Applicability of End Use Method for Long Term Load Forecasting of Islands

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Abstract: Electric load forecasting of a nation, state or a city is very important for their growth. The consumption of electricity is directly proportional to the economic development of a region. Long term electric load forecasting gives you the idea of load requirement after 5 years or 10 years or 15 years. This forecast helps the administrators for taking action to meet the electric requirement. Accuracy of this assessment will fulfill the main objective of maintaining the supply and demand of electricity. Among the various methods of long term electric load forecasting End Use method is one of the mostly used methods. It gives good result for big states and countries which are economically sound, with rich natural recourses and well connected with other states. This work finds out the applicability of End Use method for long term load forecasting of remote islands. Anadaman Nicober Islands is taken as a case study. The result shows that when forecasting goes beyond five, six years the errors are not acceptable. This work gives the direction to the administrators and researchers to explore other methods, may be some hybrid methods for long term forecasting of Islands.

***Keywords**: Forecasting, End Use, Electric Load, Econometric, long term forecasting.*

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I. Introduction

Electric power plays a fundamental role [1] in the process of economic growth and development. Accurate forecasts are helpful in formulating load management strategies in view of different emerging economic scenarios, which can be dovetailed with the developmental plan of the region [2][3]. The main function of electric power system is to provide a reliable and continuous source of electricity wherever whenever required. To provide this service each of the three main components of an electric power system – generation, transmission and distribution must perform efficiently to meet the required demand. One of the main objectives of the electric power system is to keep a continuous balance between the supply and the demand of electricity. This is possible only by an accurate assessment of requirement of electrical energy and peak load demand i.e. electrical load forecasting. The electric load forecasting has many applications including energy purchase & generation, load switching, contract evaluation and infrastructure development.

The load forecasting of electricity demand has become one of the major research fields in electrical engineering. The supply industry requires forecast with a lead time that ranges from short term (a few minutes, hours or day ahead) to long term (upto 20 years ahead). The long term forecast, in particular, has become more important, since the planning of energy generation units depend on it.

There are various types of long term electrical load forecasting methods are available [4]. Out of those three parametric techniques viz. trend analysis, end use technique and econometric technique and four artificial intelligence based method viz. ANN, fuzzy logic, wavelet and genetic algorithm/programming techniques for long term electrical load forecasting are used a lot. In most of the published work [5], the country or state is considered for long term load forecasting and not much work is carried out on isolated remote region. In this paper the applicability of End Use model (EPS methodology) for long term electrical energy forecasting is examined by taking Andaman and Nicobar Islands (A & N Islands - India), a group of 572 Islands situated in Bay of Bengal as a case study.

The long term electrical energy forecasting for A & N Islands is carried out by CEA, Govt. of India through Electric Power Survey (EPS). EPS projections are carried out by using partial End Use technique. All the expansion projects under power sector are based on the EPS reports. The UT[6][7] Administration does not carry any further survey or study in areas which are not addressed by EPS.

In the next section a brief introduction about A & N Islands is discussed then the applicability of End Use model (partial) used in EPS for A & N Islands is discussed [8]. The projections made in EPS are compared with the actual energy requirement to assess the applicability of End – Use model (partial) in long term electrical energy forecasting for A & N Islands [9,10].

II. A Brief about Andaman and Nicobar Islands (A & N Islands) – A Remote Region

Andaman Nicobar Islands (India) is a group of 572 Islands situated in Bay of Bengal with 92% of area covered under forest. It is one of the remotest parts of India where settlement started in 1858 by Britishers. Prior to 1858, only tribes used to stay in these islands. Out of 572 islands, only 37 islands are inhabited. Figure 1 shows map of A & N Islands with all the major islands. A & N Island has tremendous strategic importance from the country's security point of view.

The A & N Islands are spread over 900 km from North to South. The geographical isolation from mainland and among islands posses one of the serious problem in providing connectivity and governance. There are three districts, South Andaman, Middle & North Andaman and Nicobar district. The Middle and North has concentration of people settled under Government of India settlement scheme, while the southern group of islands has larger concentration of tribal population. There are no major industries in these islands except for a few small scale industries engaged in handicraft, agro allied activities and tourism. The economy is government driven with limited entrepreneurs in private sector. The shipping sector is the lifeline of these islands as it facilitates movement of people from one island to another.

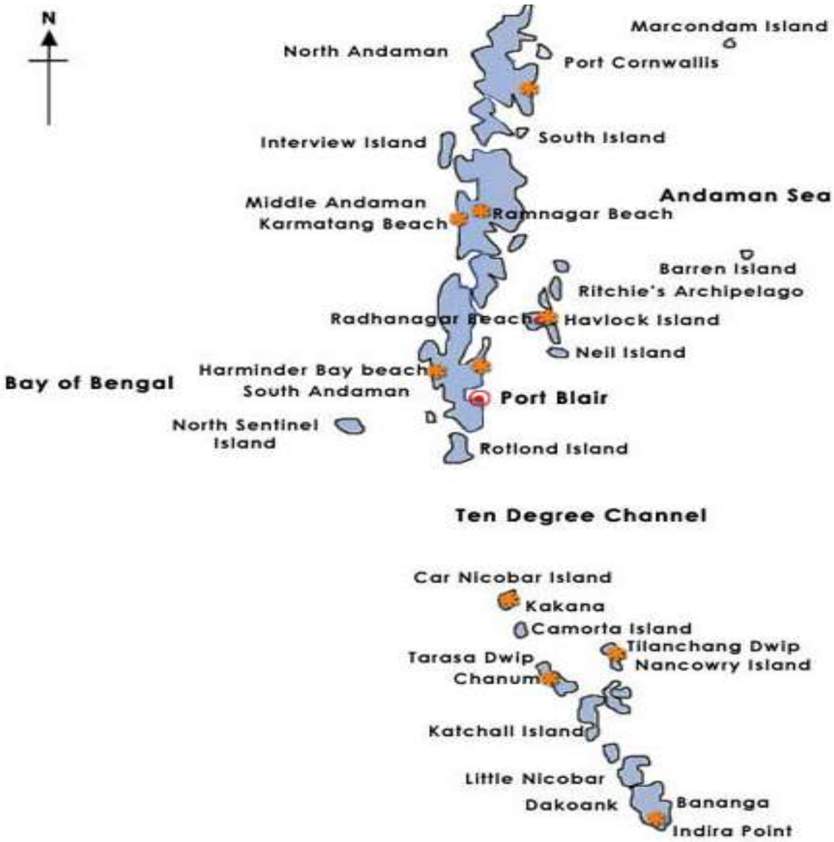

Figure 1: Map of A & N Islands showing all the major islands, Source: Survey of India Map [14]

1.1 Power System Scenario in A & N Islands

Prior to independence in 1926, a small steam driven reciprocating engine DC generator of 100 kW capacity was installed by the Britishers at RossIsland. After independence, in 1951 two steam turbine generating sets of 550 kW were installed at Chatham Islands Power House. The peak load during this period was 1.1 MW feeding in and around Port Blair. Subsequently, the generation capacity was augmented. In 1970, two DG sets of 550 kW were installed at Phoenix Bay power house, Port Blair operated in parallel with Chatham Power House. In 1977, two more DG sets SKODA with 500 kW and DUETZ with 550 kW were installed in Chatham power house, Port Blair. In 1989, 5 x 1000 KVA DG sets of Cummins were installed in Chatham power house. In 1991, 5 x 2.5 MW DG sets were installed in Chatham power house. 20 MW DG power plants established in the year 2000 at Port Blair through public private corporation. During this period, substantial capacity augmentation has also been undertaken in other inhabited islands.

Due to large distance among all the inhabited islands, there is no single grid to cater to the needs of the entire A & N Island. Stand alone power houses with DG (Diesel Generator) sets meet the local requirement of various inhabited islands. The details of electricity generation in these islands in the last 59 years are given in Table 1. The trend showing the capacity augmentation, increase in power generation and increase in per capita consumption is shown in Figures 2, 3 and 4 respectively.

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Table 1: Capacity, Generation and per-capita consumption of electricity in A & N Islands
Source: Electricity Department, A & N Administration [15]

Year	Power houses	Installed Capacity (in MW)	Generation (in MU)	Per Capita Consumption (kWh)
1951	1	1.1	0.5	16
1961	1	1.1	1.6	20
1971	10	3.0	4.3	27
1981	16	7.5	10.8	41
1991	32	15.7	51.9	113
2001	34	44.05	118.6	250.20
2002	34	44.05	138.61	266.34
2003	37	65.05	157.58	271.16
2004	34	28.05	160.12	293.32
2005	42	65.05	160.57	291.90
2006	42	66.86	183.74	287.75
2007	43	68.46	200.92	330.33
2008	43	68.46	209.36	354.09
2009	43	74.21	228.29	370.79
2010	43	81.21	238	391.40

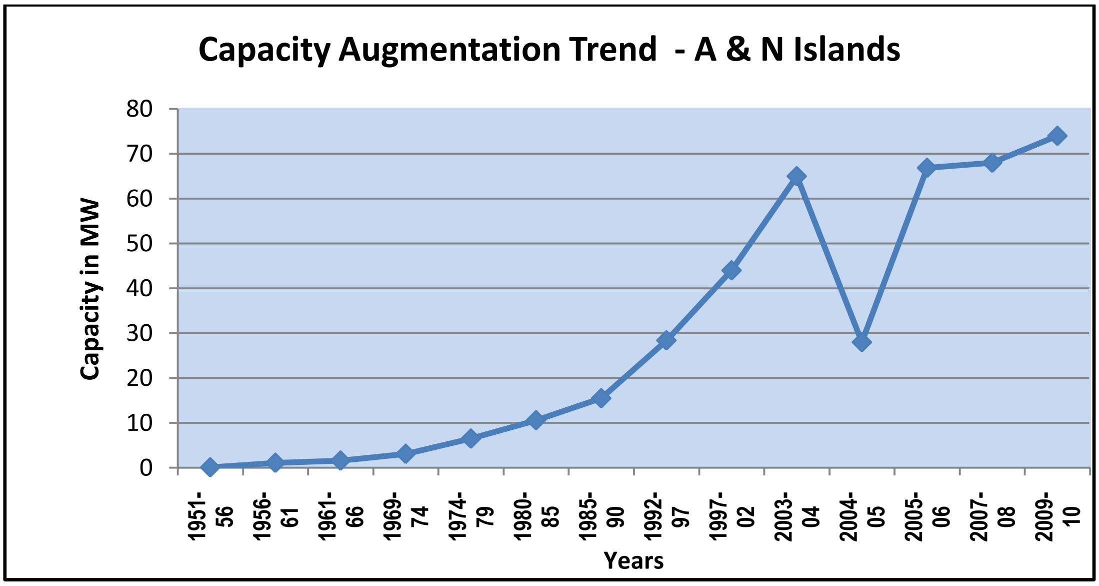

Figure 2: Capacity Augmentation Trend, Source: Electricity Department, A & N Administration [15]

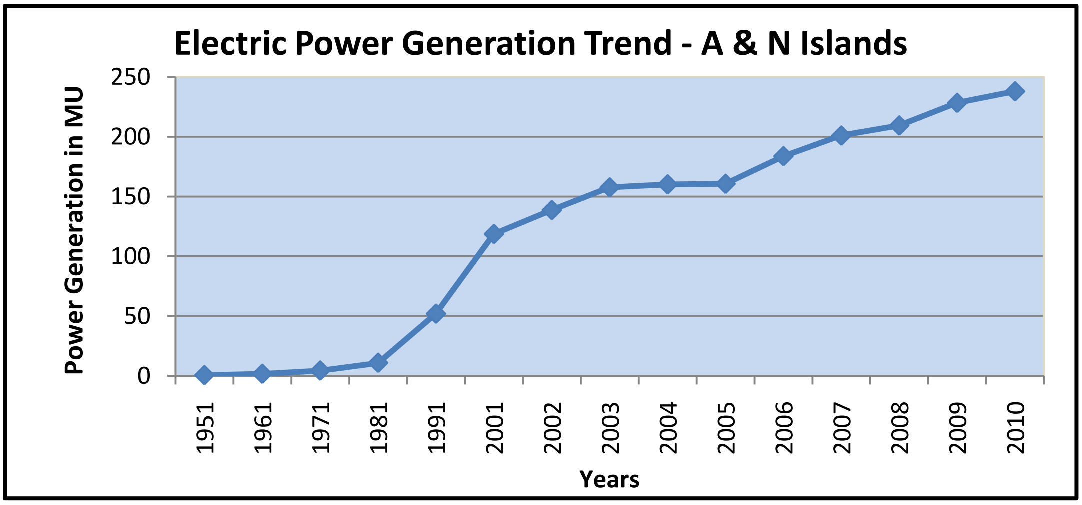

Figure 3: Trend showing increase in power generation, Source: Electricity Department, A & N Administration [15]

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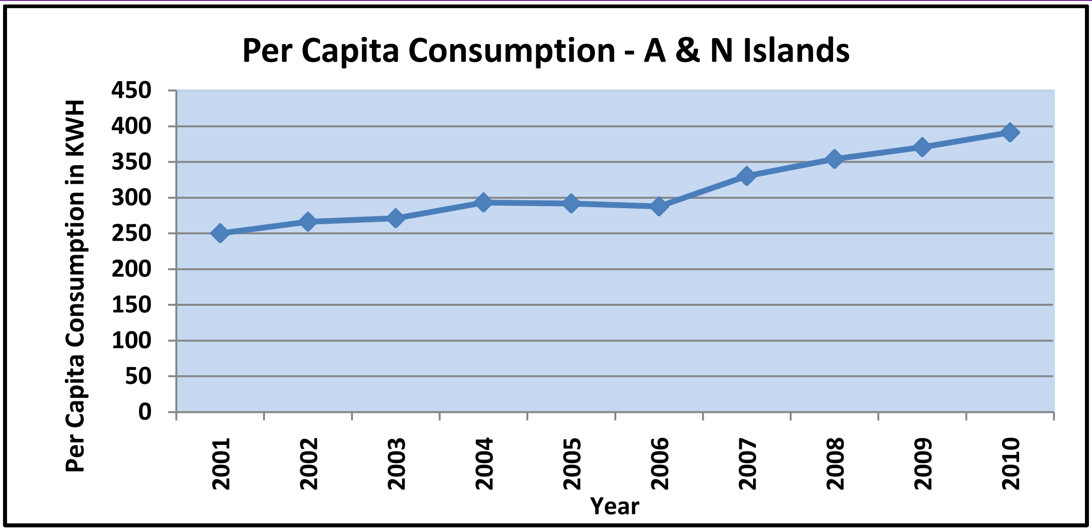

Figure 4: Trend showing per capita consumption of electricity in A & N Islands
Source: Electricity Department, A & N Administration [15]

From the above figures, it is concluded, that there is a continuous increase in the generation capacity except in the year 2005 when lot of power houses in different parts of A & N Islands were damaged due to massive earthquake of 8.9 Richter Scale followed by Tsunami.

The per capita consumption of 391 units is much less compared to national average of 553 units (as of 2006). This gives a clear indication that the power requirement will continue to increase to fill the gap between the national average and island average. One of the main reasons for low per capita consumption is lack of industrial establishments and less number of All Electric Homes (AEH). The number of consumers in A & N Islands is also showing a steady increase as shown in Figure 5. The category wise consumer detail is shown in Figure 6. Domestic consumers constitute 82% while consumer under commercial category constitutes 15.6%. Around 96% of the population of A & N Islands is getting 24 hour supply with no load shedding, however Electricity department has restricted the usage of heavy duty motors and welding equipments by industrial/commercial sector consumers between 06 – 10 PM.

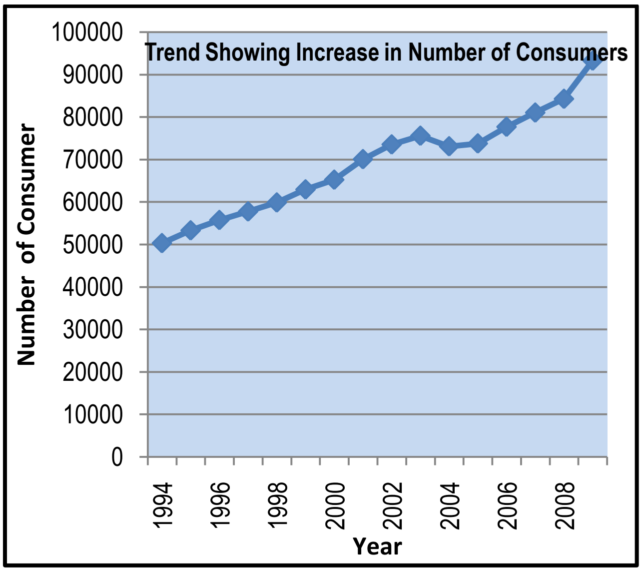

Figure 5: Electricity consumer trend in A & N Islands. Source: Electricity Department, A & N Administration **[15]**

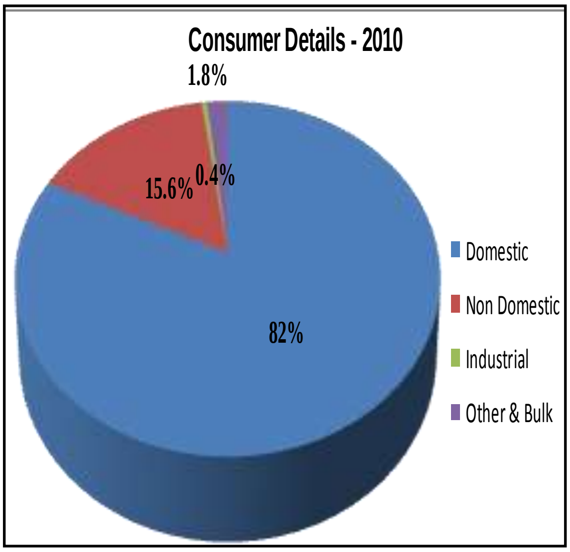

Figure 5: Category wise consumer details. Source: Electricity Department, A & N Administration **[15]**

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The electrification details of Andaman group of islands: total installed capacity of North Andaman is 6.82 MW catering to the requirement of around 42,163 people (as per 2001 Census) with two major power houses - one hydro and the other diesel, supplying electrical power all through the day. There are three more small Diesel Generator (DG) power houses in North Andaman with a capacity ranging from 0.04, 0.05 and0.12 MW supplying electrical power from 07 – 12 hour meet the electricity demand for 676 people of Jagnath Dera, Paschim Sagar and Smith Island. In Middle Andaman the total installed capacity is 12.03 MW (DG power house) meeting the requirement of four islands viz. Rangat, StraitIslands, Baratang and Long Island with a population base of 54427, 42, 6062 and 2199 respectively. The South Andaman has an installed capacity of 43.54 MW with 07 DG power houses catering to the requirement of four islands viz. Rutland, Neil, Havelock and South Andaman (proper) with a population base (as per 2001 census) of 678, 2868, 5354 and 181959 respectively. These power houses provide 24 hour supply (except Rutland which is 12 hour). In Little Andaman which comes under South Andaman district, has a installed capacity of 3.11 MW with two DG power houses, one in Hutbay catering to the requirement of 17428 people and second in Dugong Creek catering to the requirement of 100 people. Other small islands in Andaman group of islands such as Narcondum, East Island, Stewart Island, CurlewIsland, AvesIsland, InterviewIsland, North Passage and John Lawrance are electrified through solar source with a population base of 02 – 39. The total installed capacity of Andaman group of islands is 65.86 MW with a firm capacity of 45.91 MW.

The bar graph shown in Figure 7 indicates the percentage power consumption for major islands with respect to the total power consumption of A & N Islands. From the bar chart it is seen that South Andaman (proper) consumption is around 74% of the total consumption of A & N Islands. These islands are selected based on the consumption (in a decreasing order) when compared to the total power consumption of A & N Islands. Islands like Neil, Havelock, Little Andaman, Diglipur have tremendous tourism potential.

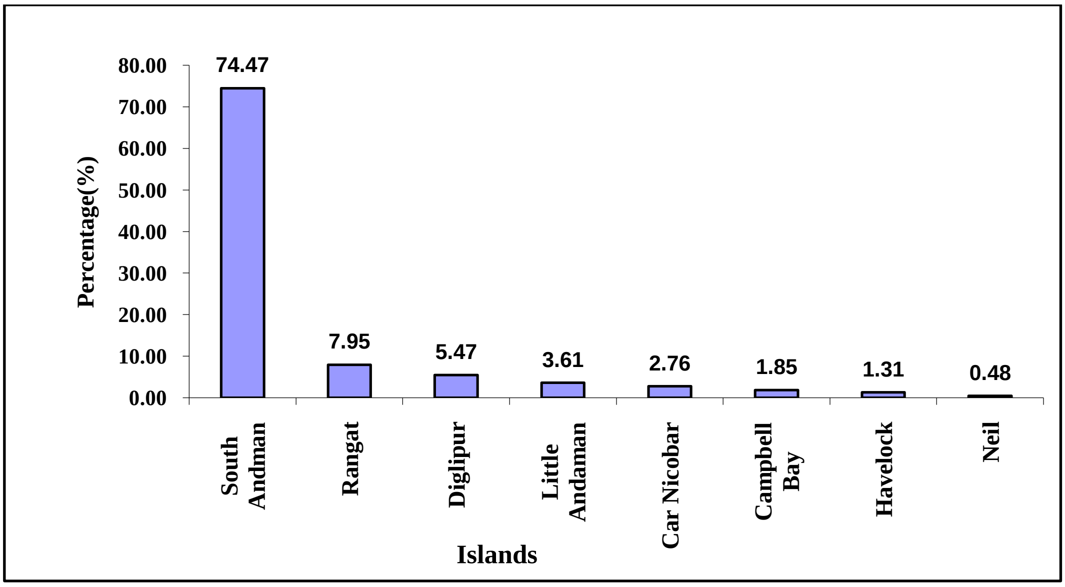

Figure 7: Bar graph showing the consumption percentage of 08 major Islands compared to total consumption of A & N Islands
Source: Electricity Department, A & N Administration **[15]**

III. Applicability of End use model for A & N Islands - EPS Projection

Govt. of India carries out the Electric Power Survey (EPS) to forecast short term, medium term and long term requirement of electrical utilities. The first EPS was published in 1963 and till now, 17 (seventeen) EPS have been conducted. Table 2 shows the details of EPS conducted from 1973 to date along with the year of publication and methodology followed for the projections.

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Table 2: Electric Power Survey from 1973 onwards. Source: CEA Report [11]

Electric Power Survey	Year of Publication	Methodology Used
8th Survey	1973	Partial End Use
9th Survey	1974	Partial End Use
10th Survey	1977	Partial End Use
11th Survey	1982	Partial End Use
12th Survey	1985	Partial Econometric & Partial End Use
13th Survey	1987	Partial End Use
14th Survey	1991	Partial End Use
15th Survey	1995	Partial End Use
16th Survey	2000	Partial End Use
17th Survey	2006	Partial End Use

The Electric Power Survey calculates the estimated consumption for different categories like domestic, commercial, public water works, irrigation, industry and railway traction for using partial End Use Technique. The partial End Use technique is a combination of End Use technique for the sectors where sufficient data for the past is available and the programme for the future is well defined and trend analysis in the case of others (non – industrial bulk consumers like Research Establishments, Port Trusts, Military Engineering Services). The approach followed for estimation of consumption under different categories is detailed below in Figures 8, 9 and 10.

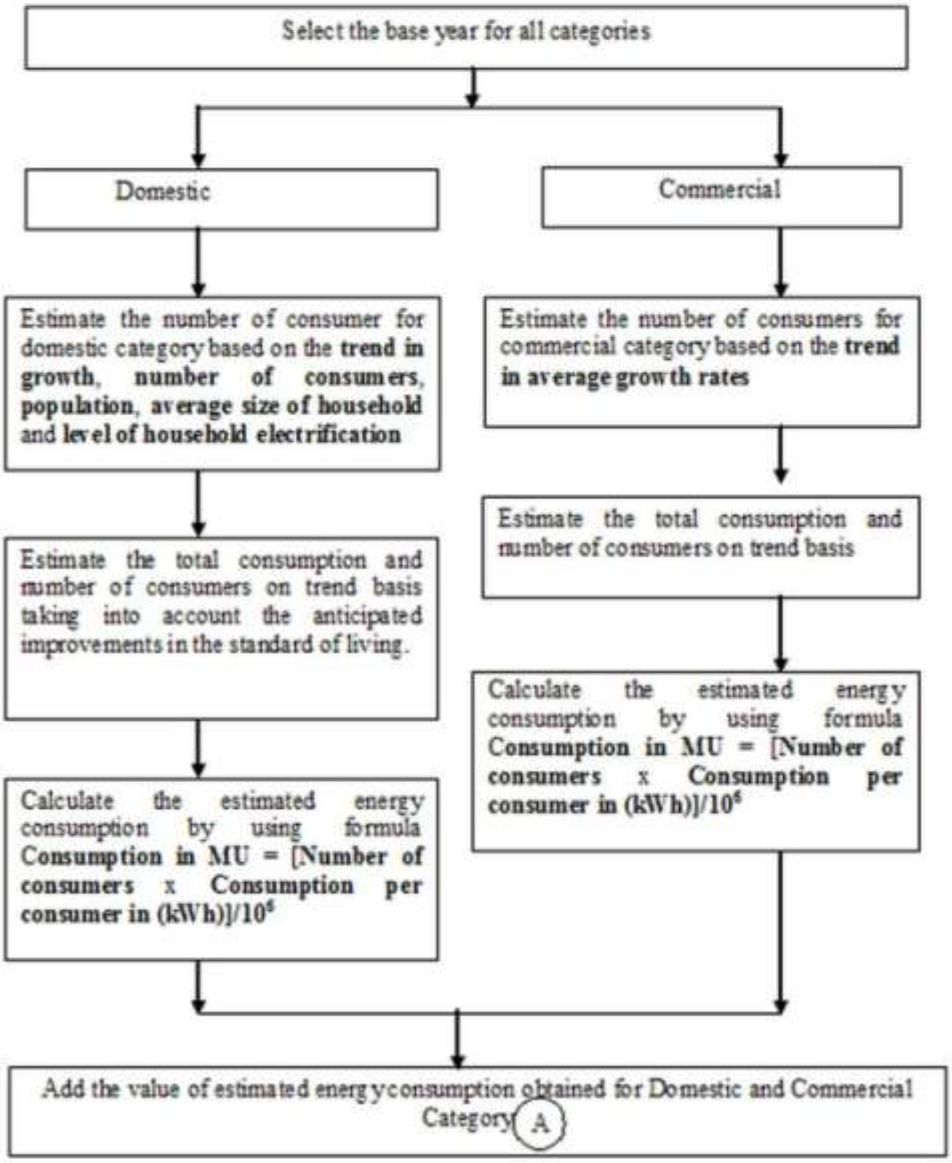

Figure 8: Flow Chart showing the approach followed in 17th EPS to calculate the energy consumption for domestic and commercial category
Source: Methodology of 17th Electric Power Survey Report [17]

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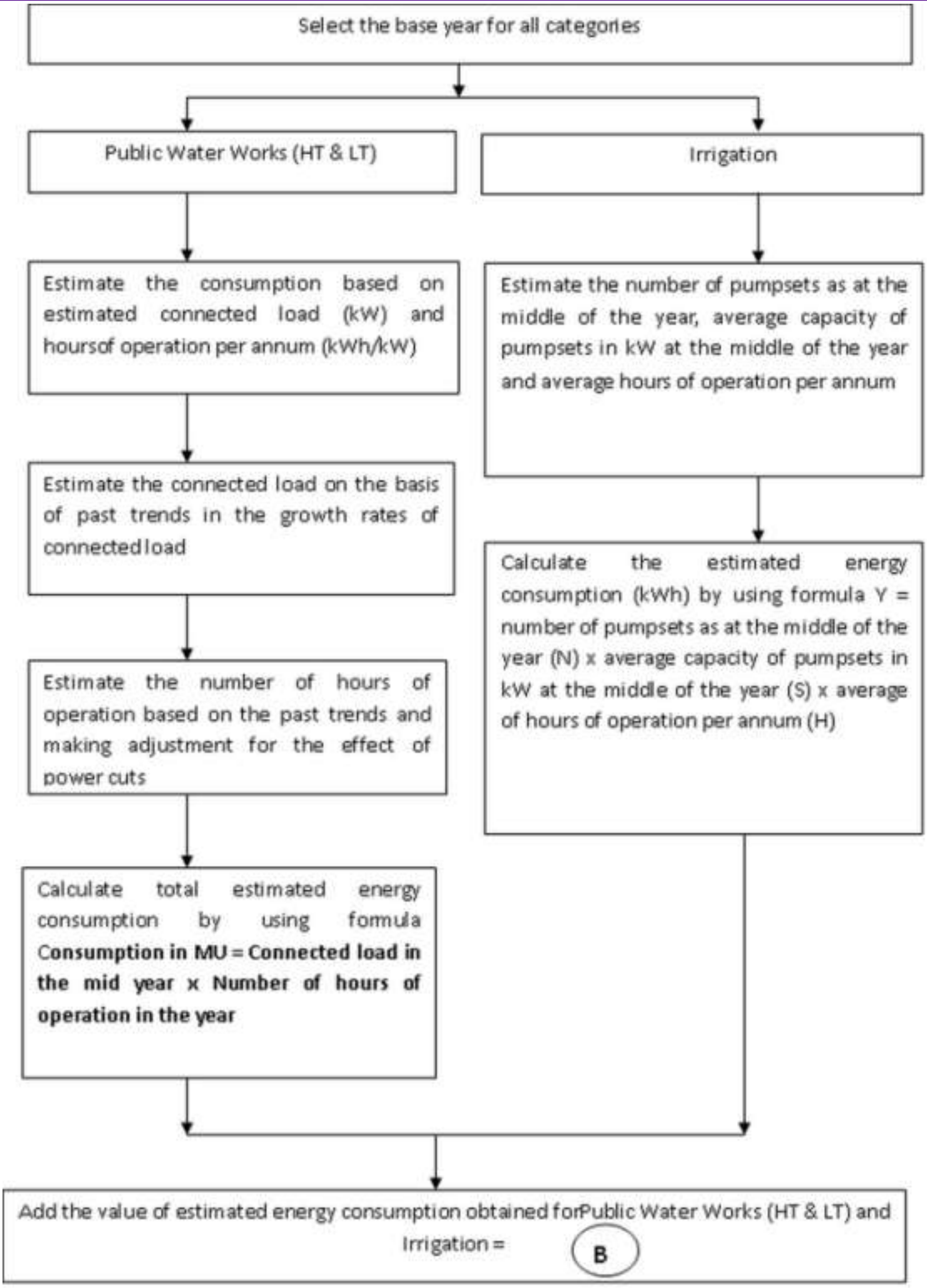

Figure 9: Flow Chart showing the approach followed in 17th EPS to calculate the energy consumption for Public Water Works (HT & LT) and Irrigation category

Source: Methodology of 17th Electric Power Survey Report [17]

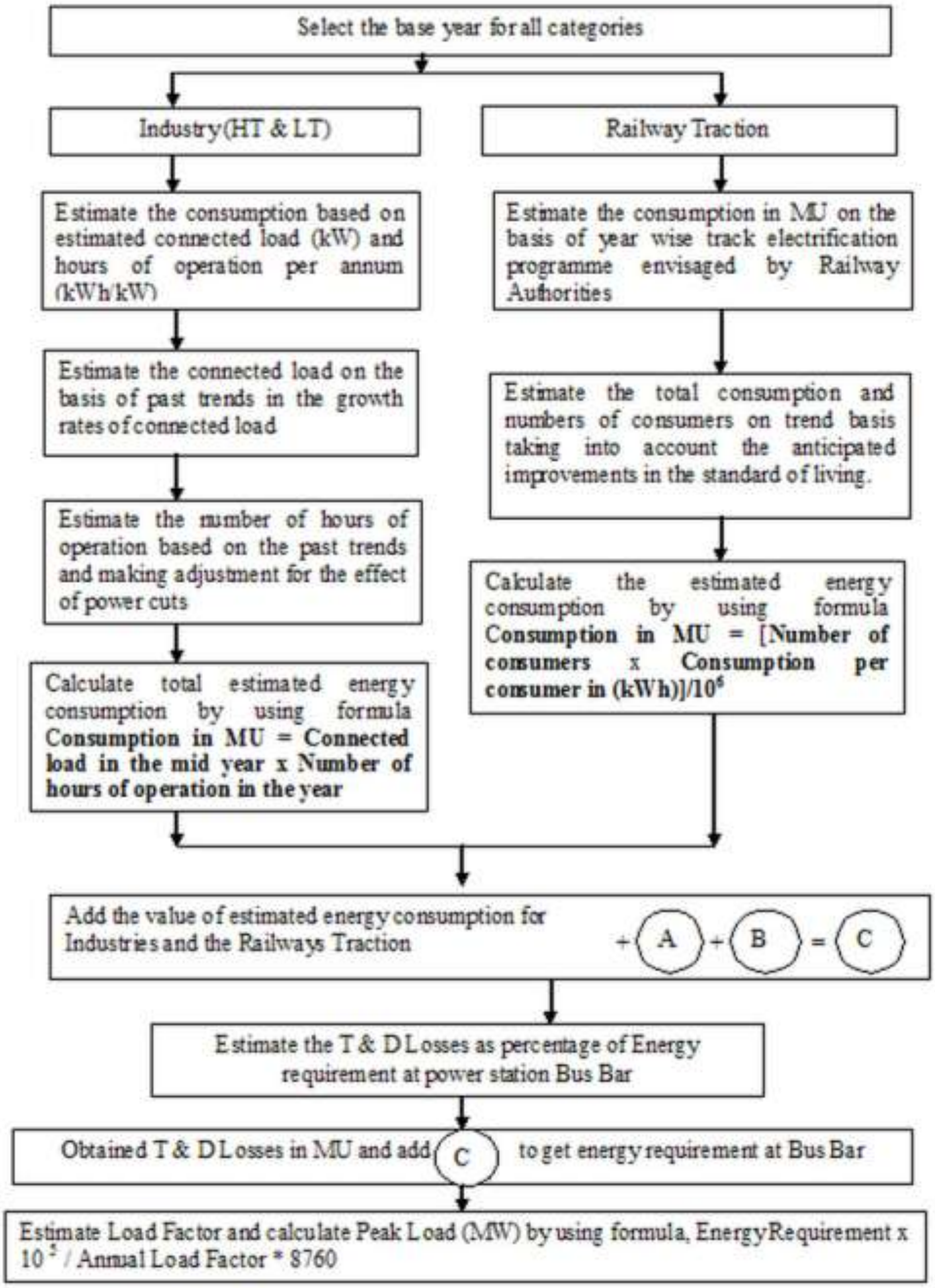

Figure 10: Flow Chart showing the approach followed in 17^{th} EPS to calculate the energy consumption for Industry (HT & LT), Railway Traction category and calculation of peak load
Source: Methodology of 17^{th} Electric Power Survey Report **[17]**

The EPS projections (11^{th} to 17^{th}) for energy requirement carried out by partial End Use technique for A & N Islands **[67]** is complied and compared with the actual requirement and shown in Table 3(a). Table 3(b) shows the percentage variation of energy requirement projected in EPS with actual.

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Table 3(a) Comparison of estimated energy requirement (EPS) with actual (1975 – 2010)
Source: Electric Power Survey, Ministry of Power, Govt. of India**[10, 15, 18]**

Year	Actual Energy Requirement (in MU)	11th EPS (1978)	12th EPS (1983)	13th EPS (1986)	14th EPS (1989)	15th EPS (1994)	16th EPS (1998)	17th EPS (2003)
1975-76	6.16							
1976-77	6.81							
1977-78	7.71							
1978-79	8.61	**8.69**						
1979-80	9.51	10.69(1)						
1980-81	10.41	12.82(2)						
1981-82	12.11	15.49(3)						
1982-83	14.23	18.17(4)						
1983-84	16.54	21.06(5)						
1984-85	18.84	20.45(6)	20.45(1)					
1985-86	20.69		23.33(2)					
1986-87	24.52		26.36(3)					
1987-88	31.04		29.55(4)	36.9(1)				
1988-89	32.69		32.69(5)	43.5(2)				
1989-90	39.18		36.53(6)	51.3(3)				
1990-91	38.44			60.4(4)	11.74(1)			
1991-92	50.32			71(5)	57.56(2)			
1992-93	60.42			83(6)	68.86(3)			
1993-94	67			96(7)	82.63(4)	77.32		
1994-95	72			114(8)	98.66(5)	86.27		
1995-96	81				118(6)	96.27(1)		
1996-97	87				140(7)	107.23(2)		
1997-98	93				166(8)	119.26(3)		
1998-99	99.9				195(9)	133.11(4)	**105**	
1999-00	**112.82**				**229(10)**	**146.96(5)**	**119(1)**	
2000-01	118.55					162.89(6)	135(2)	
2001-02	131.92					180.4(7)	148(3)	
2002-03	138.61						161(4)	
2003-04	153						176(5)	
2004-05	126						194(6)	
2005-06	168							
2006-07	190					295(12)	236(8)	
2007-08	200.93							215(4)
2008-09	209.36							243(5)
2009-10	228							274(6)
2010-11	238							307(7)
2011-12						115(17)	374(13)	344(8)
2012-13								382(9)
2013-14								422(10)
2014-15								461(11)
2015-16								500(12)
2016-17							591(18)	537(13)
2017-18								571(14)
2018-19								601(15)
2019-20								628(16)
2020-21								649(17)
2021-22								665(18)

Table 3(a) Comparison of estimated energy requirement (EPS) with actual (1975 – 2010)
Source: Electric Power Survey, Ministry of Power, Govt. of India**[10, 15, 18]**

The indication (1) in the cell of the above table represents energy requirement forecast for a time period of one year
The indication (2) in the cell of the above table represents energy requirement forecast for second year
:
The indication (8) in the cell of the above table represents energy requirement forecast for eighth year

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Table 3(b) Variation in estimated energy requirement (EPS) with actual (1975 – 2010)

Year	Actual Energy Requirement (in MU)	Variation with actual in (%) as per 11th EPS	Variation with actual in (%)as per 12th EPS	Variation with actual in (%)as per 13th EPS	Variation with actual in (%)as per 14th EPS	Variation with actual in (%)as per 15th EPS	Variation with actual in (%)as per 16th EPS	Variation with actual in (%) as per 17th EPS
1975-76	6.16							
1976-77	6.81							
1977-78	7.71							
1978-79	8.61	0.93						
1979-80	9.51	12.41						
1980-81	10.41	23.15						
1981-82	12.11	27.91						
1982-83	14.23	27.69						
1983-84	16.54	27.33						
1984-85	18.84	8.55	8.54					
1985-86	20.69		12.76					
1986-87	24.52		7.50					
1987-88	31.04		-4.80	18.88				
1988-89	32.69		0.00	33.07				
1989-90	39.18		-6.76	30.93				
1990-91	38.44			57.13	24.19			
1991-92	50.32			41.10	14.39			
1992-93	60.42			37.37	13.97			
1993-94	67			43.28	23.33	15.40		
1994-95	72			58.33	37.03	19.82		
1995-96	81				45.68	18.85		
1996-97	87				60.92	23.25		
1997-98	93				78.49	28.24		
1998-99	99.9				95.20	33.60	5.11	
1999-00	**112.82**				**102.98**	**30.26**	**5.48**	
2000-01	118.55					37.40	13.88	
2001-02	131.92					36.75	12.19	
2002-03	138.61						16.15	
2003-04	153						15.03	
2004-05	126						53.97	
2005-06	168							
2006-07	190					55.26	24.21	
2007-08	200.93							7.00
2008-09	209.36							16.07
2009-10	228							21.78
2010-11	238							28.99

Table 3(b) Variation in estimated energy requirement (EPS) with actual (1975 – 2010)

IV. Result

The observations made are one year forecast of energy requirement carried out through EPS from 1975 – 2010 shows variation of 5% to 24% from actual. Five year forecast of energy requirement carried out through EPS from 1975 – 2010 shows variation of 0% to 41% from actual. Ten year forecast of energy requirement carried out through EPS from 1975 – 2010 shows variation of 102% from actual. Twelve year forecast of energy requirement carried out through EPS from 1975 – 2010 shows a variation of 55% from actual. Seventeen year forecast of energy requirement carried out through EPS from 1975 – 2010 shows a variation of 97% from actual.

V. Conclusion

The large deviation of forecasting result is because, the long term electrical energy and peak load forecasting is carried out taking all the 37 inhabited islands as single entity with an assumption of same growth rate for all inhabited islands. The result does not suggest least cost option for power generation taking into account the local resources or the resources in close vicinity both in mainland India and overseas. The result also does not suggest measures to improve efficiency by fuel substitution and demand side management. The projections are not made for different economic scenarios in spite of the fact that islands like Havelock, Neil, and Ross & Smith are expected to have higher growth rate due to tremendous tourism potential. The applicability of End Use method for remote islands does not give good results. So for better result, further studies can be done to apply other techniques like time series analysis, fuzzy systems or computational intelligence methods. Hybrid methods by combining any of these techniques may also be tried for improving the forecast accuracy.

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