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Wien Automatic System Planning – IV based Future Energy growth Estimation

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Abstract: Electrical energy plays a vital role in meeting the demands in all walks of human life. This energy is the key element for industrialization and technological growth in the world. This paper aims an analytical approach to project the future energy growth of the Tamil Nadu power system using Wien Automatic System Planning – IV (WASP-IV). With an ever increasing power demand, the state has the disproportionate generation capacity of power. Hence estimating the future load demand and Energy requirement is essential to meet the demand through various energy planning strategies like Generation Capacity Expansion Planning (GCEP) and Demand side Management (DSM). For GCEP, WASP-IV is well suited to make long term energy planning, which require estimation of future energy growth in GWh. In this paper, peak load demand of the state is observed in MW from the Southern Regional Power Committee report. Using WASP-IV Energy in GWh is estimated for 30 years from the base case year of 2015. Load duration curve is duly drawn and using curve fitting method in MAT LAB, fifth order polynomial coefficients were found. This is required to insert the load demand data to LOADSY module of WASP-IV. Through the obtained results, in which power system planner could alter the candidate options of generation system for the future need to generate the sufficient power.

Keywords: Energy, Peak Load, Generation Capacity Expansion Planning, Demand side Management, Wien Automatic System Planning, Load Demand.

I. INTRODUCTION

Electricity has been the major driving source for sustaining and promoting the economy of any country in the world. The energy is the pivotal source in domestic, industrial, scientific and medical fields. In all these centuries, the practice has been there to generate, transmit and retail the electricity to meet the demand. However, the demand is not consistent due to various factors which in turn, at times, may create a void in case of generation. This results with disproportion in case of demand against generation, evoking a need to maintain the balance in electricity systems. If the generation of power is not met with the existing demand, it may end up with a revenue loss for both the generators and the consumers. Thus, a unified approach is essential to bring together the generation, transmission and distribution in a systematic way. The generation system should be such that a continuous power supply is provided with respect to the load or demand. Based on this factor, there comes a need to estimate the projected demand and generation of power to provide necessary electricity source. This estimate is made by way of proposing various power installation processes.

II. LITERATURE

Tamil Nadu, an Indian state, which is basically a mediocre industrial state in south India, is meeting a power crisis in recent years. This crisis could have been avoided if proper estimation had been proposed in the earlier years. Hence, this study is aimed at making an estimate of the energy demand for the period of 30 years, from 2015 to 2044. The state government is making all out efforts to retain its industrial and economic growth by meeting the power demand. A

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comprehensive analysis of the reliability of the Tamil Nadu state's power system in the year 2014 and 2015 [1], [2] was taken for analysis. The restricted peak demand during the period was examined using Wien Automatic System Planning-IV (WASP-IV). An approximated estimation of the peak load demand and the peak load shortage for Tamil Nadu state during the year 2012 was made. Based on this, the load growth rate per annum was evaluated on the basis of past data [3]. By using WASP-IV, Peak load in MW was estimated for generation capacity expansion planning to meet the future demand [4].

This paper is constructed with five sections. Section III deals with the actual power demand of the Tamil Nadu state during the past eleven years (from 2005- 2015). The base year, 2015, is made for the consideration of every day load data. WASP-IV implementation proposals are made in Section IV while the results are presented with analysis in section V Section VI sums up the observation and contains conclusion.

III. Load Demand

The peak load demand of Tamil Nadu power system observed from [5] is given in Table I. Using Time series analysis it was found that there had been 5.83% of increase in demand for the past eleven years. By taking it to the analytical results, it is forecasted that there should be a 6% peak load demand in MW for the next future 30 years.

TABLE I
Tamil Nadu Power System Peak Load Demand from 2005-2015

Sl. No.	Year	Peak demand in MW	Sl. No.	Year	Peak demand in MW
1	2005	7647	7	2011	11728
2	2006	9375	8	2012	12813
3	2007	8860	9	2013	13632
4	2008	10334	10	2014	13771
5	2009	9799	11	2015	13766
6	2010	11125		-	-

In this paper, in order to estimate the energy demand in GWh, 2015 year is taken as the base year and its day by day demand is taken from [6] which is given in Table II.

IV. WASP-IV Implementation

The WASP-IV version can be released under the arrangements to Member States which have the necessary analytical and computer capabilities [7].

Module 1: LOADSY (Load System Description), processes information describing period peak loads and load duration curves for the power system over the study period.
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),
Module 7 :REPROBAT (Report Writer of WASP in a Batched Environment),

4.1 Execution of LOADSY

4.1.1 Input / Output Files

The LOADSY module of WASP-IV uses an input file called "LOADSY.DAT" provided by the user and produces two output files namely "LOADDUCU.BIN" and "LOADSY.REP". Before execution of this module, the user has to prepare "LOADSY.DAT" file exactly in accordance with the details given in the next section. The "LOADDUCU.BIN" file generated by the module contains information on system load to be used by other modules of WASP-IV."LOADSY.REP" is the output file of this module which reports the results of present execution.

4.1.2 Input data preparation

The type-X and type-A data records are used only once, as the first two data records, and apply to all years of the study period. For each year, the first data record is a type-B record and the last one is a type-1 record with INDEX=1 indicating end of input data for the given year. A type-1 with INDEX=2 (3 or 4) record tells the computer that the next group of record(s) to be read is of type equal to the INDEX number. Thus, it is necessary that the proper sequence of data records be used; otherwise, it will lead to wrong calculations or interruption of program execution and the printing of an error message. Each type-1 record with INDEX=2 (3 or 4) and the corresponding type-2 (3 or 4) record(s) will constitute a group. Some of these groups must be supplied for the first year of study and are used for subsequent years only if there is a change in information for the respective year. The group of input lines involving one type-1 INDEX=2 and one (or two) type-2 records give the peak loads of the periods expressed as the ratio of the period peak loads to the annual peak load given in the type-B record for the same year. Each time this group of records is used in the LOADSY input data, the corresponding type-2 record (or records) must contain the ratios for all periods, even if the values of the ratios for one or more periods do not change from the values applicable for the preceding year.

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TABLE II
TAMIL NADU POWER SYSTEM PEAK LOAD DEMAND FROM 2005-2015

Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
10621	11377	11596	12327	11130	11580	13677	12573	13754	11750	10566	10010
11178	11830	11917	12343	11761	12029	13766	11752	13520	10885	11661	9223
10842	11923	12039	12633	11148	11590	13215	11420	12029	11690	12481	9392
10592	12253	12100	12362	12110	11548	13036	12247	12725	10228	12163	9768
11084	12384	12143	12065	12072	12258	12265	12291	11620	11847	12196	9951
10980	12421	12148	12727	12257	12334	13329	13255	11262	11742	12212	8767
11658	11882	11993	12525	12806	11890	12934	12963	12235	11885	11797	10760
11980	11561	11219	12691	12311	12728	13623	13255	12796	12415	10019	10614
11695	12081	12438	12482	12386	13048	13119	12680	13151	12501	8296	10587
11973	12379	12655	12441	11302	12974	13135	13469	13067	12804	7359	11003
11381	12517	12511	12659	11818	13193	13493	13114	13531	11333	9119	11068
11693	12642	12472	11773	11422	12250	12048	13165	12931	11915	10038	11078
12022	12491	12766	11164	10592	13042	13298	13658	11868	12075	10213	9861
11829	12229	12728	10448	10885	11821	13607	13627	13206	12259	10474	11355
10666	11445	11578	10470	10907	13137	12990	11895	13243	13132	8981	11852
9812	12028	12311	10664	10321	12405	13593	11163	13311	13307	10136	11713
10229	12135	12084	11070	9563	12958	12902	12497	12812	12765	10697	11825
10367	11905	12319	10122	10009	12290	12637	12403	13196	12295	11140	11867
11298	12203	12862	10154	10512	12118	11814	12929	13272	12890	11099	11962
11782	12071	12483	11054	11336	11592	13165	13166	11912	12923	11014	10915
11937	11942	12546	11309	11844	10618	12961	12296	13427	11629	10894	12343
11359	11569	11702	11789	13038	12032	12103	12149	13577	12707	9275	12575
11269	11813	12975	11904	12240	12423	13065	10714	11933	13202	10660	12546
11564	12221	12966	11688	11563	13244	13379	12405	11813	13055	11149	12563
11368	12102	12752	10561	12963	13114	12708	12622	11796	12051	11368	12285
10867	12199	13051	9861	12948	13085	11727	12622	12111	12754	11655	11662
11761	12044	12988	11092	12860	12949	12359	12616	11384	12796	11562	11352
11772	11957	12711	11647	11916	12004	12503	12616	11778	12334	11430	12627
12011	-	12102	11798	11968	13065	12693	12616	11927	13184	9965	12437
12149	-	12714	11870	12262	13278	12277	12213	12059	12763	10781	12539
11991	-	12569	-	12826	-	12915	13376		11986		12680

Input data on load duration curves (LDC's) must be specified for each period into which the year has been sub-divided, at least for the first year of study and may be changed every year if necessary. Input data on LDC's are prepared using the normalized load duration curve of the period, for which load magnitudes are expressed as fractions of the peak load of the period and the respective load duration values as fractions of the total hours of the period or no. of days in year. Input data on normalized LDC for the periods may be expressed, either in the form of a Fifth order polynomial describing the shape of the curve for each period (type-3 records), or in a discrete form by points (load magnitude and load duration) of the curve (type-4 records). For a given case study these two options are mutually exclusive in the same year, i.e. if records type-3 are used for a particular year, then type-4 records should not be used and vice-versa. It is, nevertheless, permitted to change the LDC Input Option from year to year with the only restriction that each time a change of the option is made, the complete set of LDC's input information for all periods must be included for that year . If the Fifth-order polynomial option for LDC input data is chosen, then type-3 records preceded by one type-1 INDEX=3 record) are used to give the coefficients, an, of the polynomial approximating the normalized LDC for each period of the year. It may happen that these coefficients are identical for two or more periods; however, it is still necessary to have a separate record for each period. The Fifth-order polynomial option for LDC input data obtained

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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, which is listed in Table III. These coefficients were inserted to WASP-IV for estimating energy demand in GWh.

TABLE III
FIFTH ORDER POLYNOMIAL COEFFICIENTS FROM CURVE FITTING METHOD

A0	A1	A2	A3	A4	A5
1.007	-0.2866	1.451	-4.123	4.793	-2.028
1.005	-0.1895	0.3144	-0.3815	0.3409	-0.1918
1.011	-0.3015	1.351	-3.622	4.233	-1.809
0.9991	0.03316	-0.8949	1.855	-1.935	0.7208
1.01	-0.202	-0.07618	0.1077	0.2605	-0.3595
1.014	-0.4515	3.079	-9.529	11.68	-4.975
0.9995	-0.00465	-0.9948	2.951	-3.396	1.297
1.008	-0.2442	0.482	-1.716	2.927	-1.672
1.026	-0.8361	4.939	-13.38	14.91	-5.848
1.027	-0.781	4.558	-12.69	15.02	-6.358
1.024	-0.7426	2.784	-7.255	8.936	-4.146
0.993	0.1548	-1.43	2.245	-1.527	0.2597

If the period LDC's are to be input by points of the curve, then groups of type-1 INDEX=4, type-4 (-4a and -4b) records are used to give the required information. The type-4 Record indicates the number of periods (NP) and the index (IPER) of the periods for which LDC data are specified in the type-4a and type-4b records that follow. For the first year in which the LDC point-by-point option is used, the value of NP on record type-4 must be equal to the value of NPER specified in record type-A and in this case the indices (IPER (I)) are not required since one record type-4a for each period must be included as input data and their ordering (1, 2, 3, ...) is automatically handled by LOADSY. For the next and subsequent years, NP will indicate the number of periods with new LDC information and IPER the index of the respective periods. A data record type-4a is needed for each period with new LDC data. Each type-4a record will tell the computer the number of points (NPTS) of the LDC used as input data and either that these points are to be read (IO=0) from records type-4b which follow, or that the LDC of this period is identical to the LDC of a preceding period IO (IO > 0).For this option to be valid, the value of IO must be less than the index of the current period (e.g.if current period = 3 then IO = 1 or 2) and the value of NPTS given in record type-4a for current period must be equal to NPTS of period IO (and no record type-4b follow). Finally, recordstype-4b are used to specify the points of the normalized LDC of the period using one record per point, each one containing the load magnitude (LD) and load duration (DUR) as fractions of the period peak load and the total hours of the period. It is necessary that the first point on the curve be adjusted to the period peak load [LD (1) = 1.0, DUR (1) = 0.0] and the last point to the minimum load of the period [LD (NPTS) = minimum load and DUR (NPTS) = 1.0]. Points must be arranged in a descending order in such a way that the LDC does not have a point with positive slope. Regardless of the LDC input data option used, the order in which the curves for the different periods are given must be consistent with the ordering of the period peak load ratios on data record (s) type-2.

A . Load Duration Curve

Figure 1. Shows the LDC of the base year 2015. The following information were observed from LDC:

1. The minimum load had been present throughout the specified period.
2. Selection of base load and peak load power plants were authorized.
3. Any given point on the load duration curve represents the total duration in hours for the corresponding load and all loads of greater values.
4. The area under the load duration curve represents the energy associated with the load duration curve.
5. The average demand during some specified time period of a month can be obtained from the load duration curve.

B.Load factor

Load factor is defined as the ratio of the average load over a given period to the maximum demand (peak load) occurring in that period. In other words, the load factor is the ratio of energy consumed in a given period of the times of hours to the peak load which has occurred during that particular period.

$$\text{Load factor} = \frac{\text{average load}}{\text{peak load}} \qquad (1)$$

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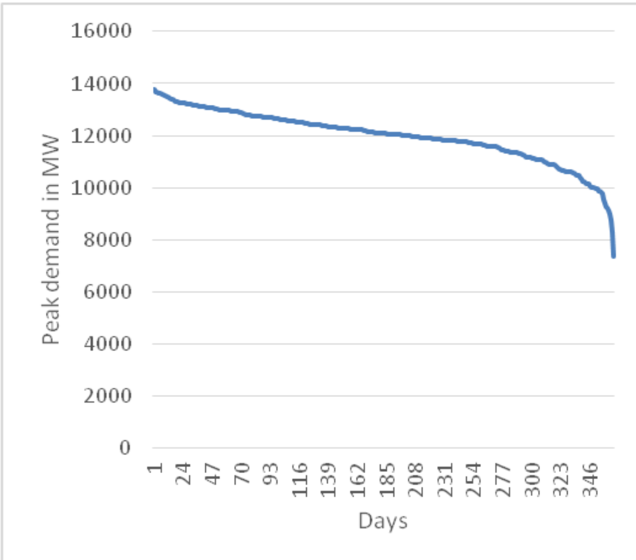

Fig. 1 Load Duration Curve of the Year 2015
Source: Southern Regional Power Committee Report

Load factor means how efficiently we use energy. It is the measure of the utilization of electrical energy during a given period to the maximum energy which would have been utilized in that period. The load factor plays an important role in the cost of generation per unit (kWh). The higher the load factor the smaller will be the generation cost for the same maximum demands. Peak loads as fraction of annual peak load obtained from the analytical calculation is tabled in Table IV.

V. RESULTS AND DISCUSSION

By Using WASP-IV, Energy requirement of Tamil Nadu power system is estimated for long term energy planning of 30 years from 2015-2044. In the base year, energy requirement was 105383.8 Gwh and the same would be 571010.4 Gwh in the 30th year showing a gradual increase of 5.8% as average as shown in Table 5.

TABLE IV
MONTH LOAD FACTOR OF BASE YEAR 2015

Jan'15	Feb'15	Mar'15	Apr'15	May'15	Jun'15	Jul	Aug	Sep	Oct	Nov	Dec
0.8825	0.9183	0.9481	0.9245	0.9471	0.9646	1.00	0.9922	0.9991	0.9667	0.9067	0.9211

TABLE V
30 YEAR PEAK, MINIMUM LOAD DEMAND AND ENERGY DEMAND

Year	Peak load Mw	Min.Load Mw	Energy Gwh	Year	Peak load Mw	Min.Load Mw	Energy Gwh
2015	13766	7493.6	105383.8	2030	32991	17958.8	252558.4
2016	14592	7943.2	111706.8	2031	34970.5	19036.4	267711.9
2017	15467.5	8419.8	118409.3	2032	37068.7	20178.5	283774.7
2018	16395.5	8925	125513.8	2033	39292.8	21389.2	300801.1
2019	17379.3	9460.5	133044.6	2034	41650.4	22672.6	318849.2
2020	18422	10028.1	141027.3	2035	44149.4	24033	337980.2
2021	19527.3	10629.8	149488.9	2036	46798.4	25474.9	358259
2022	20699	11267.6	158458.2	2037	49606.3	27003.4	379754.5
2023	21940.9	11943.6	167965.8	2038	52582.7	28623.6	402539.8
2024	23257.4	12660.3	178043.8	2039	55737.6	30341.1	426692.1
2025	24652.8	13419.9	188726.4	2040	59081.9	32161.5	452293.7
2026	26132	14225.1	200049.9	2041	62626.8	34091.2	479431.3
2027	27699.9	15078.6	212053	2042	66384.4	36136.7	508197.1
2028	29361.9	15983.3	224776.1	2043	70367.5	38304.9	538689
2029	31123.6	16942.3	238262.6	2044	74589.5	40603.2	571010.4

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VI. CONCLUSION

This paper explains the analytical approach to estimate the future energy demand for the state of Tamil Nadu for the period of 30 years, 2015 – 2044. In order to make the estimation more effective, WASP –IV is used in assessing the probable or approximate increase of power demand for the study period. For the purpose of authenticity, the Southern Regional Power Committee report is taken for the base year, 2015. From this source, the load duration curve is arrived to frame the estimate. As WASP-IV is used, various modules covered under this system are dealt with to get the Input / Output variations. By employing MATLAB, through curve fitting method, fifth order polynomial coefficients of the LDC is obtained. Based on the calculations, it is shown that the estimated energy demand for the said 30 years would be at the rise of 6%, from 105383.8 Gwh in 2015 to 571010.4 Gwh in 2044 as per the chronicle data.

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Dr.S. Kannan received the B.E., M.E., and Ph.D. Degrees from Madurai Kamaraj University, Madurai, India in 1991, 1998 and 2005 respectively. He was a visiting scholar in Iowa State University, Ames, from October 2006 to September 2007, supported by the Department of Science and Technology, Government of India, with the BOYSCAST Fellowship. He is presently working as professor and Head of Department of Electrical and Electronics Engineering, Ramco Institute of Technology, Rajapalayam, India. His research interests include Power System Deregulation and Evolutionary Computation. He is a Sr. Member of IEEE, Member in IET, Fellow of IE (I), Sr. Member in CSI, Fellow in IETE, Life member SSI, and Life member of ISTE.