International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Wind Power Plant Modelling in Wasp-Iv Through Ssa

Booma Jayapalan, Velmurugan Ramakrishnan

Abstract: ***This paper deals with the simulation results obtained with regard to the restricted load demand in the state of Tamil Nadu for the year 2015. There are certain approaches in long term benefits of wind power plant modelling in WASP-IV. They all have some kind of approximations such as, load modification approach and supply-side approach. In Supply-Side Approach, Wind Power Plant (WPP) is meant to have both unreliable thermal plant capacity and the hydro capacity of Run-of-River (RoR), to make this approach more effective. As Capacity Factor (CF) is estimated as 18.6% for WPP, the FOR is estimated to be 81.4%. For solar energy generation system too, such a process is applied whereby the average CF is considered to be 40% while the FOR is assumed to be 60%. In the representation of WPP as RoR hydro plant, the constraint in the form of inflow energy.***

Keywords**:** ***Wind Power Plant, Run-of-River, supply side approach (SSA), WASP-IV.***

I. INTRODUCTION AND LITERATURE

Electricity is a potential source for sustaining and enhancing a country's economy. Since there is no possibility or mode to store up electricity for longer period, a need arises to devise a method to fill the gap between demand and generation. This includes, mainly, reservation of a certain amount of electricity as a source to fulfill the demand at any time. When this reservation is not maintained there could be inevitable load shedding. Occasionally, generating units go off due to unexpected technical defects.

So, generation system reliability is to be maintained in order to avoid load shedding. Literatures [1,2] focuses RES penetration as an alternate for increasing generation for Tamil Nadu. Generation Expansion Planning for realistic power system by incorporating wind power plant with reliability constraints were discussed in [4,5,6,7].WASP-IV is used to analyses whether power generation is adequate or not, assuming 100% security of the system[8] .

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
Booma Jayapalan*, Assistant Professor, PSNA College of Engineering& Technology, Dindigul, Tamil Nadu, India., boomakumar2005@gmail.com
Velmurugan Ramakrishnan, Professor,Mallareddy Engineering College for Women, Secundrabad, Telangana, India,velsvictor@gmail.com

II. TAMIL NADU POWER SECTOR- AT A GALANCE

Tamil Nadu (TN) is one of the prominent states in South India. The Central Electricity Authority released the data for the power condition in the year 2015 [9]. According to this report, TN faced the lowest peak load demand of power totaling 7359 MW during November 2015 and the highest peak demand of power 13,766 MW during July 2015. The minimum energy shortage faced by the state during November 2015 is 7864.3 GWh while the state's maximum energy shortage during July 2015 is 9449.2 GWh. Thus, the data clearly exhibits the average peak load demand of 11981.84 MW and the average energy demand of 105383.9 GWh during the year 2015.

TN is considered as one of the leading states in India. The state has been maintaining its show of installing the RES in every five-year plan. In the 9th five year plan from 1997 to 2002, TN could generate 856 MW of wind plant installed capacity. There has been a rise from this installed capacity value to 3475 MW during 2002-2007. The wind installed capacity of the state during the 11th five year plan, 2007-2012, was 6970 MW [10]. However, in the subsequent years, up to 2015, the installed capacity of Wind Power Plant (WPP) is 7076 MW, 7206 MW and 7394 MW during the years 2013, 2014 and 2015 respectively. Figure 1.1 illustrates the distribution of the combined generation mix of TN in the year 2015 [11].

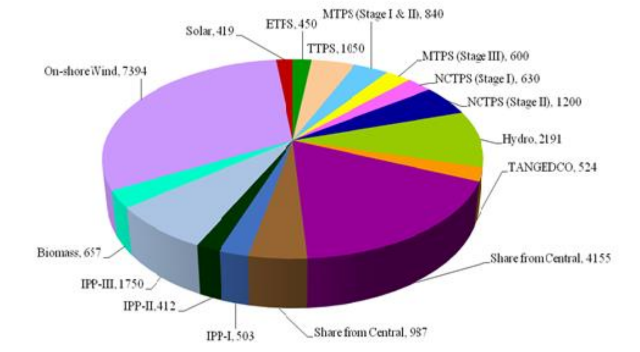

Fig. 1.Generation mix in the year 2015. (Capacity in MW)

III. WASP-IV IMPLEMENTATION

WASP-IV has seven modules viz., Load System Description (LOADSY), Fixed System Description (FIXSYS), Variable System Description (VARSYS), Configuration Generator (CONGEN), Merge and Simulate (MERSIM), Dynamic Programming Optimization (DYNPRO) and Report Writer of WASP in a Batched Environment (REPROBAT) [12].

The first three modules are numbered in symbols, since they can be executed independently in any order. Modules 4, 5 and 6 must be executed in order, after the execution of modules 1, 2 and 3. The summary report of all the six modules, in addition to its optimum or near optimum results are given in module 7. Figure 1.2 gives the long term GCEP execution flow chart based on WASP-IV. The base data related to restricted peak demand is gathered from the official source called Southern Regional Power Committee (SRPC) report for evaluating the reliability index [13].

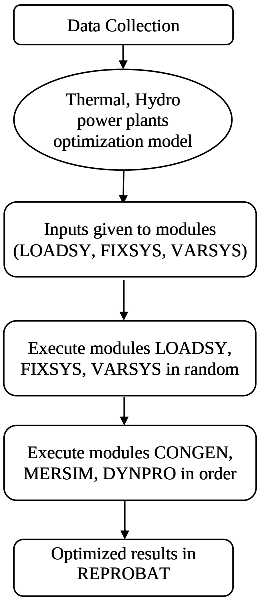

Fig. 2.WASP-IV execution flow chart

Based on these data, the reliability indices LOLP and ENS are estimated. Table 1.1, shows the summated annual load demand, for the year 2015. It is clear that in case of restricted load demand, the minimum demand is 7,359 MW, the maximum demand is 13,766 MW while the annual energy required is 105383.8 GWh. These data leads to the estimation of the annual load factor as 87.39 % for the restricted demand using WASP-IV.

TABLE I. ANNUAL SUMMARY OF DEMAND IN 2015

Year	*Minimum demand (MW)*	*Peak demand (MW)*	*Energy requirement (GWh)*	*Load Factor (%)*
2015	7359	13766	105383.9	87.39

IV. WIND POWER PLANT MODELLING IN WASP-IV

There are certain approaches in long term benefits of wind power plant modelling in WASP-IV [14,15]. They all have some kind of approximations such as, load modification approach and supply-side approach (SSA).

A. Load Modification Approach

Wind turbine is set as a negative load under load modification approach. The calculation of anticipated energy production from the wind turbine is subtracted first from the original chronological load curve. Thus, the load duration curve could be drawn. Optimization is done for expansion plants without Wind Power Plant (WPP) and then added with the optimal case. However, while calculation is done for long term adaption there are certain constraints in these calculations in terms of accuracy. This approach is suitable for calculations made for short-term analysis only, being not able to derive unassuming or uncertain wind pattern in future periods.

B. Supply-Side Approach

Major factor proposing this supply-side approach is the valid advantage, in which WPP is treated as conventional plant in WASP-IV. This WPP is meant to have both unreliable thermal plant capacity and the hydro capacity of Run-of-River (RoR), to make this approach more effective.

a. SSA: Representation of WPP as thermal plant

In order to have generation from solar or wind plants in WASP-IV, it is applicable by treating them as thermal plants, as per sliding window technique. From the study, the capacity factor of each of the wind plants and solar plants is mentioned. As Capacity Factor (CF) is estimated as 18.6% for WPP, the FOR is estimated to be 81.4%. For solar energy generation system too, such a process is applied whereby the average CF is considered to be 40% while the FOR is assumed to be 60%. The calculation of Capacity Factor is done as follows:

CF = Annual Energy Produced (MWh)/ Rated capacityx8760h

Forced Outage Rate (FOR) =1 – CF.

b. SSA: Representation of WPP as RoR hydro plant

This analysis focuses on modelling of WPP from a hydro plant while having the constraint in the form of inflow energy. There are striking similarities between Run-of-River hydro generation and wind generation as follows: i) Both wind plants and hydro plants need the utility for generation once produced and cannot be stored as it is. ii) Both face seasonal variations. iii) Both are characterized by a level of uncertainty (wind conditions or hydrological conditions).

V. RESULTS AND DISCUSSION

This section deals with the simulation results obtained with regard to the restricted load demand in the state of TN for the year 2015. WPP model is made as the thermal plant and as the hydro plant on RoR modelling basis. In similar manner, solar power plant is also modelled as thermal plant.

Simulation Results for Load Demand

The focus is made on the load demand and proportionate generation from thermal and hydro modelled WPP. The data from the simulated results of study are tabulated in Table1.2. This table contains the peak demand, minimum load demand, energy demand and load factor for each month in the year 2015. As such, it can still be observed that the minimum energy requirement 7864.3 GWh occurred in the month of November 2015 with minimum load factor being 86.32%. Similarly, the maximum energy requirement, 9449.2 GWh, occurred in the month of July 2015 with the load factor being 94.03%. The maximum load factor occurred in February 2015.

TABLE II. SIMULATION RESULTS FOR LOAD DEMAND

Year	*Month*	*Minimum demand (MW)*	*Maximum demand (MW)*	*Load Factor (%)*	*Energy Demand (GWh)*
2015	January	9882.0	12149.0	93.72	8312.0
	February	11346.2	12642.0	95.59	8821.6
	March	11256.5	13051.0	95.02	9052.6
	April	9903.6	12727.0	91.43	8494.2
	May	9654.9	13038.0	90.27	8591.8
	June	10854.8	13278.0	93.92	9103.3
	July	11729.3	13766.0	94.03	9449.2
	August	10718.8	13658.0	92.43	9215.6
	September	11153.1	13754.0	91.66	9203.2
	October	10326.2	13307.0	92.77	9011.5
	November	7493.6	12481.0	86.32	7864.3
	December	8818.9	12680.0	89.29	8264.7

In that year, November month have the minimum energy generation and August month have the maximum energy generation. The total generated energy of 74508 GWh (78.24%) is from non-renewable sources, of which 63.85% is contributed by the thermal based power plants. While nuclear plants constitute 7.71%, gas plants constitute 5.35% and 1.33% from the diesel plants. Like-wise, the accumulated generation from renewable sources is 20,728.1 GWh (21.7%). This value comprised constitution of 12.65% of WPP, 6.72% of hydro plants, 1.54% of Solar and 0.85% of biomass sources. Ennore plant, which contributed the least amount of power generation, is known for its long run being 47 years old, is shut down in 2017.

Simulation Results for WPP as Hydro Plant

When WPP is modelled as RoR hydro plant, the total energy generation from all the plants including RES is 98511.2 GWh. The minimum and maximum energy generation occurred in the month of December and July respectively. The energy generation patterns are as follows: out of the total generation of 78034.4 GWh 79.2% from non-renewable sources; coal based power plants contribute 65.59%, 5.19% from gas plants, 0.97% from diesel plants and 7.46% from nuclear plants. The renewable sources and its total generation is 20,476.4 GWh, which is 20.79%. Among the RES, hydro plants shares 4.26%, solar shares 1.49%, bio-mass shares 0.62% and 14.41% of WPP. The seasonal variations of generations from WPP are observed due to RoR modelling. This approach captures some variability and some uncertainty and it is appropriate for long term studies.

Comparison of WPP Modelling in WASP-IV

Table 1.3 shows the comparison of WPP modelling in WASP-IV, which clearly exhibits the advantages of the proposed work on hydro modelled WPP making use of the RoR modelling. By utilizing the thermal modelling, the accumulated energy generation from all the plants has been arrived as 95231.7 GWh, with the ENS average at 10139.6 GWh. Comparatively, WPP modelled hydro plants based on RoR could generate energy of 98511.4 GWh with the ENS average at 6863.5 GWh. The state of TN has an advantage from the seasonal wind during the period from June to November. However, generating the energy through the thermal modelling of WPP does not yield sufficient energy. When both the WPP models are compared, the WPP with the RoR modelling during the seasons proved promising effect. During the year 2015, the thermal modelled WPP could produce the LOLP of 54.5% in continuous day source for 199 days in a year. But this amount differed when compared to the yield out of RoR modelling, where LOLP is 41.3% in 151 days in a year.

To be more precise and clear, there has been a vast difference in the case of energy generated during the six months where both RoR and thermal modelling are applied. Compared to the net installed capacity of 23,762 MW, this is very high and the LOLP has the higher value out of high capacity of wind plant. The difference is due to the disproportion between the total capacity and the derivation of wind availability due to intermittent natural changes. This makes it necessary for additional capacity generation from other sources to meet the deficit. Annual energy generated from all the plants is based on thermal and RoR modelling. As per LGBR 2014-2015 and 2015-2016, released by CEA, Ministry of Power, Government of India, the energy requirement and energy availability is 98822 GWh and 92123 GWh respectively. The ENS value thus obtained from LGBR is 6690 GWh. On the other hand, WASP-IV determines ENS from thermal modelled WPP as 10139.6 GWh.

TABLE III. COMPARISON OF WPP MODELLING IN WASP-IV

Month	*Energy Demand (GWh)*	*WPP as Thermal plant modelling*			*WPP as RoR modelling*		
		Energy Generation (GWh)	*Reliability Indices*		*Energy Generation (GWh)*	*Reliability Indices*	
			LOLP (%)	*ENS (GWh)*		*LOLP (%)*	*ENS (GWh)*
Jan	8312.0	7660.1	46.9	651.7	7643.8	49.7	667.8
Feb	8821.6	7914.5	60.7	907.1	7882.5	65.9	938.6
Mar	9052.6	7989.2	66.3	1063.0	7942.4	73.6	1109.3
Apr	8494.2	7725.0	52.0	768.9	7699.8	56.2	794.5
May	8591.8	7665.4	58.5	926.0	7625.4	64.5	965.7
June	9103.3	7868.4	70.4	1234.7	8847.9	20.6	254.1
July	9449.2	8095.8	73.6	1353.3	9163.7	22.9	285.5
Aug	9215.6	8443.5	52.9	771.9	9004.0	17.6	211.0
Sept	9203.2	8426.4	52.5	776.1	8988.7	17.9	213.1
Oct	9011.5	8340.4	47.6	670.2	8535.5	36.5	474.0
Nov	7864.3	7549.1	24.4	305.9	7648.5	17.8	215.1
Dec	8264.7	7553.2	48.1	710.9	7529.2	51.9	734.8
Tot	-	95231.7	-	10139.6	98511.4	-	6863.5
Avg	-	-	54.5	-	-	41.3	-

The deviation from LGBR thus obtained is 51.57%. Similarly, ENS for RoR modelled WPP is 6863.5 GWh by which deviation between LGBR and WASP-IV ENS is 2.59%. Thus, RoR modelling gives closer deviation of ENS compared to authenticated load generation balance report.

This deviation may also be due to demand variations in LGBR and SRPC report. Hence, the RoR model may be useful for further planning studies. The comparative data could not be made as there is no authentication available for LOLP. This planning study may be carried out to improve the reliability and to meet the demand in future. From the study, it is clear that sliding window technique of thermal modelled WPP is not suitable for reliability aspect. The variations in the case of ENS, as estimated from the two WPP modelling, are due to the different wind availability and the intermittent nature of wind.

VI. CONCLUSION

This paper deals with the evaluation of reliability of the generation in TN state for the year 2015 through its indices. Generation system reliability is usually calculated on the basis of the LOLP and ENS indices. Both indices were calculated through WASP-IV. Using the optimal solution obtained from WASP-IV, the LOLP and ENS values relating to the whole period can be obtained. From the comparative merits of these two, LOLP as probable days of failure to supply and ENS, the amount energy not served, the latter has advantage with regard to evaluation of system reliability. With thermal modelled WPP, LOLP is 199 days or 54.5%, and ENS is 95231.7 GWh. Whereas in RoR modelled WPP LOLP is 41.3% and ENS is 6863.5 GWh only. Thus, the proposed objective of utilizing ENS criteria is valid in this research study. Further, it can be inferred that WPP modelled as RoR offers better reliability with lesser ENS. To make efficient generation from the wind plants, WPP as RoR hydro capacity model is adopted. In addition, there is a better extent of reliability in RoR model, when ENS is applied as a reliability criterion. To be more precise, there is 3.44% increase in the generation of energy while the value of ENS is found to be 32.3% lesser.

The energy based reliability index ENS from WASP-IV simulation is compared with LGBR-CEA report. This validates that in thermal modelled WPP, ENS variation obtained is 51.57% than in RoR modelled WPP where the variation is 2.59%. Thus, the RoR modelled WPP in WASP-IV is validated with LGBR-CEA report.

REFERENCES

1. Booma Jayapalan, Mahadevan Krishnan, Karunanithi Kandasamy & Kannan Subramanian, 2017, 'Renewable energy penetration and its impact on Reliability: A case study of Tamil Nadu', Journal of Computational and Theoretical Nanoscience vol. 14, no. 8, pp. 4036-4044.
2. Mel George 2011, 'Analysis of the power system impacts and value of wind power', International Journal of Engineering, Science and Technology, vol. 3, no. 5, pp. 46-58.
3. Karunanithi, K, Kannan, S & Thangaraj, C 2014, 'Generation expansion planning for TN: A case study', International Transaction Electrical Energy Systems, John Wiley & Sons Ltd, online library, pp. 1-17.
4. Rajesh, K, Kannan, S & Thangaraj, C 2016, 'Least Cost Generation expansion planning with wind power plant Incorporating emission using Differential Evolution Algorithm', Elsevier, International Journal of Electrical Power and energy systems, vol. 80, pp. 275-286.
5. Booma Jayapalan,, K.Mahadevan and S.Kannan," Selection of optimal capacity of Wind Turbine Generator for Generation expansion Planning by considering cost and reliability"International Journal of Applied Engineering Research, Vol. 24, Pg.No. 8403-8406, 2014. [ISSN: 9734562].
6. Booma Jayapalan,, K.Mahadevan and S.Kannan,"Minimum Cost Estimation of Generation Expansion Planning Incorporating Wind Power Plant" ARPN journal of Engineering and Applied Sciences, Vol. 10, No. 7, April, 2015.
7. Booma Jayapalan, Mahadevan Krishnan, Karunanithi Kandasamy & Kannan Subramanian, 2018," "Integrated Strategies for Load Demand Management in the state of Tamil Nadu", Journal of Electrical Engineering, Vol.18, Edition 4, pp 151 – 160.
8. Bahram Noshad, Mina Goodarzi & Shahla Kivan 2012,'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, vol. 5, no. 7, pp. 2961-2966.
9. Central Electricity Authority/yearly report-2015 on monthly generation Available from: < http://www.cea.nic.in/monthly_gen.html > [10.05.2016].
10. A report on 'Power for All, TN', 2016, A joint initiative of Government of India and Government of TN.
11. Installed capacity (in MW) of power utilities in the states/uts located in southern region, Central Electricity Authority, reports on installed capacity. Available from: <www.cea.nic.in/reports/monthly/ installed capacity.pdf > [10.05.2016].
12. Wien Automatic System Planning Package Version 2001, IV User's manual, International Atomic Energy Agency, Vienna.
13. Southern regional power committee Bangalore, progress report-2015 (from January to December). Available from: <http://www.srpc.kar.nic.in/html/all uploads.html> [10.05.2016].
14. Arif, A, Malik, S & Cornelius Kuba 2013, 'Power generation expansion planning including large scale wind integration: A case study of Oman', Journal of Wind Energy, vol. 2013, no. 1, pp. 1-7.
15. Muhammad Fahad Shinwari, Muhammad Latif, Naveed Ahmed, Hassan Humayun, Qureshi I M, Ihsan ul Haq & Yasin Chohan 2012, 'Optimization Model using WASP-IV for Pakistan's Power Plants Generation Expansion Plan', IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), vol. 3, no. 2, pp. 39-49.

AUTHORS PROFILES

Booma Jayapalan, Assistant Professor, PSNA College of Engineering& Technology, Dindigul, Tamil Nadu, India., boomakumar2005@gmail.com

Velmurugan Ramakrishnan, Professor, Mallareddy Engineering College for Women, Secundrabad, Telangana, India,velsvictor@gmail.com