	WECS	100	67	6700	2729.2	18.6
8	TANGEDCO	5	103	515	1089.5	96.6
9	IPP	10	118	1180	2507.1	97.0
10	KALP	2	165	330	476.3	65.9
11	OTHE	10	65	650	888.2	62.4
12	CENT	5	506	2530	3380.7	61.0
Total					18523.5	–

was 19,982.5 GWh (Table 104.7). The energy not served was 674.9 GWh. The LOLP was 34.04 %. The LOLP has drastically reduced because of lower value of ENS compared with other periods. In the fourth period, all plants were in service. The total energy produced by all plants in the year 2012 was 78,812.62 GWh and total energy demand was 85,687.4 GWh and shown in Table 104.8. The overall energy shortage in the year 2012 was 6,874.78 GWh. The overall LOLP was 74.30 % (271.208 days/year).

In order to get standard/accepted LOLP of one day in ten years (0.02739 %), we have to add additional generation capacity of 5,723 MW. Table 104.9 shows the additional capacity requirement from the plants. With the addition of 5,723 MW capacity, the total energy generation will increase from 78,812.7 GWh to

Table 104.5 Energy generation of year 2012-Period 2

S. No.	Name of the plant	No. of units	Peak cap. (MW)	Total cap. (MW)	Peak energy (GWh)	Energy (GWh)	Cap. factor (%)
1	HYDRO	33	211.2	250	415.0	500.0	10.4
2	ENN	3	150	450	478.0	955.9	97
3	TUTI	5	210	1050	71.2	1494.7	65
4	METT	4	210	840	61.6	1294.5	70.4
5	NR.C	3	210	630	60.1	1262.4	91.5
6	BIO	3	290	870	936.2	1429.0	75
7	WECS	100	67	6700	2607.0	2729.2	18.6
8	TANGEDCO	5	103	515	83.5	716.0	63.5
9	IPP	10	118	1180	442.1	1918.5	74.2
10	KALP	2	165	330	219.2	657.7	91
11	OTHE	10	65	650	916.3	1323.6	93
12	CENT	5	506	2530	1056.2	5042.0	91
Total					7346.4	19323.5	–

Table 104.6 Energy generation of year 2012-Period 3

S. No.	Name of the plant	No. of units	Peak cap. (MW)	Total cap. (MW)	Peak energy (GWh)	Energy (GWh)	Cap. factor (%)
1	HYDRO	33	396.3	469.4	840.0	1000.0	20.8
2	ENN	3	150	450	320.8	641.5	65.1
3	TUTI	5	210	1050	99.6	2092.5	91
4	METT	4	210	840	80.2	1683.2	91.5
5	NR.C	3	210	630	37.7	791.5	57.4
6	BIO	3	290	870	936.2	1429.0	75
7	WECS	100	67	6700	2607.0	2729.2	18.6
8	TANGEDCO	5	103	515	136.1	1086.6	96.3
9	IPP	10	118	1180	594.3	2506.1	97
10	KALP	2	165	330	219.2	657.7	91
11	OTHE	10	65	650	916.5	1323.8	93
12	CENT	5	506	2530	1056.2	5042.0	91
Total					7843.8	20983.1	–

Table 104.7 Energy generation of year 2012-Period 4

S. No.	Name of the plant	No. of units	Peak cap. (MW)	Total cap. (MW)	Peak energy (GWh)	Energy (GWh)	Cap. factor (%)
1	HYDRO	33	211.2	250	415.0	500.0	10.4
2	ENN	3	150	450	477.6	955.5	97
3	TUTI	5	210	1050	99.6	2092.5	91
4	METT	4	210	840	80.2	1683.2	91.5
5	NR.C	3	210	630	60.1	1262.4	91.5
6	BIO	3	290	870	936.2	1429.0	75
7	WECS	100	67	6700	2607.0	2729.2	18.6
8	TANGEDCO	5	103	515	47.4	453.4	40.2
9	IPP	10	118	1180	331.6	1868.5	72.3
10	KALP	2	165	330	219.2	657.7	91
11	OTHE	10	65	650	902.8	1309.1	92
12	CENT	5	506	2530	1056.2	5042.0	91
Total					7232.9	19982.5	–

Table 104.8 Summary of result for the year 2012

S. No.	Name of the plant	Cap./unit (MW)	No. of units	Cap. factor (%)	Energy (GWh)
1	HYDRO	–	33	13.03	2500.00
2	ENN	150	3	89.02	3509.12
3	TUTI	210	5	84.5	7772.71
4	METT	210	4	86.22	6344.30
5	NR.C	210	3	82.97	4578.80
6	BIO	290	3	68.81	5244.50
7	WIND FARM	67	100	18.6	10916.71
8	TANGEDCO	103	5	74.16	3345.46
9	IPP	118	10	85.14	8800.29
10	KALP	165	2	84.73	2449.28
11	OTHE	65	10	85.08	4844.66
12	CENT	506	5	83.5	18506.79
Total					78812.62

Table 104.9 Results for reliability indices-various scenarios

S. No.	Additional capacity required (MW)	Total energy generated (GWh)	LOLP	ENS (GWh)	Contribution of RES
1	4054	85,592.3	One day in one month	95.2	51.59%
2	5153	85677.9	One day in one year	9.2	51.16%
3	5723	85683.6	One day in ten years	3.8	48.80%

85,683.6 GWh and ENS will be 3.8 GWh. Now total installed capacity becomes 23,659 MW. The contribution of renewable power will be 9,356 MW, approximately 39.54 %. In order to get approximately LOLP of one day in one year, we have to add additional generation capacity of 5,153 MW. With the addition of 5,153 MW capacities, the total energy generation will increase to 85,677.9 GWh and ENS will be 9.2 GWh. Now total installed capacity becomes 23,089 MW. In order to get approximately LOLP of one day in one month, we have to add additional generation capacity of 4,054 MW. With the addition of 4,054 MW capacities, the total energy generation will increase to 85,592.3 GWh and ENS will be 95.2 GWh. Now total installed capacity becomes 21,990 MW.

104.5 Conclusion

In this paper, reliability evaluation of Tamil Nadu power grid for the year 2012 was studied. The LOLP for the year was 74.3 % and approximately 271 days/year. In other words during the year 2012, the generation (available) was not being able to meet the demand approximately for nine months. This value is very high, even though total installed capacity was 17,936 MW and nearly 6,000 MW higher than that of peak demand. The higher value of LOLP is due to high wind power installed capacity since it is intermittent in nature and poor capacity adequacy. The result shows that additional capacities of 5,723 MW, 5,153 MW and 4,054 MW needs to be installed from various resources to get LOLP of one day in ten years, one day in one year and one day in one month.

References

1. Rallapalli SR, Ghosh S (2012) Forecasting monthly peak demand of electricity in India-A critique. Energy Policy 45:516–520
2. Jayabalan (2009) Study on power scenario in Tamil Nadu centre for Asia studies. http://www.asiastudies.org/file/publication/balan/TNEB%20paper.pdf. Accessed 10 Feb 2013

3. Schenk KF, Chan S (1981) Incorporation and impact of wind energy conversion system in generation expansion planning. IEEE Trans Power Apparatus Syst 100:4710–4718
4. Noshad Bahram et al (2012) Generation expansion planning for Iranian power grid aiming at providing reliability by comparing WASP-IV program and proposed algorithm by dynamic programming. Indian J Sci Technol 5:2961–2965
5. Shinwari Muhammad Fahad et al (2012) Optimization model using WASP-IV for Pakistan's power plants generation expansion plan. J Elect Electron Eng 3:39–49
6. Malik Arif S, Kuba Cornelius (2013) Power generation expansion planning including large scale wind integration: a case study of Oman. J Wind Energy 2013:1–8
7. Wien automatic system planning package version-IV (2001) User's manual. International Atomic Energy Agency, Vienna
8. Tamil Nadu Energy department Policy Note (2013). http://cms.tn.gov.in/sites/default/files/documents/energy7.pdf. Accessed 10 Feb 2013
9. Southern regional power committee Bangalore, progress report from January to December (2012) http://www.srpc.kar.nic.in/html/all uploads.html. Accessed 10 Feb 2013