ELECTRICITY DEMAND FORECASTING

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Introduction

- The Electricity Act, 2003, envisages enabling framework conducive to development of Power Sector, promoting transparency and competition and protecting interest of consumers.
- National Electricity Policy announced by the Government in February 2005- to provide broad framework for development of Power Sector.
- National Electricity Plan by CEA to provide blue print for Power Sector Expansion. Planning an important statutory function of CEA for planned growth of the Power Sector in an optimum way, keeping in view conservation of resources

National Power Surveys

- Electricity (Supply) Act 1948 enacted after Independence to rationalize growth and control of electricity supply industry.
- Act provided for establishment of State Electricity Board.
- CEA set up at National level through this Act.
- Periodic & Systematic National Power Surveys conducted under section 3 (1) of Electricity Act, 1948
- Electricity Act 2003 also stipulates CEA to carry out demand assessment.

National Power Surveys

- First Committee on EPS set up in Dec., 1962 and EPS Report finalised in July, 1963.
- At present 18th EPS in existence and 19th EPS committee constituted and likely to submit EPS report shortly.

Purpose of Load Forecasting

- Load forecasting forms basis for planning of additional generating capacity, associated transmission network, augmentation of distribution network etc.
- Unit commitment and economic dispatch.
- Fuel procurement
- Estimation of funds requirement to meet future needs of electricity.
- Essential input to industries manufacturing electrical items used in electricity supply.
- Essential input to manufacturers of steel, cement, aluminum etc.

Major Elements of Load Forecasting

- Load Forecasting estimates amount of electricity required in geographical area served by Power System.
- To forecast energy i.e. MWh required and peak demand i.e. MW to be met
- Load factor to be used i.e. shape of the load curve- dependent on types of load
- To estimate T&D losses
- To estimate diversity factors at Regional and all-India level

CATEGORIES OF LOAD FORECASTING

Depending on the prediction time, the categories are :

- Ultra Short Term Load Forecasting- Within one hour
- Very Short Term Load Forecasting- Up to one day
- Short Term Load Forecasting- One day to one week
- Medium Term Load Forecasting- One week to one year
- Long Term Load Forecasting- Longer than a year

IMPORTANCE OF LOAD FORECASTING

- Ultra short term load forecasting: security assessment, fuel scheduling
- Very short term load forecasting – optimization of generators which are synchronised to the system
- Short term load forecasting – unit commitment, estimation of load flows and to make decisions that can prevent overloading,
- Long term load forecasting - important for power procurement, contract evaluations and decisions on capital expenditures.

FACTORS AFFECTING FORECASTS

- **Economic Factors-** Service area demographics, levels of industrial activities, changes in farming sector, appliances used etc.
- **Time Factors-** Seasonal effects, day of the week, legal and religious holidays etc.
- **Weather Factors-** Temperature, Humidity, thunderstorms etc.
- **Random Disturbances-**The factors having uncertain effects on system load e.g. Strikes, shutdowns etc.

FORECASTING METHODOLOGY

- Trend Analysis
- Time Series Method
- End Use Method
- Econometric Method
- Partial End-Use Method – method presently in use for load forecasting in Central Electricity Authority.

FORECASTING USING TREND ANALYSIS

- This methods examine trends and cycles in historical data, and then uses mathematical techniques to extrapolate to the future.
- The assumption is that the forces responsible for creating the past, will continue to operate in future.
- This is often a valid assumption when forecasting short term horizons, but it falls short when creating medium and long term forecasts.
- The further out we attempt to forecast, the less certain we become of the forecast.
- The stability of the environment is the key factor in determining whether trend extrapolation is an appropriate forecasting model.

TIME SERIES BASED FORECASTING

- A time series is a sequence of observations taken sequentially in time
- An intrinsic feature of a time series is that, typically adjacent observations are dependent
- **Time Series Analysis** is concerned with techniques for the analysis of this dependence

TIME SERIES BASED FORECASTING

- Examine the past behavior of a time series in order to infer something about its future behavior
- A sophisticated and widely used technique to forecast the future demand
  - Examples
    - Univariate time series: AR, MA, ARMA, ARIMA, SARIMA, ARIMA-GARCH
    - Multivariate: VAR Co-integration

TIME SERIES DATA ANALYSIS

- **Secular Trend**: long run pattern
- **Cyclical Fluctuation**: expansion and contraction of overall economy (business cycle)
- **Seasonality**: annual sales patterns tied to weather, traditions, customs
- **Irregular or random component**

TIME SERIES BASED FORECASTING

- Assumes past rates of change in electricity use or electricity use per consumer will continue – growth rate calculated from historical data.
- Separate trending forecast compiled for each customer class and geographical location.
- Advantage- access to basic sales and peak statistics.
- Disadvantage-Assumption that future will be like past- often untrue; changes in technology, changes in Policies etc. difficult to capture.
- Accurate for short term forecasting.

ECONOMETRIC FORECASTING

- Assumes past relationships between electricity use and various economic or demographic variables continue to hold in future.
- Generally more detailed than trend forecasting.
- Variables- GDP, electricity prices (by consumer groups), prices of other household necessities, household income, prices of alternate fuels etc.
- Essential to judiciously choose variables which are largely not interdependent.
- Relationship between variables and demand identified. Projections for driving variables obtained to drive the econometric forecasts.

ECONOMETRIC FORECASTING

- Typically done separately for each major customer group then aggregated to estimate system wide figures.

  Electricity requirement $= a * GDP^{b} * (Electricity\ Price)^{c}$

- Past data utilized to statistically estimate a, b, c.
- Forecasts made by using future projections of GDP and electricity prices
- Fundamental assumption that relationship between regression variables does not change.

END-USE FORECASTING

- Builds up estimates of energy requirement starting with analysis of what electricity is used for.
- Example: Household requirement-lighting, water heating, air conditioning etc.

  Energy requirement for AC= no. of household*fraction with AC*cooling reqd. per household*energy intensity of each AC
- Each of the above parameters estimated by surveys etc.

END-USE FORECASTING

- Advantages -Detailed and provides more information to planners; Assumptions made are easy to follow, check and revise as new data becomes available; Provide framework for estimating impacts of energy efficiency options and DSM.
- Limitation-Forecasts are data intensive, surveys needed to collect good data on energy end uses.

METHODOLOGY OF LOAD FORECASTING USED IN CEA

- Forecast of electrical energy consumption using past trends/ end-use
- This methodology known as partial end-use method
- Dis-aggregation of demand into a smaller technically defined components
- Allows one to estimate impact of physical and technological changes such as effect of conservation, new technologies, increased efficiency etc.

BOTTOM UP APPROACH OF FORECASTING

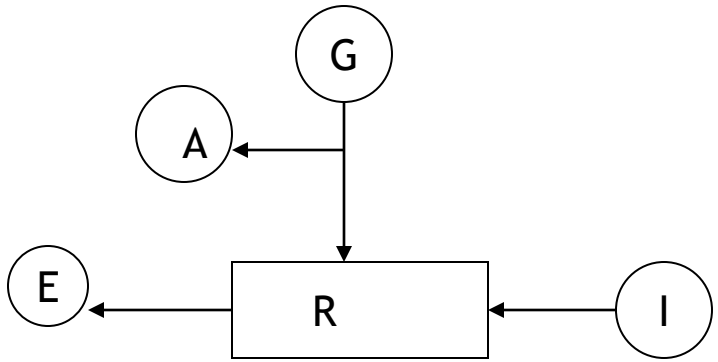
- In this approach, the forecaster uses electricity sales data at consumer level to make predictions for each sector.
- Then statistical methods sum up the forecasts to create the forecast at the higher group level.
- This method starts with the component parts to create a forecast for the entire business.
- All sectors are worked out separately and lumped together, bottom up forecasting averages out the all sectors separately resulting properly represent each individual component.
- Bottom up approach of forecasting is thus often more successful than top-down forecasting at the consumer level.

FORECASTING CATEGORIES ADOPTED

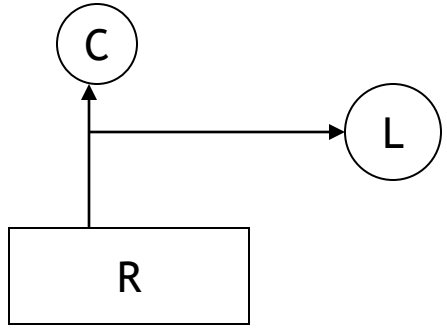
- Domestic
- Commercial
- Public lighting
- Public water works
- Irrigation
- Industrial
- Railways
- Bulk supply to non-industrial consumers

ENERGY REQUIREMENT-MkWh (AT POWER STATION BUS-BARS)

GENERATION END



CONSUMERS END



R= G - A + I - E = C + L

R ENERGY REQUIREMENT AT POWER STATION BUS-BARS

G GROSS GENERATION

A CONSUMPTION IN POWER STATION AUXILIARIES

I IMPORT FROM OTHER SYSTEMS/ STATES

E EXPORT TO OTHER SYSTEMS/ STATES

C TOTAL CONSUMPTION AT CONSUMERS END

L T & D LOSSES

METHODOLOGY OF FORECAST (contd.)

CATEGORY	CONSUMPTION
1. Domestic and Commercial	No. of Consumers X Consumption/ Consumer
2. Public Lighting, Public Water Works and LT Industries	Connected Load X Hours of Operation/Yr
3. Irrigation i) Pump Sets/ Tubewells	No. of Pumps Sets X Average Capacity Per Pump X Average Hours of Operation /Yr Programme of Energisation of Pump Sets Decided in Consultation with State Govt.
ii) Lift Irrigation Schemes	For Each Scheme on the Basis of Connected Load and Average Hours of Operation

METHODOLOGY OF FORECAST (contd.)

CATEGORY	CONSUMPTION
4. HT INDUSTRIES	
i) H.T. < 1 MW	On The Basis of Past Trend and Scope of Future Development
ii) H.T. > 1 MW	*Projections Made Separately for Each Industrial Unit on the Basis of Production Capacity, Anticipated Production and Norms of Production etc. - Data Collected from Each Unit Annually Directly * Demand to be Met by Captive Power Plant is Deducted from this to Arrive at Demand on Utility

METHODOLOGY OF FORECAST (contd.)

CATEGORY	CONSUMPTION
5. Railway Traction	Projections Made on the Basis of Track Electrification Programme Envisaged by Railway Board
6. Non Industrial	Individually on the Basis of Data Furnished by the Consumers Otherwise Past Trend
TOTAL CONSUMPTION AT CONSUMERS' END	SUMMATION OF CONSUMPTION AT CONSUMERS' END

METHODOLOGY OF FORECAST (contd.)

- T&D losses based on trend and future improvement Plan
- Energy requirement at Bus-Bar obtained by adding T&D losses to Total Energy Consumption at Consumer End.
- Annual Load Factor based on analysis of load mix.
- Peak Load by applying load factor on energy requirement at bus-bar
- Regional peak by applying diversity factor among states/UTs
- All-India peak sum of simultaneous peak loads of regions & Islands

DETAILS OF DATA COLLECTION

- Connected Load
- No of consumers
- Hours of operation
- No of Pump sets in past & future programme
- Irrigation details
- Railway electrification programme.
- Load shedding details
- load factor /load curve
- Diversity factor (Within regions)
- Contract demand, connected load, self-generation, energy consumption, Future programme from industries having demand more than 1 MW.

IMPORTANT FEATURES OF A LOAD FORECASTING MODEL

- **Accuracy**

  Based on the operational characteristics of the particular power company
- **Adaptability** to changing conditions over time
- **Robustness-**Identification of highly influential data points are necessary
- **Economical** in both execution time and core storage

INTELLIGENT METHODS OF LOAD FORECAST

- They have emerged from the field of Artificial Intelligence.
- They simulate the way human experts approach a problem.
- AI methods offer powerful problem **representation**, a capability of **reasoning** and the **ability to learn**.
- Learning can be summarized as the acquisition of skills and knowledge through interaction with the environment.
- Intelligent methods offer solutions to a range of problems that have proven difficult to solve using traditional deterministic or probabilistic mathematical techniques.

SOME INTELLIGENT METHODS

- Expert Systems
- Artificial Neural Networks
  - (a) Supervised
  - (b) Unsupervised
- Fuzzy Systems
- Support Vector machines
- Evolutionary Programming
- Simulated Annealing
- Hybrids

ISSUES IN LONG TERM FORECAST

- Errors in forecasting can lead to bad planning which can be costly
- Too high forecasts lead to more power plants and transmission resources than is required - unnecessary capital expenditure
- Too low forecasts prevent optimum economic growth and may lead to the installation of many costly and expensive-to-run generators (having short gestation period).
- These costs will finally be borne by consumers.

ISSUES IN LONG TERM FORECAST

- Long-term forecast must take the view that the future is open to the effect of many human actions.
- It has to reflect the role of electric energy in the society.
- Government policy as well as strategic decisions taken by a utility are important factors in determining future energy demand –PFA, Renewable energy programme , Make in India etc
- Many uncertainties arise from the impact of changes in public perception , view points and policies.
- DSM, efficiency improvement and conservation programmes have to be factored in load forecast.

ISSUES IN LONG TERM FORECAST

- Success of forecast depends on the materialization of the envisaged policies and programmes.
- How to tackle the uncertainties and arrive at a reasonable forecast ?
- Precise forecasting is a herculean task, even to the extent of providing a set of reasonable confidence levels.

The only certainty in load forecasting is uncertainties.

18th EPS PROJECTION vs ACTUAL

Year	Electrical Energy Requirement (MUs)		
	18th EPS	Actual	Dev. in %
2010-11	870,831	861,591	1.06%
2011-12	936,589	937,199	-0.07%
2012-13	1007,694	995,557	1.20%
2013-14	1084,610	1002,257	7.59%
2014-15	1167,731	1068,923	8.46%
2015-16	1257,589	1114,235	11.40%

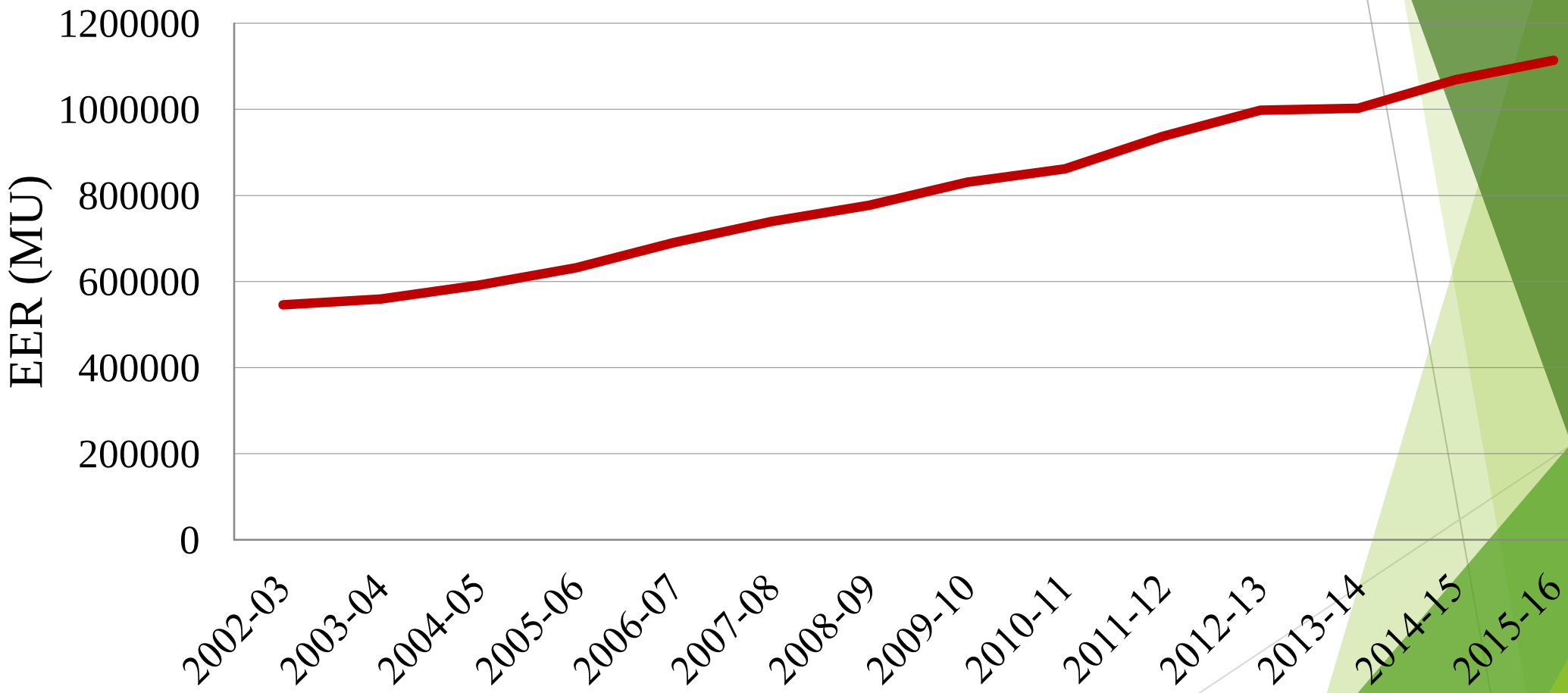
Upto 11.4 % deviation in electrical energy requirement

18th EPS PROJECTION vs ACTUAL

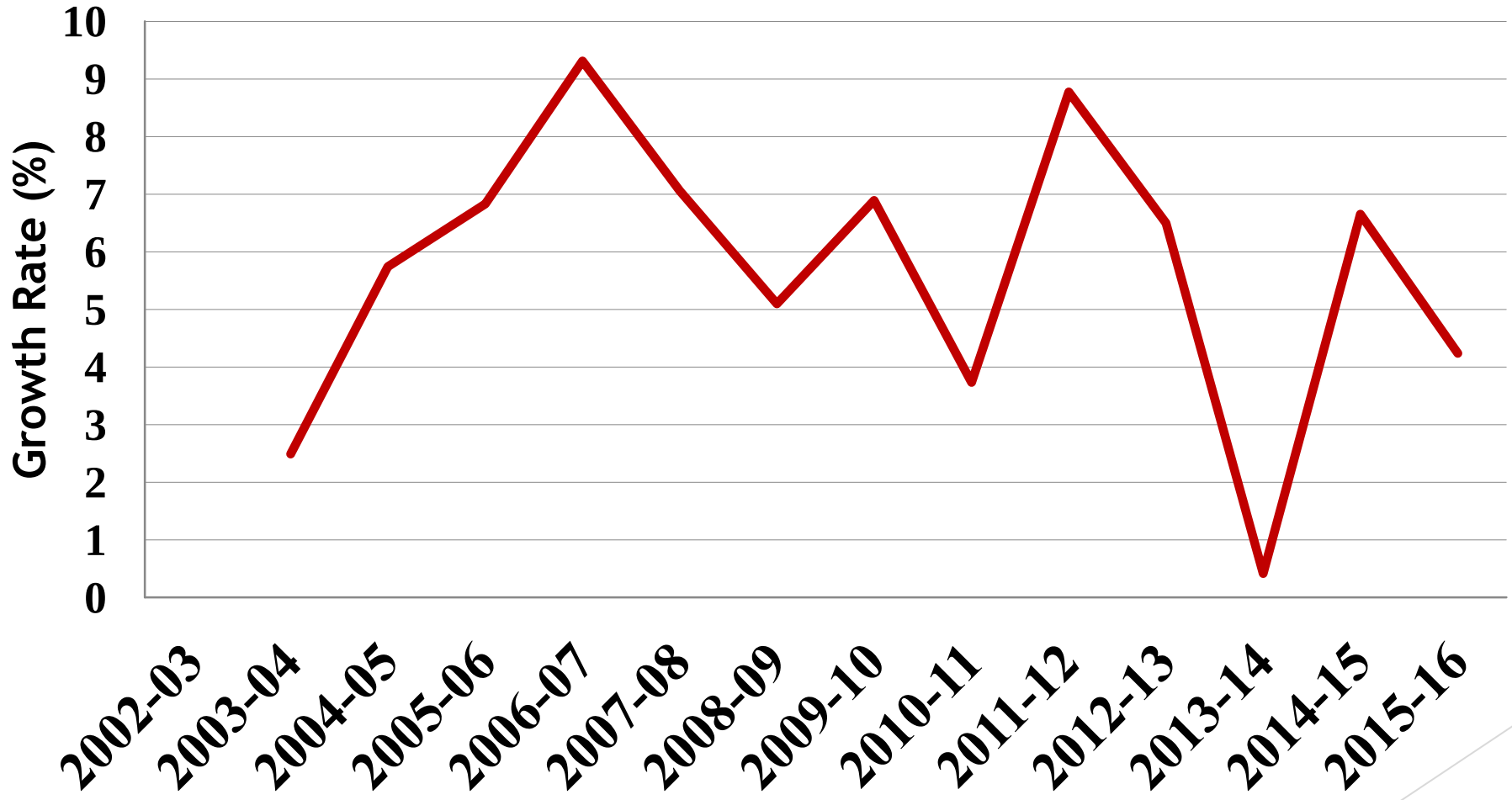
Year	Peak Load (MW)		
	18th EPS	Actual	Dev. in %
2010-11	1,22,287	1,22,287	0.00%
2011-12	1,32,685	1,30,006	2.02%
2012-13	1,43,967	1,35,453	5.91%
2013-14	1,56,208	1,35,918	12.99%
2014-15	1,69,491	1,48,166	12.58%
2015-16	1,83,902	1,53,366	16.60%

Upto 16.6 % deviation in peak demand

GROWTH OF ELECTRICAL ENERGY REQUIREMENT (MU)



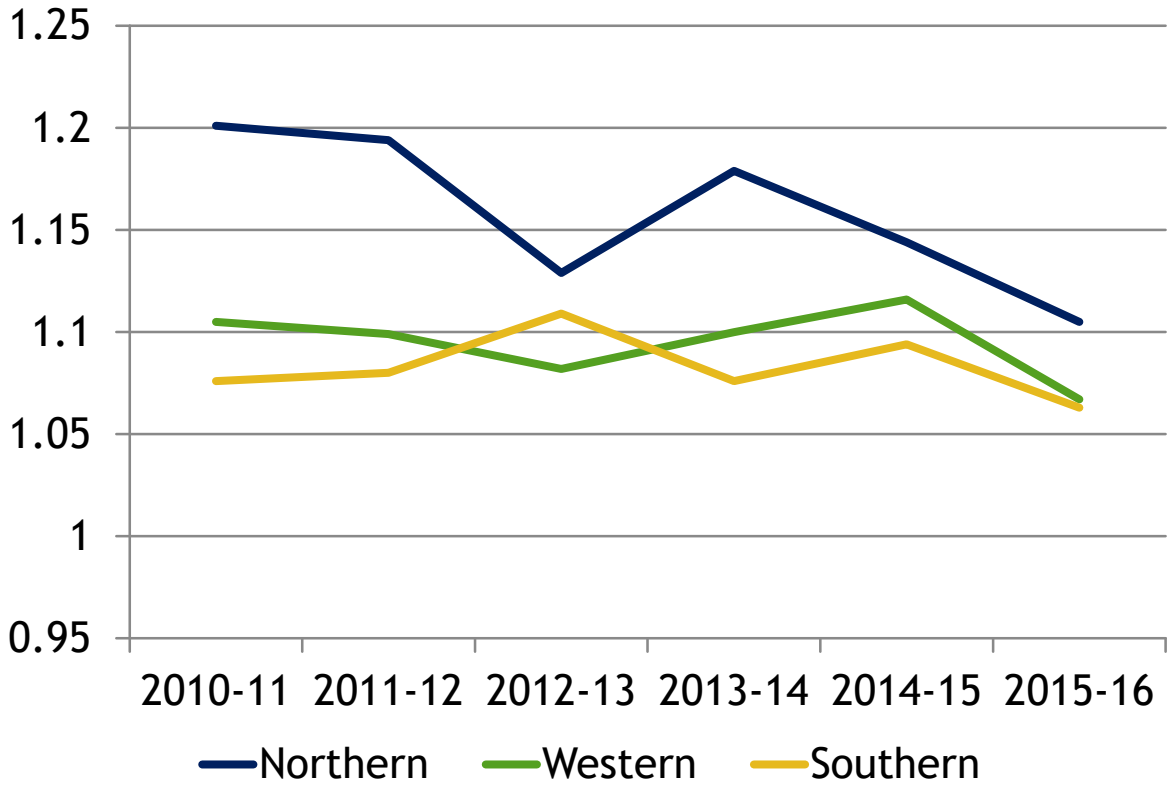
GROWTH RATE OF ELECTRICAL ENERGY REQUIREMENT

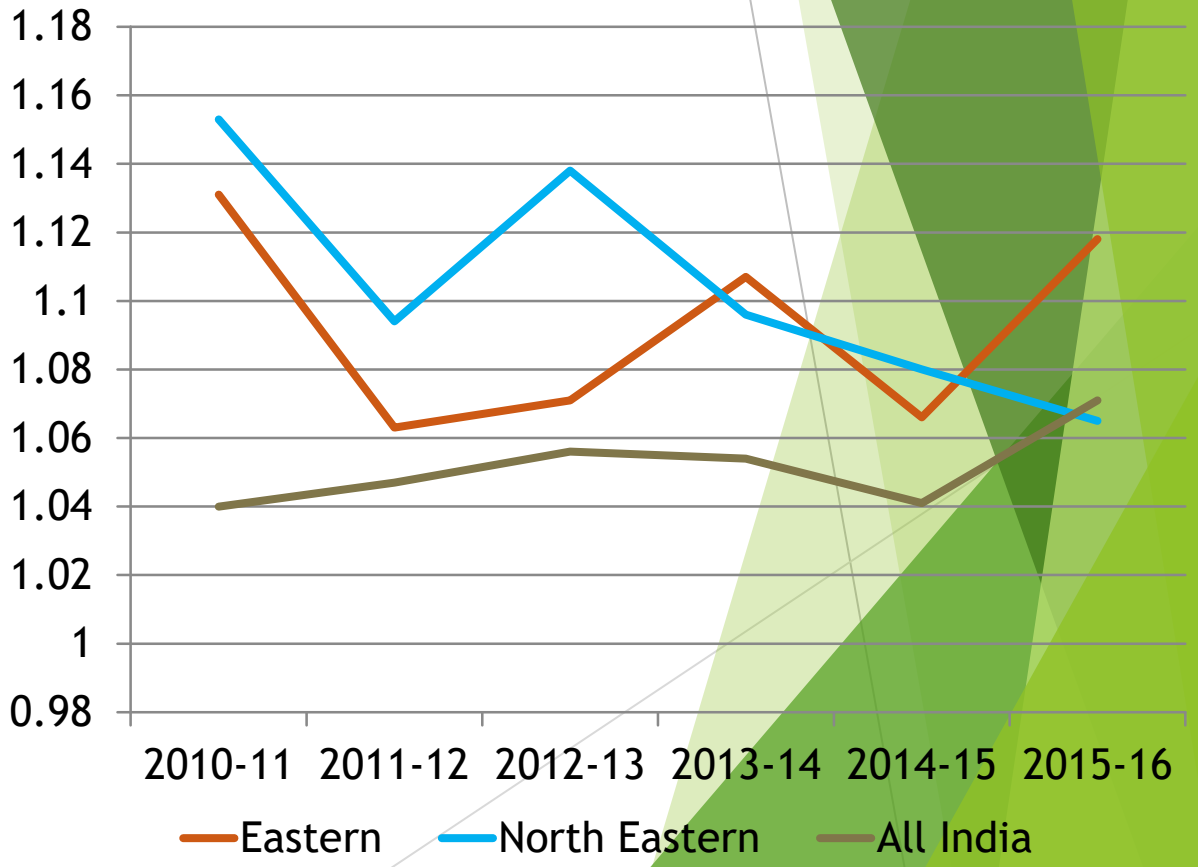


Year	Growth Rate (%)
2003-04	2.49
2004-05	5.74
2005-06	6.83
2006-07	9.31
2007-08	7.06
2008-09	5.10
2009-10	6.89
2010-11	3.73
2011-12	8.78
2012-13	6.50
2013-14	0.42
2014-15	6.65
2015-16	4.24

Growth rate has been in the range of 0.4 % to 9.31 %

DIVERSITY FACTOR (2010-11 to 2015-16)





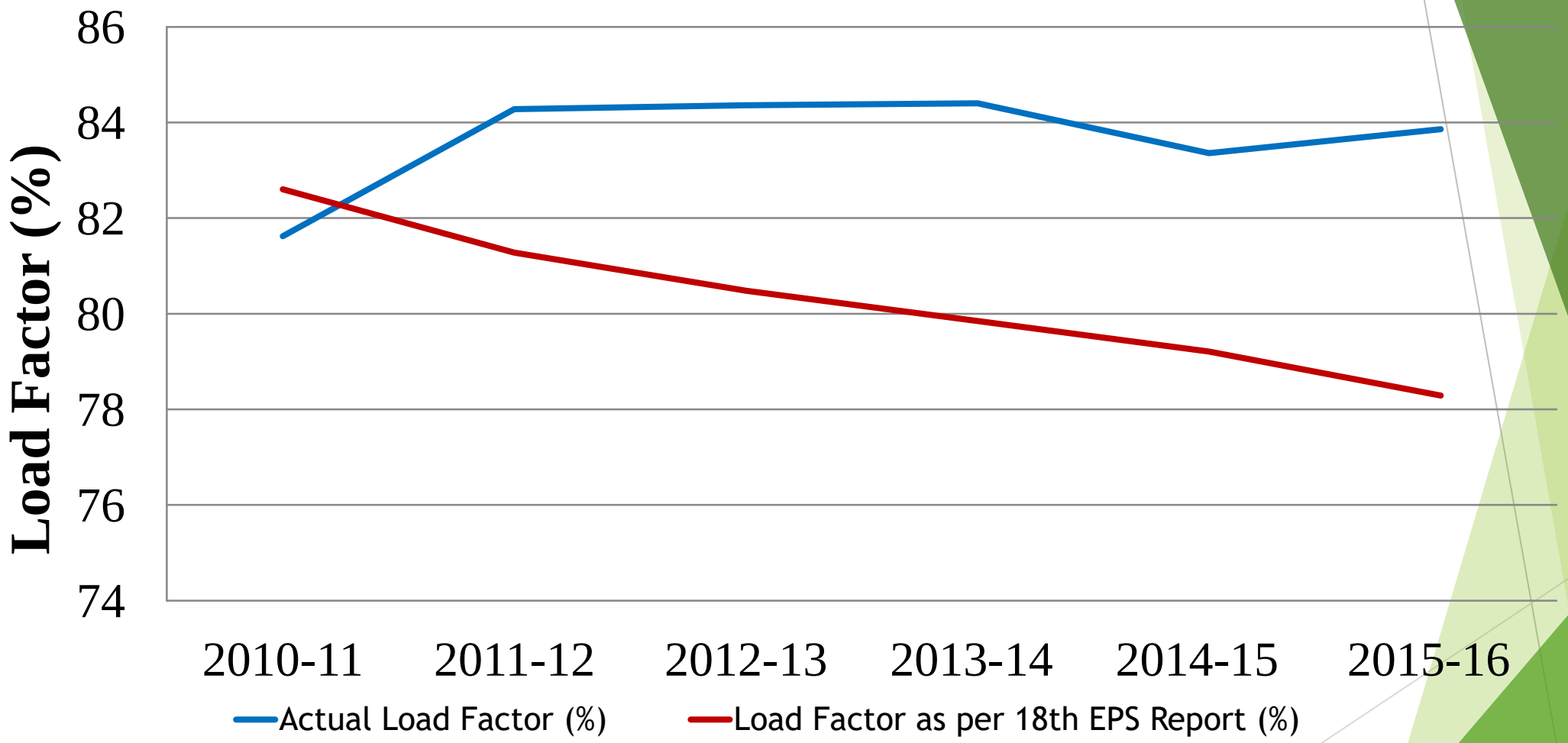
DIVERSITY FACTOR

Region	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Northern	1.201	1.194	1.129	1.179	1.144	1.105
Western	1.105	1.099	1.082	1.100	1.116	1.067
Southern	1.076	1.080	1.109	1.076	1.094	1.063
Eastern	1.131	1.063	1.071	1.107	1.066	1.118
North Eastern	1.153	1.094	1.138	1.096	1.080	1.065
All India	1.040	1.047	1.056	1.054	1.041	1.071

ALL-INDIA LOAD FACTOR

Year	Actual Load Factor (%)	Load Factor as per 18th EPS Report (%)
2010-11	81.62	82.60
2011-12	84.28	81.28
2012-13	84.36	80.48
2013-14	84.40	79.85
2014-15	83.36	79.21
2015-16	83.86	78.29

ALL-INDIA LOAD FACTOR



THANK YOU