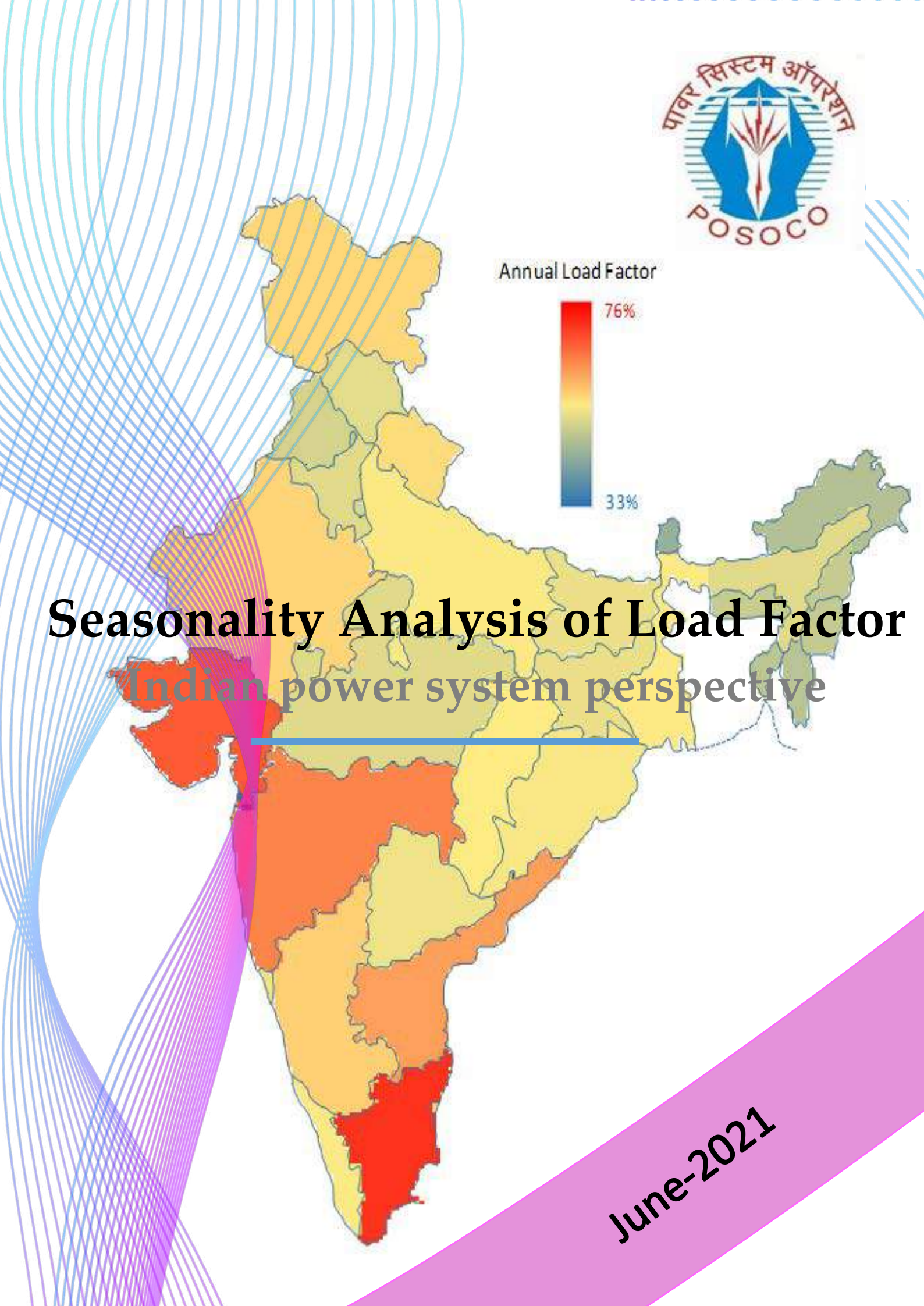

Seasonality Analysis of Load Factor

Indian power system perspective

June-2021

Seasonality analysis of load factor

Indian Power System perspective

Second Edition

All India and regionwise

Power System Operation Corporation Limited

(A Government of India Enterprise)

June 2021

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सचिव
भारत सरकार
Alok Kumar, I.A.S.
Secretary
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MESSAGE

India is among the world's largest electricity consuming nations. Despite the ongoing pandemic, India recorded the all-time highest demand of **191.5 GW on 30th June 21** and all-time highest energy consumption of **4384 million units on 30th June 2021.**

With rapid capacity addition and better grid management, the peak and energy shortage have reduced substantially. Now, the thrust is to facilitate transition towards green power from renewable energy sources and to provide quality power at competitive price. Simultaneously, India has aggressively promoted optimization and economy in the planning as well as operation horizon by considering the load and diversity factor.

Load Factor is an important metric for system operation, perspective planning and policy making in the power sector. The efforts made by POSOCO towards compilation of volume-2 of the highly data intensive report on 'load factor' is truly commendable. The report provides insights into the evolving pattern of consumer demand in the power system and helps in understanding the future requirements. I, compliment the POSOCO team involved in this work and look forward to effective utilization of the inferences from this report.

(Alok Kumar)
Secretary (Power), Govt. of India

RIGHT TO INFORMATION

स्वच्छ भारत
एक कदम स्वच्छता की ओर

केन्द्रीय विद्युत विनियामक आयोग

CENTRAL ELECTRICITY REGULATORY COMMISSION

केंद्र वि वि आयोग
CERC

Indu Shekhar Jha
Member

Message

The Central Electricity Regulatory Commission is committed to ensure optimal utilization of resources, encourage sustainable development by promoting renewable energy sources and protecting the interests of the consumers by regulating the cost of supply. CERC endeavours to achieve the objectives through the regulatory instruments such as tariff and market design. The introduction of real-time market, and the initiatives towards establishing a market for ancillary services by the CERC aims to enhance utilization of available capacity and also complement system reliability.

Load factor is a key indicator that is referred in the decision-making process at the policy making, perspective planning, regulatory as well as operation level. Historical trend of load factor provides deep insights into the various aspects of utilization of the system by the end users and it reveals the areas that require attention.

I am happy to go through the 2nd edition of the report on power system load factor compiled by POSOCO. It has valuable information for all stakeholders in the power sector at the Central as well as State level. I would encourage everyone to derive benefit from this report.

(I. S. Jha)
Member, CERC

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PREFACE

The electric power system in India has been growing exponentially and the Indian Power Grid has become one of the largest synchronous grids in the world after synchronization of the Southern region with the rest of the grid in December 2013. As India is achieving high growth in its Gross Domestic Product (GDP), ensuring 24x7 power supply to all is a thrust area. Quality power to all at competitive price with the increased standard of living, would have a significant impact on the load curve in the coming years. Moreover, unprecedented scenario like COVID-19 pandemic has also wedged the electricity demand and its trend drastically. Therefore, load factor is essentially important in holistic understanding of the power system and it can be an important metric in system operation, planning and long-term strategy in the sector.

This 2nd edition of the report, attempts to draw insights from the load curves by analysis of time series data, archived at National Load Despatch Centre (NLDC) since 2009. It presents state-wise, region-wise and country-wise load factors. Load diversity at national level has also been analyzed for ready reference of the stakeholders.

The report provides visualization of the trend and seasonality of load factor. Information could be used for planning of generation, transmission and distribution by the central and state level power system planning agencies. Load factor analysis can also provide insight into the restrictions being placed on the consumers.

On behalf of the team, I would like to thank all concerned for the support and guidance in compilation of this report.

(K. V. S. Baba)
Chairman and Managing Director

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Executive Summary

Electricity demand/consumption characteristics in a power system are often defined by connected load, estimated demand, maximum demand met, minimum demand met, average load, load factor, diversity factor, utilization factor and so on. The above characteristics are influenced by factors such as availability of generation resources, demographics, energy policy, network interconnections, access to electricity, system reliability, market design, price of electricity, economic development, weather, and other factors.

Load factor is defined as the ratio of the average load to the peak load during a certain period. It is always less than unity. High load factor is desirable as it implies that the fixed cost, which is proportional to the maximum demand, is distributed over a greater number of units (kWh) supplied. This will lower the overall cost of the supply of electric energy. Thus, the system load factor affects the overall economics of power system.

Load factor trends provides cues for policy interventions to channelize future investments towards higher capacity utilization of assets. While evaluating different policy trajectories, the policy makers could prefer the one that increases the load factor. Regulators are also deeply concerned about the cost of supply and the utilization of assets. Load factor trends provides cues for regulatory interventions through market design.

Load factor is one of the basic inputs in perspective planning. Load factor is relevant in the selection of type of generation and transmission capacities for the system. It is required for techno economic feasibility assessment of various investment proposals. System Operators refer the historical trends of load factor to align the future maintenance and despatch strategies towards enhancing the system load factor and minimizing operational risks.

Analysis of daily, monthly, and annual load factor has been carried out in this report using 5 minutes SCADA data over the last twelve years (from 01.01.2009 to 31.12.2020) available at NLDC. Variation of load factor for all India and regions along with their daily load factor trend is given below:

Region	Daily	Monthly	Yearly	Gradient*
NR	90%	84%	73%	↓
WR	92%	86%	79%	↓
SR	91%	86%	81%	↓
ER	85%	79%	73%	↓
NER	73%	67%	59%	↓
All India	92%	88%	83%	↓

*Gradient of daily load factor

The State wise daily, monthly, and annual load factor along with trend of daily load factor is given below:

	Load Factor			Gradient of linear fit			
Name of State/ UT	**Daily**	**Monthly**	**Annually**	**Trend of Load Factor**	**Maximum Demand**	**Minimum Demand**	**Average Demand**
Andhra Pradesh	86%	76%	68%	↓	1.131	0.627	0.832
Arunachal Pradesh	69%	55%	42%	↑	0.012	0.011	0.010
Assam	70%	64%	56%	↓	0.223	0.118	0.161
Bihar	80%	72%	59%	↓	0.990	0.534	0.728
Chandigarh	74%	60%	50%	↓	0.013	0.006	0.008
Chhattisgarh	84%	75%	65%	↑	0.388	0.370	0.384
Delhi	78%	64%	54%	↓	0.291	0.165	0.221
DVC	88%	78%	71%	↑	0.256	0.239	0.246
Goa	80%	68%	62%	↑	0.055	0.040	0.047
Gujarat	89%	80%	72%	↓	1.753	1.333	1.545
Haryana	79%	69%	56%	↓	0.848	0.476	0.676
Himachal Pradesh	77%	68%	57%	↔	0.168	0.101	0.134
J&K and Ladakh	81%	74%	66%	↑	0.266	0.179	0.231
Jharkhand	80%	69%	59%	↓	0.115	0.077	0.093
Karnataka	84%	76%	66%	↓	0.957	0.662	0.796
Kerala	75%	70%	64%	↑	0.250	0.240	0.262
Madhya Pradesh	82%	71%	56%	↑	1.444	1.143	1.322
Maharashtra	88%	79%	70%	↓	2.409	1.751	2.093
Manipur	59%	53%	47%	↓	0.028	0.014	0.015
Meghalaya	71%	59%	48%	↓	0.032	0.021	0.022
Mizoram	64%	55%	43%	↑	0.012	0.004	0.008
Nagaland	68%	58%	48%	↑	0.017	0.011	0.014
Odisha	80%	71%	63%	↑	0.347	0.277	0.305
Puducherry	83%	75%	66%	↓	0.029	0.020	0.025
Punjab	83%	67%	52%	↓	0.618	0.361	0.506
Rajasthan	85%	76%	66%	↓	1.552	0.880	1.216
Sikkim	56%	46%	33%	↑	0.008	0.005	0.008
Tamil Nadu	88%	81%	73%	↓	1.406	1.046	1.239
Telangana	86%	73%	61%	↓	1.685	0.862	1.282
Tripura	64%	54%	45%	↔	0.036	0.018	0.025
Uttarakhand	81%	74%	66%	↑	0.237	0.174	0.209
Uttar Pradesh	85%	76%	64%	↓	2.649	1.454	1.982
West Bengal	78%	71%	65%	↑	0.584	0.408	0.520

The major observations from this analysis are as below:

1. The all-India annual load factor remained in the narrow range of 83-86% in the last 12 years while the daily all India diversity factor of maximum demand is increasing.
2. The high load factor could be attributed to a combination of benefits derived out of demand side management in different States, the synchronous interconnection of regional grids to form the national grid for sharing of generation capacity, rapid augmentation in transmission capacity and transfer capability to facilitate exploitation of diversity in the State/regional power system and. It moved in a narrow range over the years because the rate of growth of energy and peak demand has been around the same.
3. Maximum demand is increasing with a faster rate than the average demand and minimum demand.
4. All India daily load factor was above 90% for 70% of the time, however, in 2019 & 2020, it was 60% of the time. Variation between summer and winter is about 5-6%.
5. Daily all India Load factor is gradually decreasing. This could be attributed to significant reduction in the peak and energy shortage consequent to rapid augmentation in the conventional as well as new and renewable energy generation capacity in the grid.
6. Northern Region annual load factor shows a decreasing trend. It reduced from 79% in year 2009 to 63% in year 2020. Variation in daily load factor of Northern Region between summer and winter is about 5-6% which indicates a higher proportion of weather sensitive and agriculture load within the region.
7. Western Region annual load factor has a decreasing trend. It was 80% in year 2009 to 72% in year 2020. Variation in daily load factor between seasons over the years is about 8-10%.
8. Southern Region annual load factor is between 69-84%. Variation in load factor is more prominent in the Southern Region compared to other regions. It has decreased over the last three years. Also, variation in daily load factor between seasons over the years is about 4-5%.
9. Eastern Region annual load factor has remained steady between 68-77%. Also, seasonal variation in daily load factor is about 7-9%.
10. North-Eastern Region annual load factor varied between 59-64%. Variation in daily load factor is about 8-10%. Daily Load factor is Maximum in July-August.
11. Most of the states having decreasing load factor trend except Kerala, Chhattisgarh, Madhya Pradesh, Odisha and West Bengal.
12. There is minimal impact of seasonality on load factor pattern of Jharkhand and DVC.

13. **Key takeaways from the load factor report for policy makers are as under**:
    a. Declining trend in the load factor in Indian power system points towards the need for policies that encourage investments in flexible resources and energy storage technologies.
    b. Policies that encourage transnational interconnections to defer CAPEX and increase load factor by exploiting the regional diversity may be given preference.
    c. Demand elasticity could be enhanced by encouraging measures like demand response, demand side management, staggering of supply hours to bulk consumers.
    d. The impact of electrification of different sectors such as transportation and domestic cooking on the load factor with its fallout on overall investments could be assessed.

14. **Key takeaways from the load factor report for regulatory institutions are as under:**
    a. Declining load factor points towards need for regulatory interventions through market design (intra- day market, ancillary services) and tariff design (peaking tariff, peak hour capacity availability)
    b. Enabling mechanisms to assess and harness the reserves available within the existing capacity could be considered.

15. **Key takeaways from the load factor report for perspective planning are as under:**
    a. Declining load factor is a signal for planning flexible generation (Hydro, Pumped Storage, Gas, BESS) and transmission assets (Hybrid AC-DC, HVDC, FACTS etc.) instead of base load or inelastic resources.
    b. In an AC system low load factor signals a need for reviewing the reactive resources in the grid.

16. **Key takeaways from the load factor report for system operations are as under:**
    a. Historical trends of load factor could be referred for short-term and medium-term operation planning.
    b. Asset maintenance plans and despatch strategies could be aligned towards enhancing the system load factor and minimizing operational risks.

Data Source and Assumption

1. Demand met data considered for this analysis consist primarily of 5 minute and 15 minutes instant/average demand met data captured at National Load Despatch Centre (NLDC) from 2009-2020 through Supervisory Control and Data Acquisition (SCADA) system.

2. The data is stored at 1-minute interval which thereafter, is converted to 5 minute/15 minutes. Maximum demand met for day/months/years have been calculated by using 5/15 minutes instantaneous Demand data.

3. Some discrepancies in data creeps up due to failure of communication at some point of time. In case of missing data following assumption have been made:

    3.1. Loss of data for few hours: Previous day same hour data has been considered.
    3.2. Loss of data for entire day: Previous day data has been considered.
    3.3. Loss of data for more than a day: Same time period data of previous day has been considered.

4. The samples collected at a particular time instant through SCADA could have minor inherent skewedness in the range of seconds.

5. The drawl of a state from inter-state grid, is calculated at the periphery of the state through summation of telemetered power flow data of interconnections. Demand of each state has been calculated as the summation of internal (excluding auxiliary consumption) generation connected to state grid and drawl from the interstate grid. Hence the demand of a state includes, the intrastate transmission and distribution losses. Telemetry failures either from internal generation or from interconnections could result in erroneous demand computation. Generation from Distributed Energy Sources (DER) has not been considered for analysis in this report.

6. **Software used:** MATLAB and Microsoft Office.

7. Analysis of load factor for Andaman and Nicobar Islands and Lakshadweep, Dadra and Nagar Haveli and Daman and Diu have not been carried out in this report.

8. Captive generating stations (Estimated installed capacity of 78GW Industrial captive generation as on 31.03.2020 (source:CEA)) co-located with their loads are not included as this is not monitored in real time. Similarly, rooftop solar is also excluded.

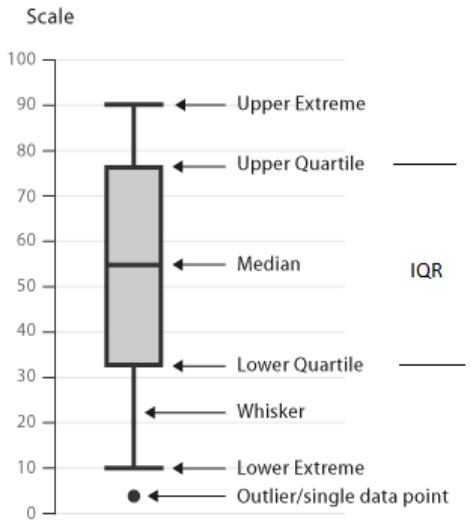
What is new in the 2nd edition

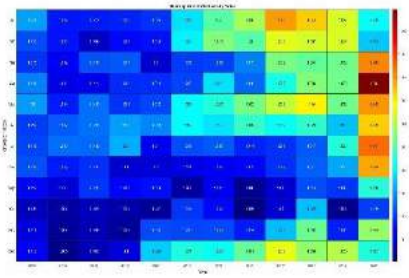
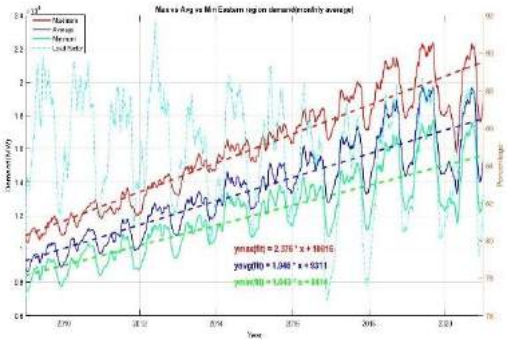
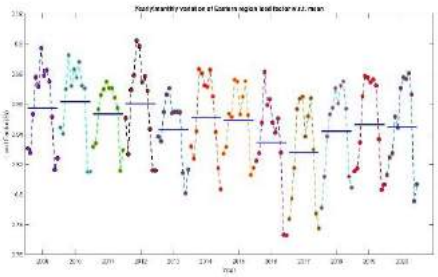
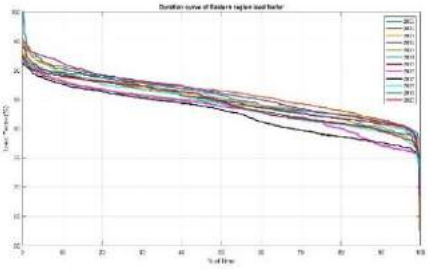
First edition of the report titled "Electricity Load Factor in Indian Power Systems" was published in the year 2016. The report presented load factor analysis through seasonality decomposition and linear trends. It also shared demand diversity and duration curves. This report may be accessed from the following link:

https://posoco.in/download/electricity-load-factor-in-india-power-system/?wpdmdl=709

In this 2nd edition, apart from seasonality decomposition, quarter-wise seasonality index analysis has also been carried out which depicts the seasonal variation of regional and all India load factor throughout the year. This analysis also brings out the load diversity that exists in the country. Distribution of load factor (for All India, regional and state demand) has been presented through heatmap and box plots also.

Load factor variation over the years has been analyzed in this report with the help of growth plot of 30 days moving average of maximum, minimum and average daily demand. Monthly average variation of load factor has been shown along with the annual average in the Cycle Sub-Series plots. Data upto December-2020 has been considered for analysis.

Sl. No.	Name of Plot	Graphical representation	Description
1	Box plots		Graphical depiction of numerical data through their quartiles. Box plots are useful as they provide a visual summary of the data quickly identify median values, the dispersion of the data set, and signs of skewness. where Lower extreme: lowest data point excluding any outliers. Lower quartile: Twenty-five percent of scores fall below the lower quartile value. Median: Middle value of the dataset. Inter Quartile Range (IQR): The distance between the top and bottom edges of the box is the IQR Upper quartile: Seventy-five percent of the scores fall below the upper quartile value Upper extreme: largest data point excluding any outliers. Outlier : Outliers are values that are more than (1.5 * *IQR)*

			away from the upper or lower quartiles.
2	Heatmaps		It shows magnitude of a parameter as color in two dimensions. Red colour indicates high value while blue colour indicates low value. The color variation gives obvious visual cues, how the parameter is clustered or it varies.
3	Growth plots		Trend of monthly moving mean of minimum/maximum/average demand along with trend of load daily load factor. The trend may be referred to visualize the rate of increase in minimum/maximum/average demands.
4	Cycle-Sub series plots		Monthly average of daily load factor vs-a-vis annual average of the daily load factor. This chart depicts the variation in annual load factor. It also highlights the months where energy intensity is higher or lower than the annual average.
5	Duration curve		Duration curve shows the proportion of time for which the variable exceeded a certain value.

1. Introduction

Load factor is a widely-accepted indicator of system efficiency, calculated as the ratio of average load to peak load in a given time period. This ratio can be influenced through utility initiatives that increase the sale of energy and/or reduce the system peak.

System efficiency refers to utilizing system assets to generate the largest possible value for customers/stakeholders. System load factor is a useful indicator of system efficiency, as increasing system load factor often means that total system costs are spread across a larger number of sales units, thus reducing the cost burden for individual customers.

Load factor is formally defined as the ratio of average load (over a given period of time) to the maximum or peak load (during the same period). Load factor provides a measure of how "peaky" system load is and may indicate the degree of asset utilization on the grid; i.e., a higher load factor correlates with higher utilization of grid infrastructure. It is calculated as:

$$\boldsymbol{Load\ Factor = \frac{Average\ load\ in\ given\ time\ period}{Peak\ load}}$$

Thus, maximum load factor generally refers that the load profile is entirely flat and does not contain peaks or troughs.

The previous report published by POSOCO "Electricity load factor in Indian power system" is available on POSOCO website. Same can be accessed via following link:
https://posoco.in/download/electricity-load-factor-in-india-power-system/?wpdmdl=709

Factors Affecting Load Factor:

- Traditional Variables used to predict electricity consumption
- Gross domestic product
- Weather factors (heating degree days, cooling degree days, seasonal differences)
- Individual customer sector growth
- Population growth
- Employment or other labor statistic
- Household size

2. Classification of Load Factor

Load factor can be calculated on a daily, monthly or annual basis. For the purpose of this analysis three types of load factors have been calculated viz; daily, monthly and yearly.

$$\mathbf{Daily\ Load\ Factor = \frac{Daily\ Average\ Load}{Daily\ Maximum\ Load}}$$

$$\mathbf{Monthly\ Load\ Factor = \frac{Monthly\ \ Average\ Load}{Monthly\ Maximum\ Load}}$$

$$\mathbf{Annual\ Load\ Factor = \frac{Annual\ \ Average\ Load}{Annual\ Maximum\ Load}}$$

3. Load Factor as per 18/19th Electric Power Survey (EPS) report of CEA

The load factor has also been assessed and forecasted by CEA in its 18th EPS report. Same has been incorporated in the earlier report also. The extract from the same is given below:

"The electric load factor of a power system depends on the pattern of utilization of different classes of load. If the system feeds block industrial loads like Aluminum and other process industries etc. having high electric load factor, the overall system load factor would also tend to be high. In regard to estimation of electric load factor for future, if the pattern of utilization of different classes of load does not differ appreciably from the past in terms of percentage of total electric load, then it was assumed that the system load factor of the past may continue. In case, the pattern is anticipated to change with respect to total electric load due to gradual withdrawal of restrictions /cuts / load shedding & under frequency conditions then it is necessary to estimate the future electric load factor. A broad analysis to ascertain the influence of load mix on the load factor was undertaken. Based on the analysis of future electric load mix, the load factor for each State/Union Territory has been worked out."

"The All India Annual Electric Load Factor (AELF) in the base year 2009-10 is around 82.7%. According to the 18th EPS, the All India AELF by 2011-12 would be 81.28% which is expected to gradually reduce to 77.51% by the end of 2016-17, and by 2021-22 load factor is anticipated to be 76.71%."

Region	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
All India	83	83	81	80	80	79	78	78	77	77	77
NR	84	81	80	80	80	80	80	79	79	79	79
WR	79	78	77	76	76	75	74	73	72	72	72
SR	78	80	77	76	74	73	72	71	71	71	71
ER	78	81	80	80	79	78	78	77	77	76	76
NER	64	63	62	62	62	62	62	62	63	63	64

Table 1:All India/Regional Load Factor Pattern (As per 18th EPS)

As per the CEA LGBR report, Actual energy supplied and peak demand has been compiled and based on which actual load factor has been calculated. A comparison of anticipated load factor as per CEA 18th EPS report and actual load factor is given below:

Region	2015-16		2016-17		2017-18		2018-19		2019-20	
	Energy supplied (MU)	Peak demand (MW)	Energy supplied (MU)	Peak demand (MW)	Energy supplied (MU)	Peak demand (MW)	Energy supplied (MU)	Peak demand (MW)	Energy supplied (MU)	Peak demand (MW)
All India	1090851	148463	1135334	156934	1204697	160752	1267526	175528	1284444	182533
NR	324009	50622	343513	52612	365723	58448	377595	61726	389285	66559
WR	345967	48199	345127	48313	368081	50085	390136	55821	388836	59416
SR	283494	39875	305107	42232	319642	47210	338960	49534	344436	53579
ER	123646	18056	126868	18788	135490	20485	144616	22733	145902	23421
NER	13735	2367	14720	2475	15764	2520	16219	2850	15984	2989

Table 2:All India Yearly Energy supplied and Peak Demand met (as per CEA LGBR report)

(Source: https://cea.nic.in/l-g-b-r-report/?lang=en)

Annual load factor (%)										
Region	2015-16		2016-17		2017-18		2018-19		2019-20	
	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual
All India	78	84	78	83	77	86	77	82	77	80
NR	80	73	79	75	79	71	79	70	79	67
WR	74	82	73	82	72	84	72	80	72	75
SR	72	81	71	82	71	77	71	78	71	73
ER	78	78	77	77	77	76	76	73	76	71
NER	62	66	62	68	63	71	63	65	64	61

Table 3:Comparison of anticipated (as per 18th EPS) and load factor (as per CEA LGBR)

As per 19th EPS report, load factor for forthcoming years are given below:

All India Load Factor (%) as per 19th EPS report						
Year	2021-22	2022-23	2023-24	2024-25	2025-26	2026-27
Load Factor	79.18	78.87	78.71	78.54	78.38	78.23

Table 4:Anticipated Load factor based on 19th EPS report

4. Diversity Factor

The load is time dependent and daily load diversity is caused by a marked and consistent difference between the daily load cycles in two or more adjoining load areas, which results in peaks at different times during the day e.g., one region may have a morning peak while the other has an evening peak. Daily load diversity results in reduced operating expenses and can be used or cancelled on short notice by an alert system dispatching group. The benefits of daily diversity can be obtained by economy energy transactions or daily diversity exchange agreements. It should be noted that this type of transaction reduces fuel expense and unit startup and shutdown costs, but may or may not have any effect on capital requirements.

Annual diversity usually results from difference in the weather patterns and/or demand requirement between two or more regional areas. For example, one region may have its annual peak load during the winter months, while other regional annual peak load occurs during the summer. However, daily diversity of all India would be significantly impacted by the difference between sun rise/ sun set timings at different geographical locations. Annual load diversity affords an opportunity for capital savings in regard to reducing installed generating-capacity requirements.

The diversity factor in power system is an important indicator of variation of maximum load across different parts of the country in a given time period. Further, interconnection of grids helps in harnessing this diversity and improving the load factor of the country. Diversity factor is usually more than one. Demand diversity factor for maximum demand is calculated as follows:

$$\textbf{All India Demand Diversity Factor} = \frac{\textbf{Sum of individual regional maximum demand}}{\textbf{Simultaneous maximum demand}}$$

Minimum demand diversity has been calculated as per the following formula:

$$\textbf{All India Demand Diversity Factor} = \frac{\textbf{Simultaneous minimum. demand}}{\textbf{Sum of individual regional minimum. demand}}$$

Regional as well as All India annual demand (maximum) diversity factor has been calculated from five-minute instantaneous SCADA data available at NLDC by averaging daily diversity factor for a year and same has been tabulated below.

Year/Region	AI	NR	WR	SR	ER	NER
2009	1.02	1.08	1.03	1.05	1.03	1.03
2010	1.01	1.09	1.02	1.02	1.02	1.03
2011	1.01	1.07	1.03	1.03	1.03	1.02
2012	1.01	1.07	1.03	1.02	1.01	1.00
2013	1.01	1.05	1.02	1.02	1.01	1.01
2014	1.02	1.05	1.02	1.03	1.02	1.02
2015	1.02	1.05	1.02	1.03	1.01	1.01
2016	1.02	1.05	1.01	1.02	1.02	1.03
2017	1.03	1.05	1.01	1.02	1.01	1.01
2018	1.03	1.05	1.01	1.03	1.00	1.02
2019	1.03	1.06	1.01	1.04	1.01	1.03
2020	1.04	1.07	1.01	1.03	1.02	1.02

Table 5:All India and Regional annual demand diversity over the years

The heat map of diversity in daily All India demand is given below. It seems load diversity of all India is increasing with respect to its past data. One of the possible reasons may be load segregation by the utilities due to increasing penetration of RE resources into the grid. Further, it is also imperative to mention that all India electricity demand had witnessed significant reduction from late March 2020 onwards due to imposition of nationwide lockdown for containment of COVID-19. In energy terms, the demand contracted by 25% in April 2020 and 15% in May 2020 on year-on-year basis. With gradual reopening of the economy, the demand picked up and started exhibiting year-on-year growth from September 2020 onwards.

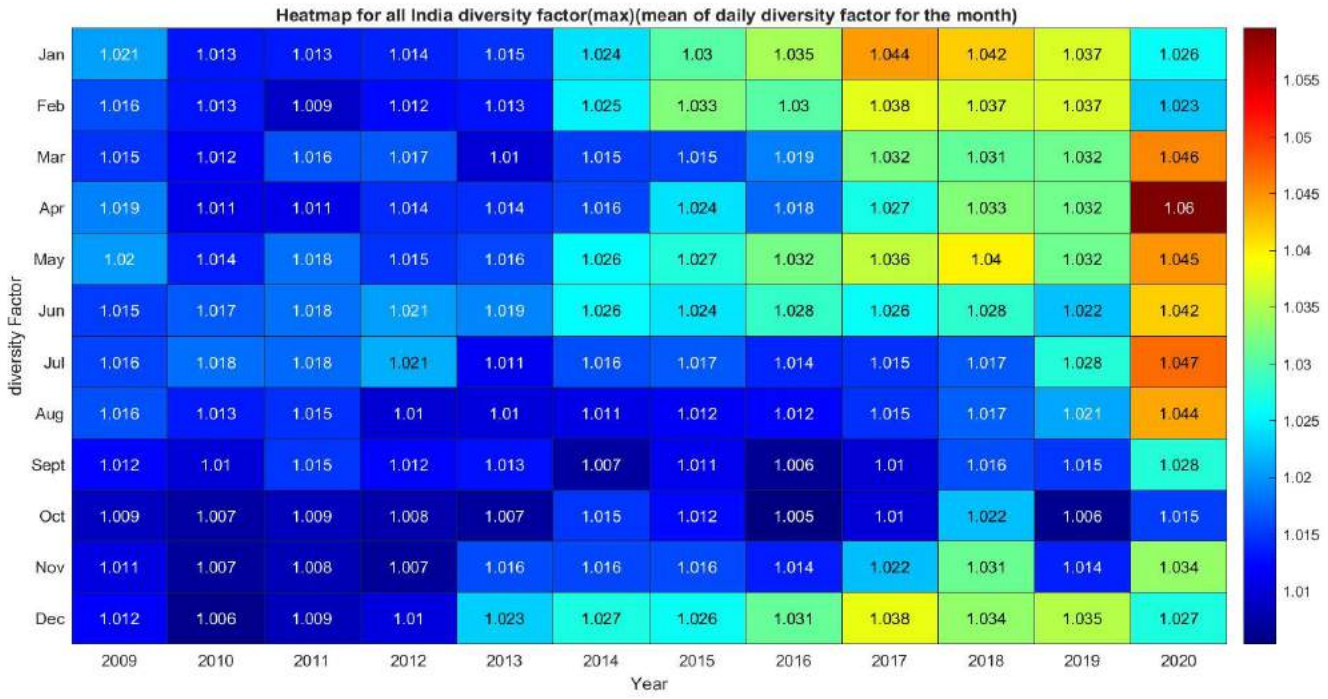


Figure 1: Heat map of avg monthly all India diversity factor (w.r.t. max)

Diversity in minimum load is also important. The simultaneous minimum All India demand would be much higher than the sum of individual minimum demand of different states on account of diversity. The diversity factor for minimum loads has also been computed in similar manner as mentioned while calculating diversity factor of maximum demand. Results are given below:

Year/Region	AI	NR	WR	SR	ER	NER
2009	1.03	1.07	1.06	1.06	1.08	1.13
2010	1.03	1.07	1.14	1.05	1.09	1.13
2011	1.02	1.07	1.07	1.05	1.09	1.17
2012	1.02	1.08	1.05	1.06	1.10	1.13
2013	1.02	1.07	1.04	1.04	1.11	1.12
2014	1.02	1.07	1.04	1.02	1.09	1.10
2015	1.02	1.07	1.04	1.02	1.09	1.10
2016	1.02	1.07	1.04	1.02	1.10	1.09
2017	1.02	1.06	1.05	1.01	1.12	1.10
2018	1.03	1.07	1.05	1.02	1.09	1.08
2019	1.02	1.07	1.04	1.01	1.09	1.10
2020	1.03	1.08	1.04	1.03	1.06	1.07

Table 6: Demand diversity for minimum all India demand

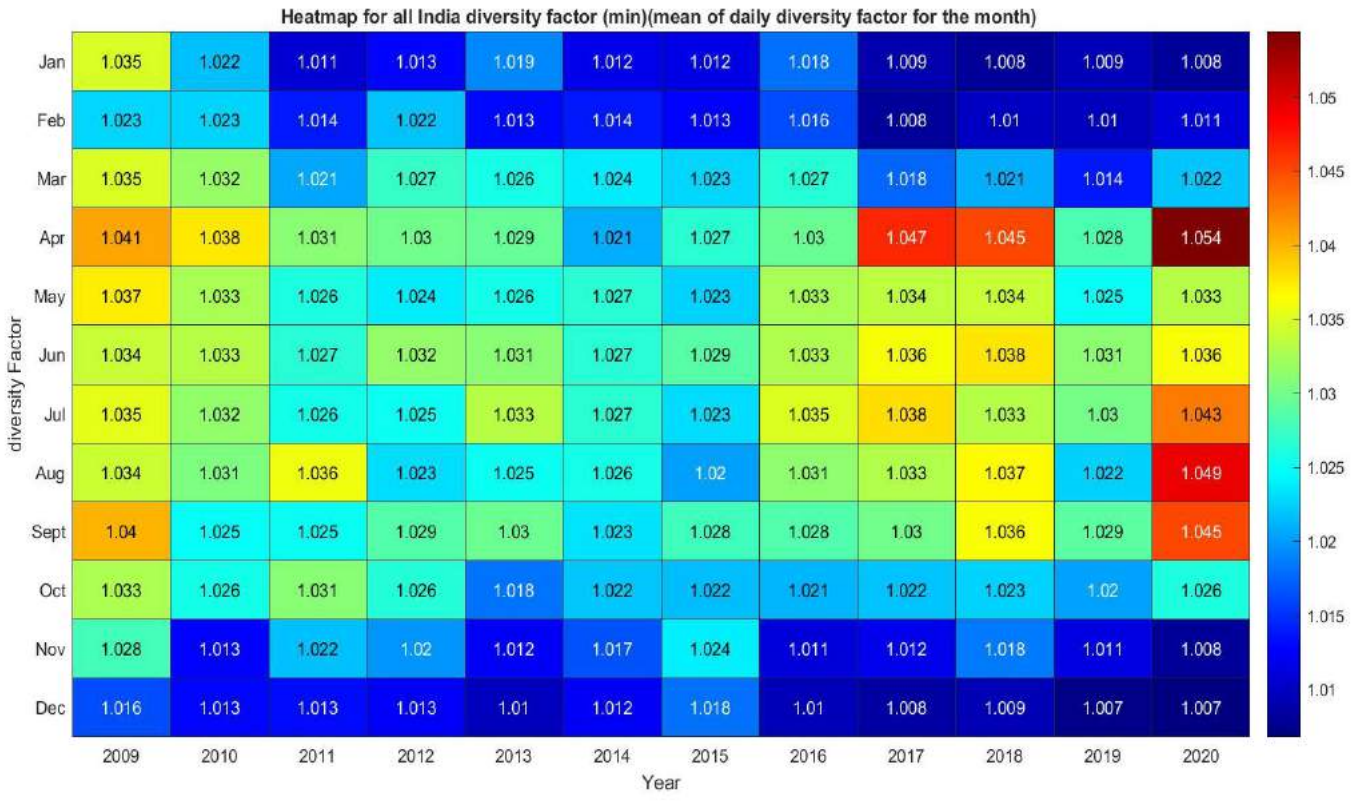


Figure 2: Heat map of avg monthly all India diversity factor (w.r.t. min)

5. Methodology used for Seasonal decomposition

5.1. Additive Method

The decomposition of a time series model, generally splits into 3 components namely trend, seasonal effects, and de-seasonalised data. Further, errors (noise) in data can also be calculated with an aim to model the random errors as some form of stationary process.

Simple additive decomposition model has been used in this report for a time series data ranging from 2009 to 2020(calendar year). Relevant equation is given below:

$$\mathbf{Y(t) = T(t) + S(t) + E(t)}$$

Where,
Y(t)= Time series data
T(t)= Trend
S(t)=Seasonality
E(t)=Error (Noise)

We generally assume to have zero-mean and to be correlated over time. Thus, by estimating and subtracting both T(t) and S(t) from Y(t), we expected to have a time series of stationary residuals i.e. E(t). Further, estimation of de-seasonalised load factor D(t) is being carried out by taking difference between Original signal Y(t) with seasonality S(t). Equation is given below:

D(t)=Y(t)-S(t)

Where,
D(t) =De-seasonalised data

In literature, linear filters are a very common way to estimate trends in time series data. Moving average is one of the most common linear filters, which for time lags from −a to a is defined as

$$\widehat{\boldsymbol{m(t)}} = \sum_{\boldsymbol{k=-a}}^{\boldsymbol{a}} \frac{\mathbf{1}}{(\mathbf{1}+\mathbf{2a})} \boldsymbol{y_{t+k}}$$

Where,
$\widehat{m}$=Moving average

The above-mentioned model works well for moving windows of odd-numbered lengths, but it should be adjusted for even-numbered lengths by adding only 1/2 of the 2 most extreme lags so that the filtered value at time t lines up with the original observation at time t

Moreover, It is important to mentioned that our time series of the estimated trend $\widehat{m}(t)$ is actually shorter than the observed time series by 2a units.

In addition to specifying the time series to be filtered, we need to pass in the filter weights to estimate the actual trend of signal.

After estimation of trend, estimate of effect of seasonality can be find out by taking the difference of Original signal by estimated trend.

$$S(t)=Y(t)-\hat{m}(t)$$

This estimate of the seasonal effect for each time t also contains the random error E(t), however, which can be seen by plotting the time series and careful comparison of Equations of Y(t) and S(t).

Further, for estimating seasonal effect, we have carried out averaging of the estimates of S(t) and repeating this sequence overall years with a sampling rate of 365 days.

5.2. Seasonality Index

A seasonality index is a measure of how a particular season through some cycle compares with the average season of that cycle. Further, it made possible to create a trend equation that reflects the average monthly/quarterly/yearly load factor and the growth rate in each month/quarter/Year of the study period.

Seasonality index has been calculated as follows:

1. Total period load factor data (from 2009 to 2020) has been segregated into four quarters namely Quarter-1(Jan-Mar), Quarter-2(Apr-Jun), Quarter-3(Jul-Sept) and Quarter-4(Oct-Dec) for each year.
2. Average of each quarter for the mentioned period has been calculated.
3. Each quarter average has been divided by total average of all quarters to find out seasonality index for each region.

Calculated seasonality index for each region is given below:

Seasonality Index						
	AI	**NR**	**WR**	**SR**	**ER**	**NER**
Quarter-1	0.991	0.993	0.992	1.005	0.977	0.986
Quarter-2	1.009	0.988	1.023	1.017	1.010	0.950
Quarter-3	1.014	1.027	0.988	0.996	1.022	1.056
Quarter-4	0.986	0.991	0.996	0.982	0.992	1.008

Table 7:Seasonality index- All India & Region wise

Based on the above table, it is observed that during Quarter-3, Northern regional load factor is having the highest seasonality index with respect to total average compared to

other quarters. However, in quarter-2, Northern region is having the lowest seasonality index and its load factor would be .988 of total average value.

Similarly, Seasonality index for Western region is highest in Quarter -2 and lowest in Quarter-3 with respect average value.

In Southern region also, Seasonality index is on higher side in Quarter- 2 compared to other Quarters. Further, In Eastern region, Seasonality index is lowest in quarter -1 and steadily increased in quarter-2 & 3 and again decreased in quarter-4. However, in North Eastern region variation quite similar to Northern region i.e. it close to total average in Quarter-1 &2 and then starts decreasing.

6. Analysis of load factor

Based on the All-India demand data from year 2009 to 2020(calendar year), daily load factor has been calculated. Same has been plotted in the graph given below along with monthly moving average and linear trend estimation.

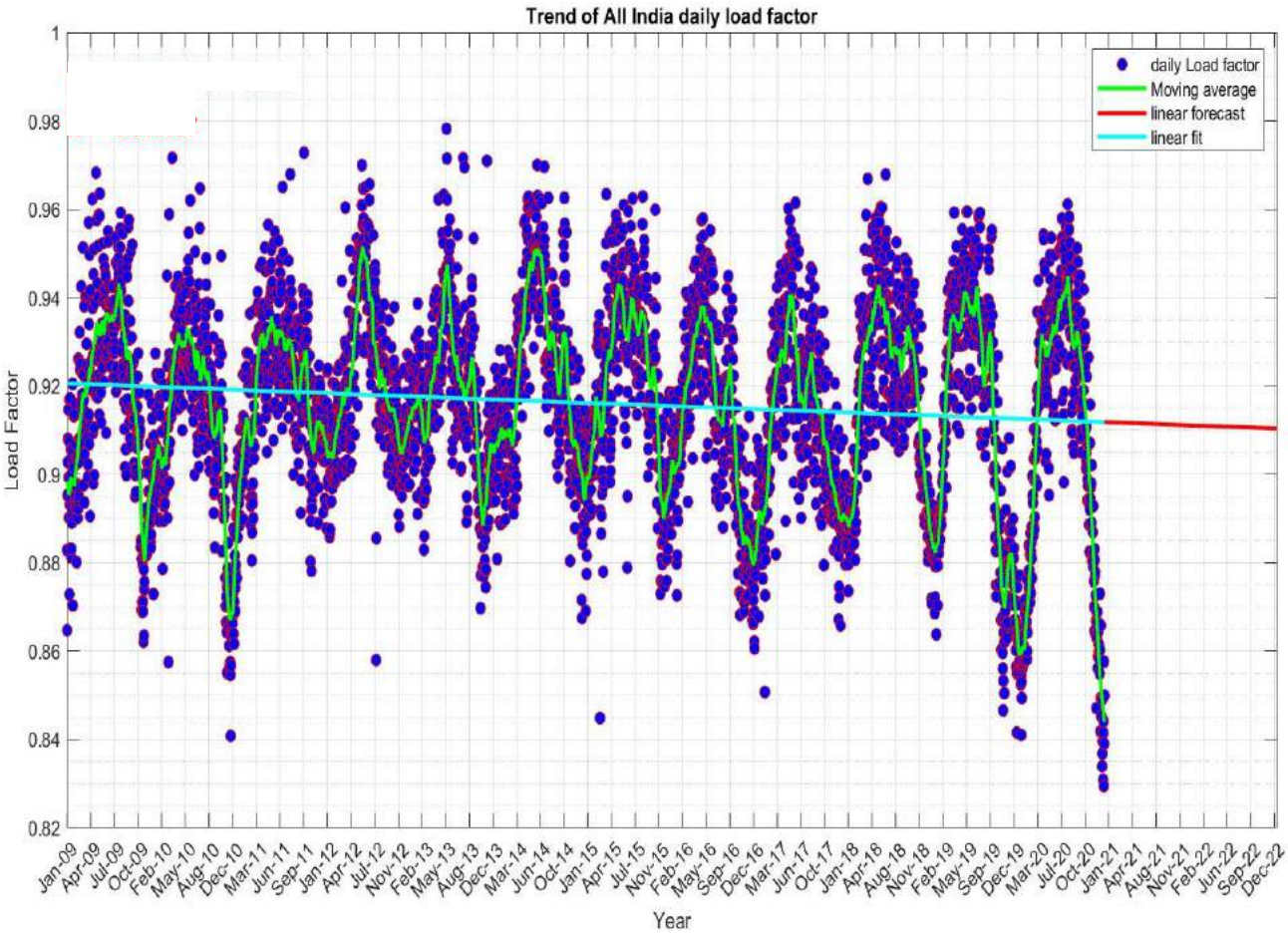


Figure 3:All India Daily load factor & estimated trend

It is evident from the linear trend estimation that load factor is relatively constant at all India level in the given period. However, it is slightly skewed towards decreasing trend with gradient of 0.0002%. Decreasing trend of load factor may also be verified from the below given graph, wherein it can be observed that gradient of peak load is more than gradient of average load. Further, linear trend for the daily load factor is also anticipated based on the given values of gradient and intercept on y-axis. Gradient and intercept on Y-axis have been calculated over historical data with application of least square curve fitting method and plotted in the above graph.

Moreover, monthly moving average of all India maximum, average and minimum demand have been given the following figure. It is observed that gradient of peak demand is higher than that of average demand. It may lead to more peaky demand in the upcoming years. From the historical data, it is also observed that ramping has been increasing day by day during peak hours with difference in maximum and minimum demand of the order of 65GW. In view of anticipated high ramping in the future due to higher peaks, it is envisaged that containing

ramp during peak hours would be a challenge to keep all India frequency with in IEGC band. Therefore, flexible ramp reserve requirement during morning and evening peak will be more critical than base load requirement.

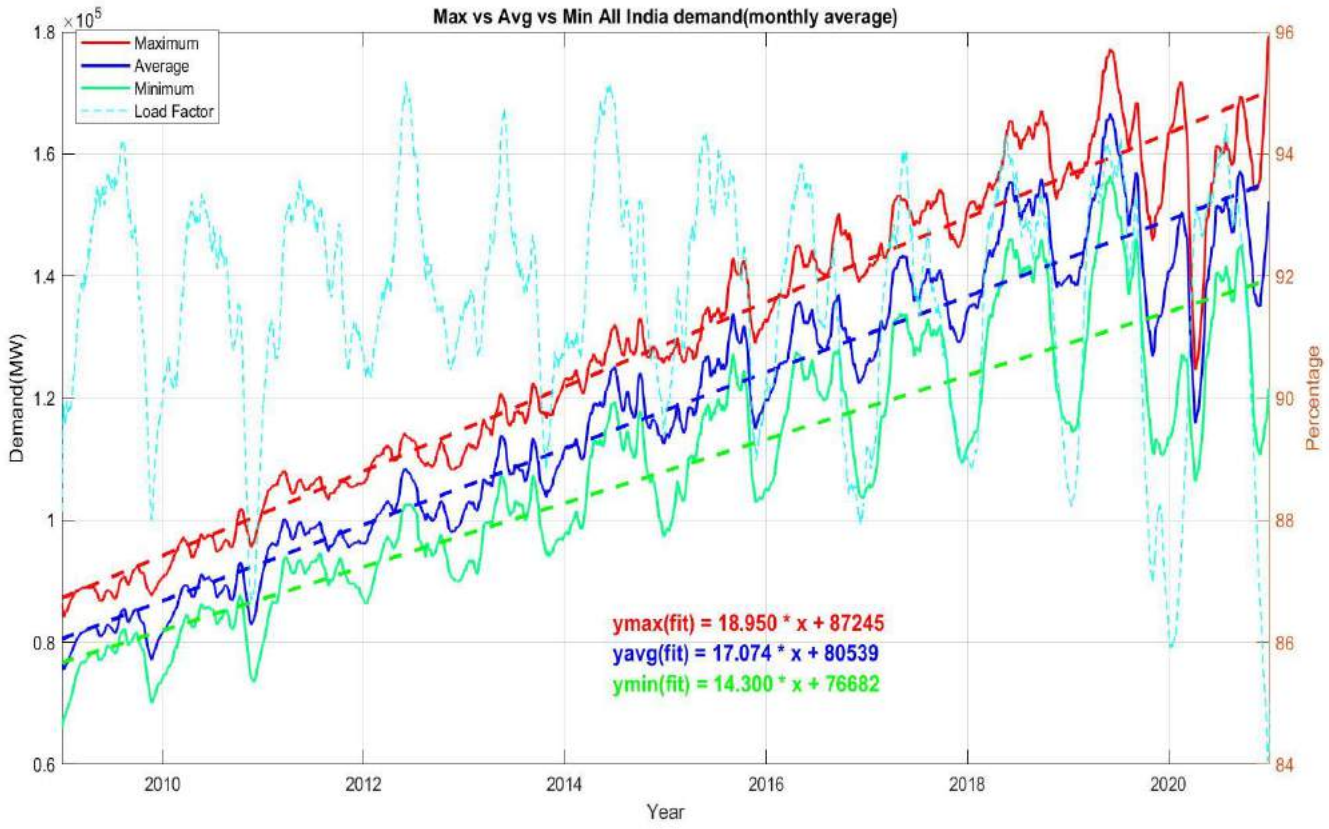


Figure 4:All India demand-Maximum vs Average vs Minimum

Details of regional and all India load factor with trend of daily load factor (from 01.01.2009 to 31.12.2020) increasing and decreasing are given below:

Region	Daily	Monthly	Yearly	Gradient*
NR	90%	84%	73%	↓
WR	92%	86%	79%	↓
SR	91%	86%	81%	↓
ER	85%	79%	73%	↓
NER	73%	67%	59%	↓
All India	92%	88%	83%	↓

Table 8:Daily, monthly and yearly loads factor of all India & regions

Note: :

- *: Sign of slope (m) of linear equation "y=mx + c" has been used to indicate the arrow direction. In case of positive slope, it is shown as "↑" and for negative slope it has been shown as "↓".

A) All India annual load factor has remained constant between 83-86%. This high load factor is due to a combination of benefits derived out of the integration of regional grids and load management done by different states. It is constant over the years because the growth of energy and peak demand has been around the same range. Daily load factor variation between summer and winter is about 5-6%.

B) Northern Region annual load factor has a decreasing trend i.e. 79% in year 2009 to 63% in year 2020 which could be on account of higher peak demand and lower minimum demand. Also, variation in daily load factor of Northern Region between summer and winter is about 5-6% which shows impact of weather sensitive loads and agriculture loads within the region.

C) Western Region annual load factor has a decreasing trend i.e. 80% in year 2009 to 72% in year 2020. Also, variation in daily load factor between seasons through-out the year is about 8-10%.

D) Southern Region annual load factor is between 69-84%. It has decreased over the last three years. Also, variation in daily load factor between seasons through-out the year is about 4-5%.

E) Eastern Region annual load factor has remained constant between 68-77%. Also, variation in daily load factor is about 7-9%.

F) North-Eastern Region annual load factor remained constant between 59-64%. Also, variation in daily load factor is about 8-10%. Daily Load factor is Maximum in July-August.

Further, as per the duration curve of the All India load factor, it has been inferred that around 6-8% of the time, load factor persists more than 94%. However, in the year 2020, around 40% of the time, all India load factor was below 90%. All India load factor duration curve for the year from 2009 to 2020 is given below:

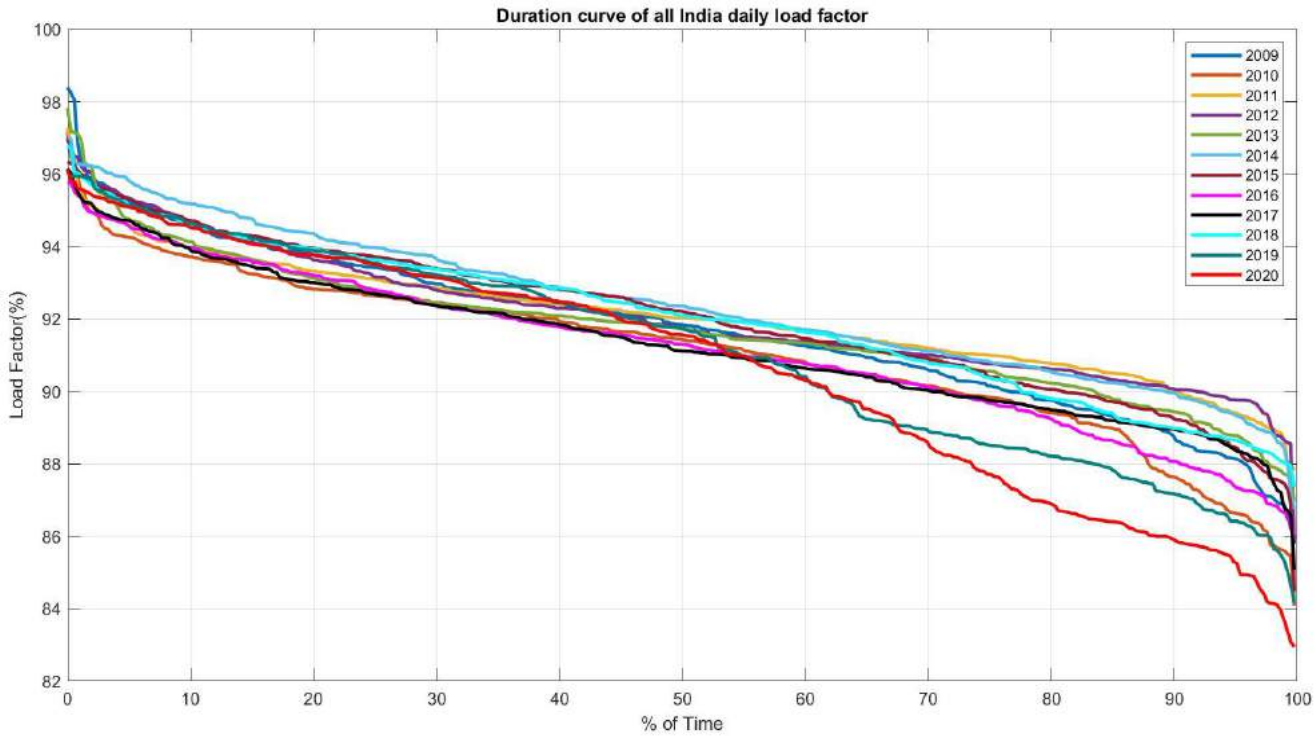


Figure 5:Yearly duration curve for all India daily load factor

Further, 2D heat map of month wise mean load factor for all India has been given below, to show the relative concentration of all India load factor.

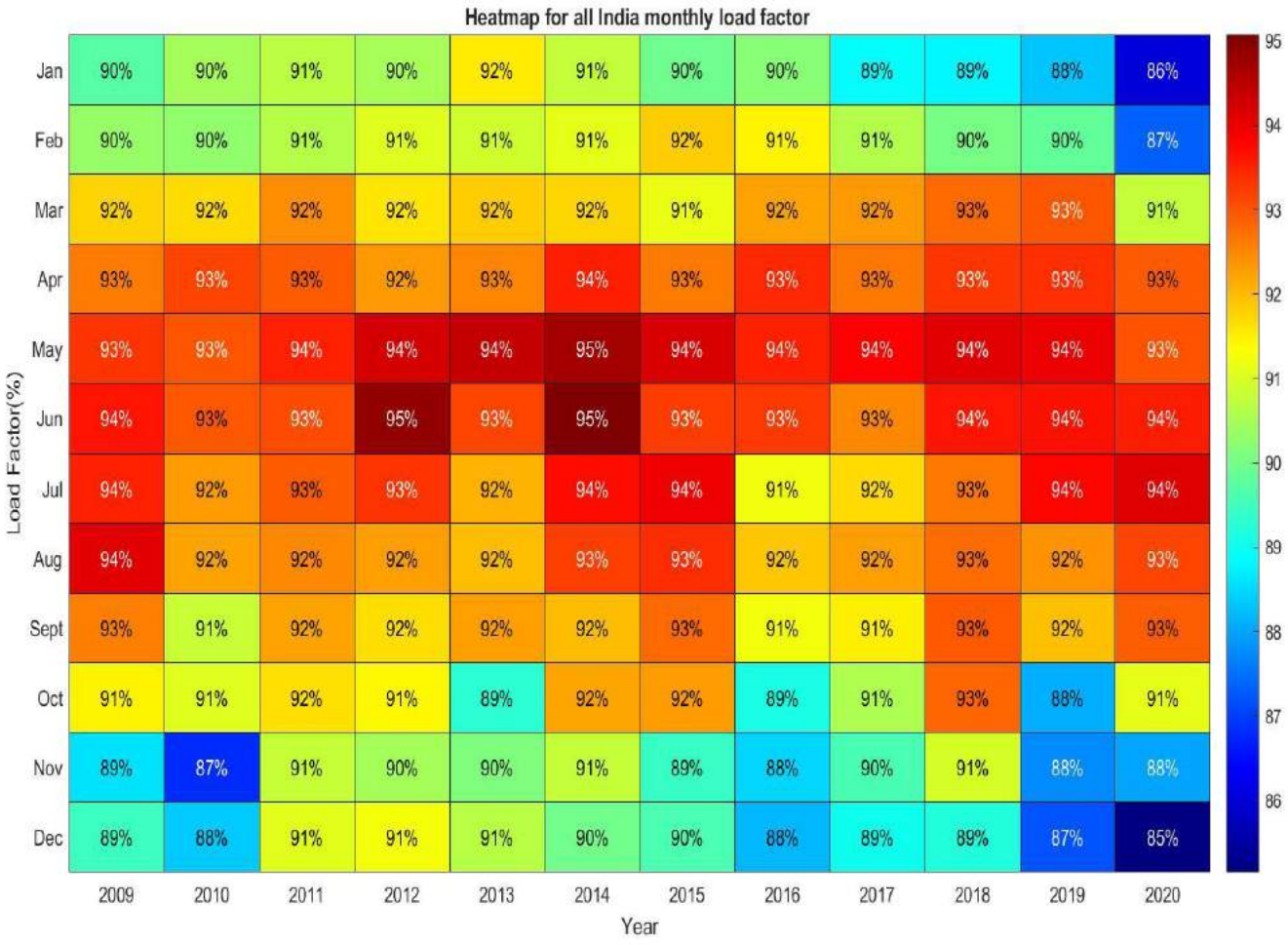


Figure 6:Heat map of monthly load factor (mean of daily load factor)

As per the above figure, it can be seen that during the month of April, May, June, July and August load factor is relatively higher than in the month of January, February, October, November and December.

Monthly and yearly variation of All India load factor can also be seen from the Cycle-Sub series plot below. Here, monthly mean load factor is plotted along with the yearly mean load factor calculated from daily load factor values.

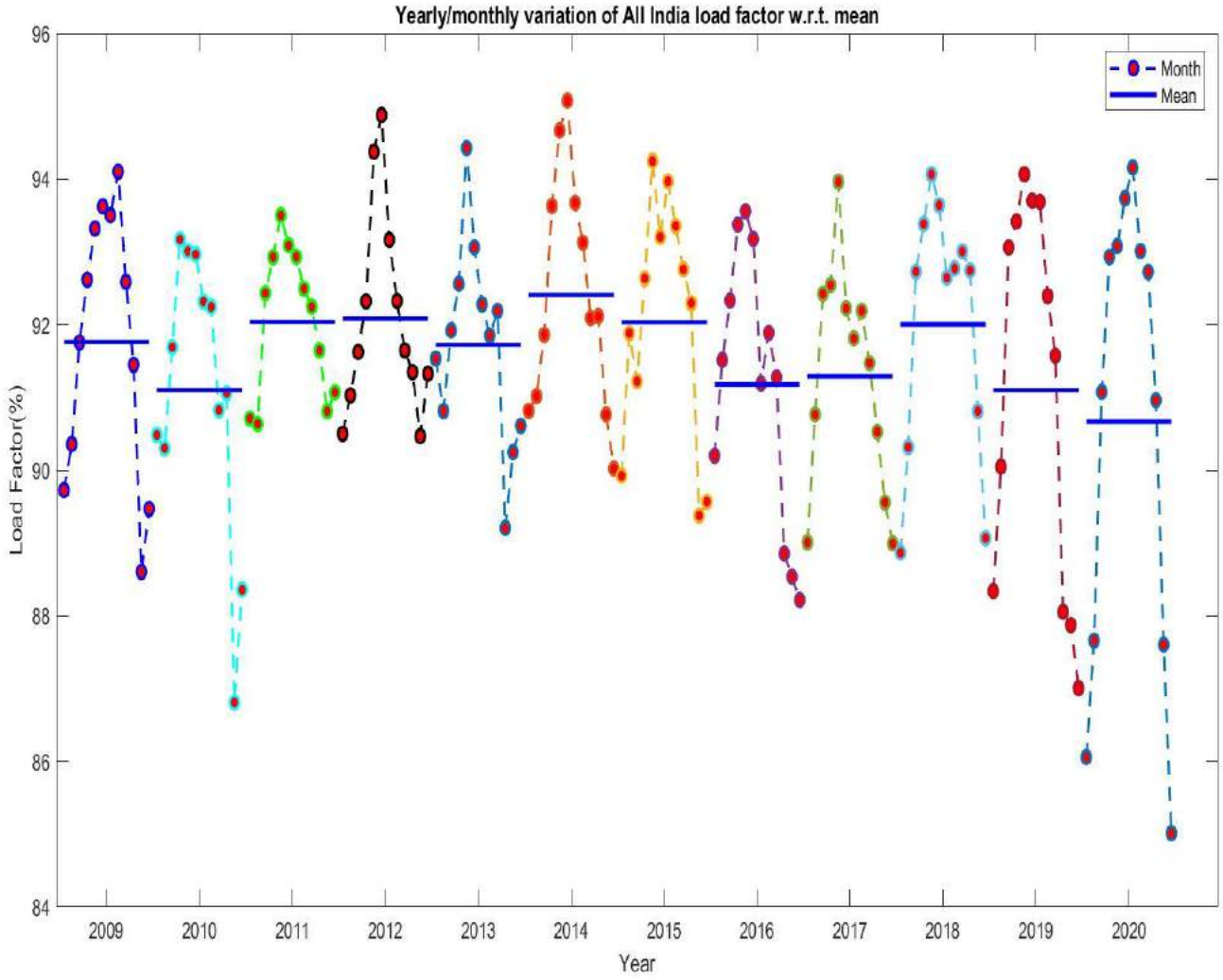


Figure 7:Monthly and yearly mean load factor

It is clearly evident from the above graph that load factor varies significantly from 85-94% during the month as suggested in heat map also but the average of daily variation of load factor between the years is varies between 91-92.5%.

Further an attempt has been made to depict the geographical heat map to show state-wise variation in daily, monthly and annual load factor for the duration 2009-2020. The calculation methodology is tabulated as below:

Type	Calculation/Description	
Daily	Daily load factor i.e. daily average demand/ daily max demand	Average of daily load factor values
Monthly	Monthly load factor i.e. monthly average demand/ monthly max demand	Average of monthly load factor values
Annual	Annual load factor i.e. annual average demand/ annual max demand	Average of annual load factor values

	Load Factor			Gradient of linear fit			
Name of State/ UT	**Daily**	**Monthly**	**Annually**	**Trend of Load Factor**	**Max DMD**	**Min DMD**	**Avg. DMD**
Andhra Pradesh	86%	76%	68%	↓	1.131	0.627	0.832
Arunachal Pradesh	69%	55%	42%	↑	0.012	0.011	0.010
Assam	70%	64%	56%	↓	0.223	0.118	0.161
Bihar	80%	72%	59%	↓	0.990	0.534	0.728
Chandigarh	74%	60%	50%	↓	0.013	0.006	0.008
Chhattisgarh	84%	75%	65%	↑	0.388	0.370	0.384
Delhi	78%	64%	54%	↓	0.291	0.165	0.221
DVC	88%	78%	71%	↑	0.256	0.239	0.246
Goa	80%	68%	62%	↑	0.055	0.040	0.047
Gujarat	89%	80%	72%	↓	1.753	1.333	1.545
Haryana	79%	69%	56%	↓	0.848	0.476	0.676
Himachal Pradesh	77%	68%	57%	↔	0.168	0.101	0.134
J&K and Ladakh	81%	74%	66%	↑	0.266	0.179	0.231
Jharkhand	80%	69%	59%	↓	0.115	0.077	0.093
Karnataka	84%	76%	66%	↓	0.957	0.662	0.796
Kerala	75%	70%	64%	↑	0.250	0.240	0.262
Madhya Pradesh	82%	71%	56%	↑	1.444	1.143	1.322
Maharashtra	88%	79%	70%	↓	2.409	1.751	2.093
Manipur	59%	53%	47%	↓	0.028	0.014	0.015
Meghalaya	71%	59%	48%	↓	0.032	0.021	0.022
Mizoram	64%	55%	43%	↑	0.012	0.004	0.008
Nagaland	68%	58%	48%	↑	0.017	0.011	0.014
Odisha	80%	71%	63%	↑	0.347	0.277	0.305
Puducherry	83%	75%	66%	↓	0.029	0.020	0.025
Punjab	83%	67%	52%	↓	0.618	0.361	0.506
Rajasthan	85%	76%	66%	↓	1.552	0.880	1.216
Sikkim	56%	46%	33%	↑	0.008	0.005	0.008
Tamil Nadu	88%	81%	73%	↓	1.406	1.046	1.239
Telangana	86%	73%	61%	↓	1.685	0.862	1.282
Tripura	64%	54%	45%	↔	0.036	0.018	0.025
Uttarakhand	81%	74%	66%	↑	0.237	0.174	0.209
Uttar Pradesh	85%	76%	64%	↓	2.649	1.454	1.982
West Bengal	78%	71%	65%	↑	0.584	0.408	0.520

Table 9:State wise load factor

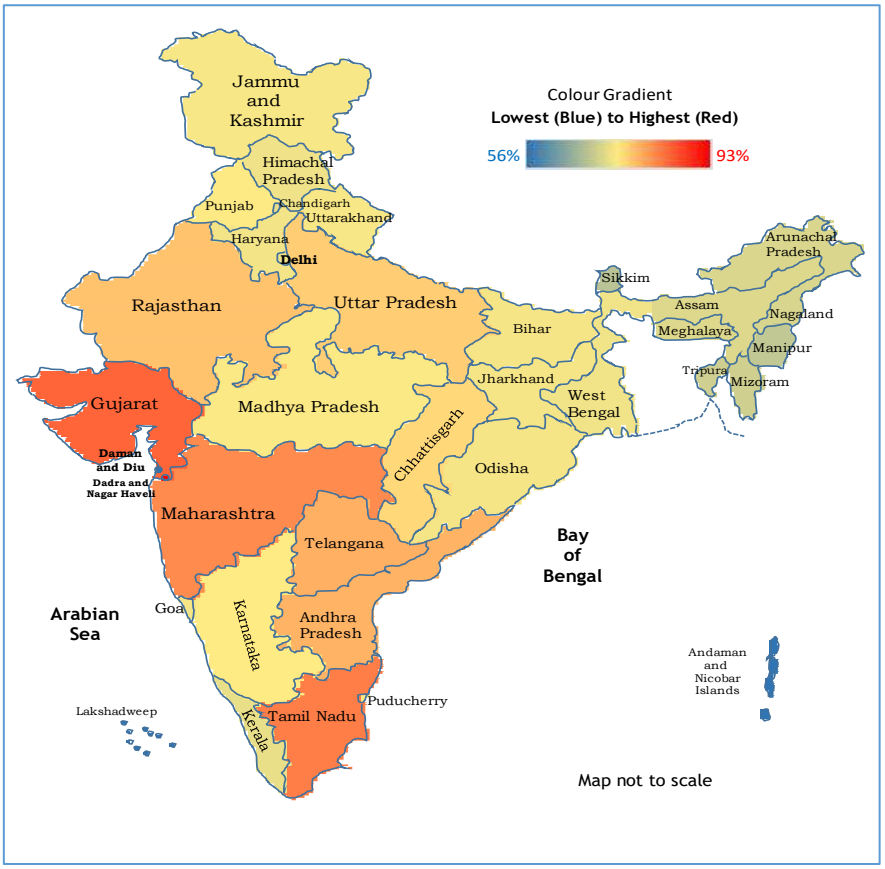


Figure 8: Daily load factor

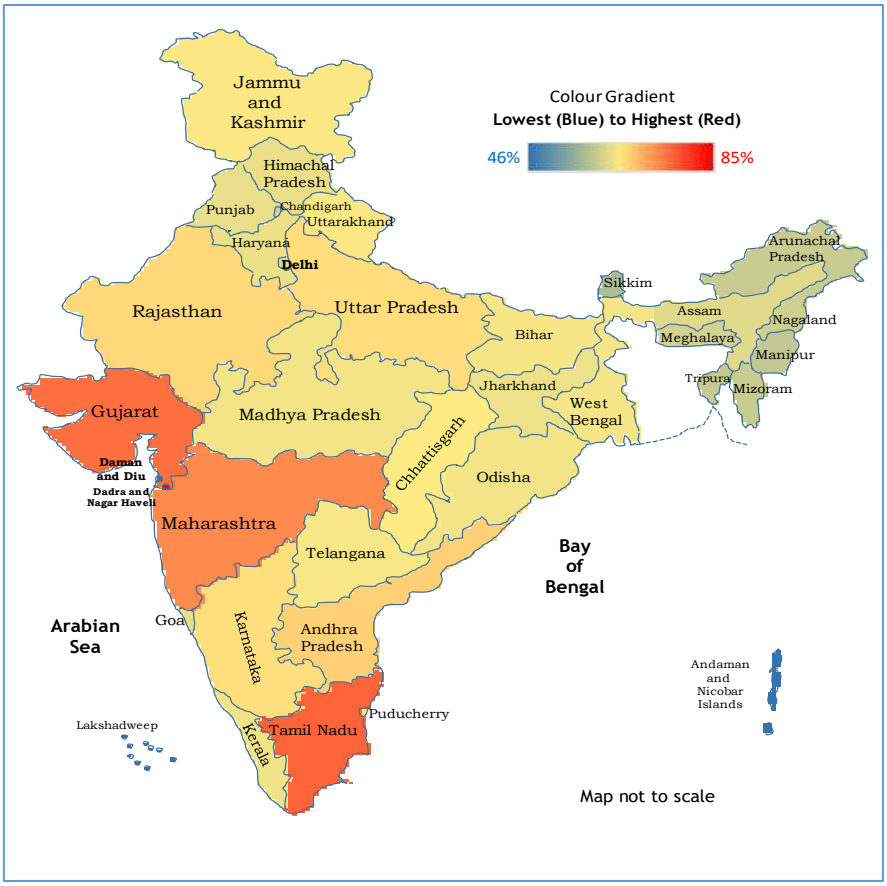


Figure 9:Monthly load factor

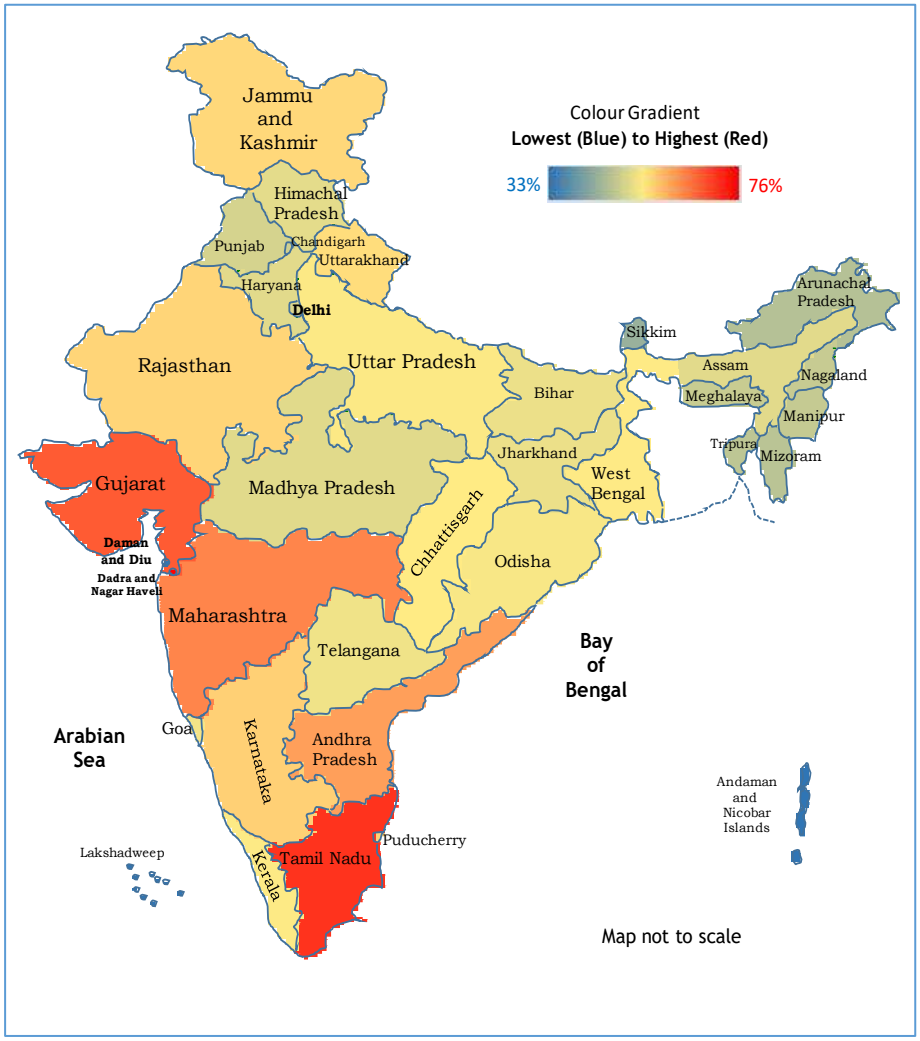


Figure 10:Annual load factor

From above heat maps, it is clearly seen that states like Uttar Pradesh, Telangana and Chhattisgarh have significantly high daily load factor but lower monthly and further diminished annual load factor. For the state like Punjab, annual load factor is much less than daily load factor due to high peak demand during paddy season i.e only for three months in a year.

Similarly, state-wise variation of the gradient of daily load factor has also been shown in the geographical heat map as shown below.

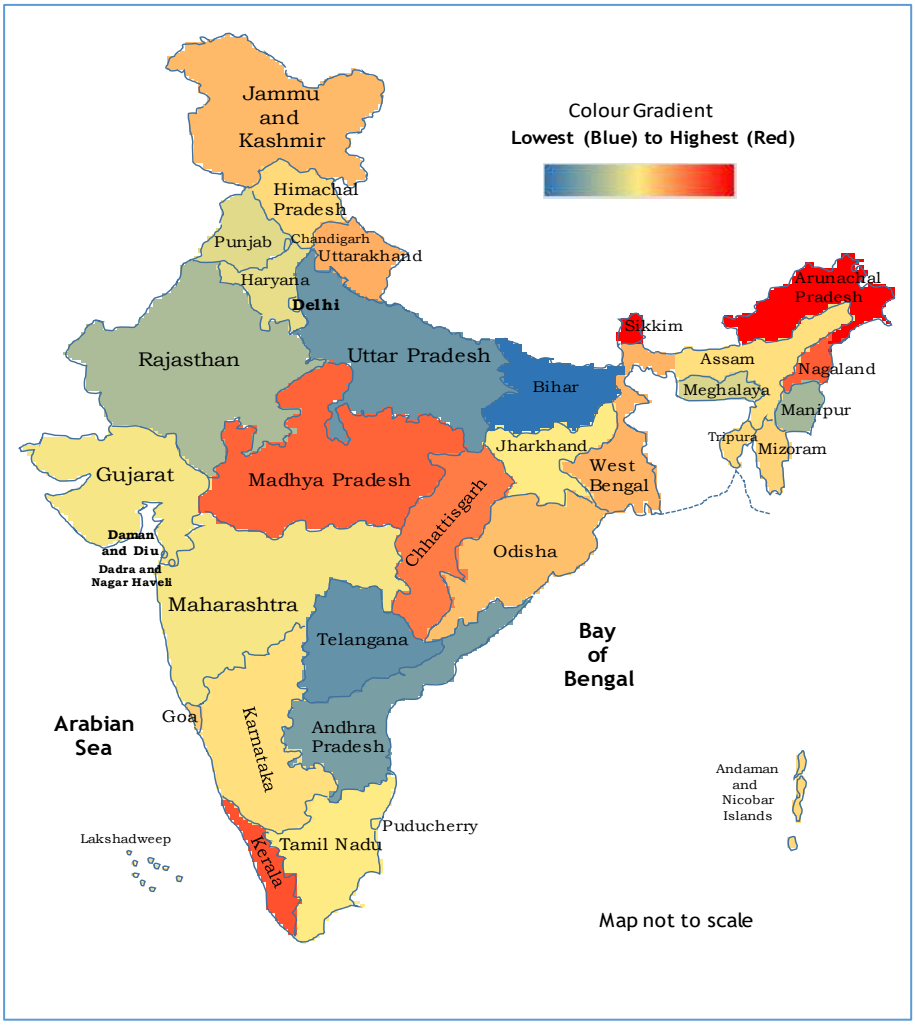


Figure 11:Gradient of load factor

States like Arunachal Pradesh, Chhattisgarh, Kerala, Madhya Pradesh and Sikkim are having increasing load factor trend for the mentioned period.

Region-wise and state-wise analysis is given at Annexure.

Further, present daily ratio of all India minimum demand to maximum demand is in the range of 65-90% which varies based on the seasonal variation of the demand. The above said ratio was on lower side in winters and other side during summers.

To observe in what proportion the minimum demand is increasing with the all India maximum demand, rate of change of minimum and maximum demand has been calculated and their ratio comes out to be 75%. Similarly, statewise slope has been calculated and given in the table on next page.

Name of the state	Slope of Maximum demand	Slope of Average demand	Slope of Minimum demand	Ratio(%)
	A	B	C	C/A
Andhra Pradesh	1.13	0.83	0.63	55
Arunachal Pradesh	0.01	0.01	0.01	92
Assam	0.22	0.16	0.12	53
Bihar	0.99	0.73	0.53	54
Chandigarh	0.01	0.01	0.01	46
Chhattisgarh	0.39	0.38	0.37	95
Delhi	0.29	0.22	0.17	57
DVC	0.26	0.25	0.24	93
Goa	0.06	0.05	0.04	73
Gujarat	1.75	1.55	1.33	76
Haryana	0.85	0.68	0.48	56
Himachal Pradesh	0.17	0.13	0.1	60
J&K,Ladakh	0.27	0.23	0.18	67
Jharkhand	0.12	0.09	0.08	67
Karnataka	0.96	0.8	0.66	69
Kerala	0.25	0.26	0.24	96
Madhya Pradesh	1.44	1.32	1.14	79
Maharashtra	2.41	2.09	1.75	73
Manipur	0.03	0.02	0.01	50
Meghalaya	0.03	0.02	0.02	66
Mizoram	0.01	0.01	0	33
Nagaland	0.02	0.01	0.01	65
Odisha	0.35	0.31	0.28	80
Puducherry	0.03	0.03	0.02	69
Punjab	0.62	0.51	0.37	59
Rajasthan	1.55	1.22	0.88	57
Sikkim	0.01	0.01	0.01	63
Tamil Nadu	1.41	1.24	1.05	74
Telangana	1.66	1.28	0.86	52
Tripura	0.04	0.03	0.02	50
Uttar Pradesh	2.65	1.98	1.45	55
Uttarakhand	0.24	0.21	0.17	73
West Bengal	0.58	0.52	0.41	70

Table 10: Coefficient of the trend line for Minimum and Maximum loads

7. International experience on Load Factor

A literature survey has been carried out to have a glimpse of international load factors of different countries. Electricity consumption data for the countries in Europe, which comes under ENTSO-E is available in public domain on their website. Load factor for those countries has been calculated from the above mentioned data and given in following table (some of the countries has been omitted wherever historical data was not available). Based on the given table, it is observed load factor of the mentioned countries are generally varying between 50-70% barring some of the countries.

Country Name/Year	2015	2016	2017	2018
Austria	70%	68%	69%	68%
Bosnia and Herzegovina	65%	65%	64%	69%
Belgium	74%	73%	73%	72%
Bulgaria	53%	54%	51%	60%
Switzerland	71%	71%	73%	73%
Czech Republic	73%	70%	69%	68%
Germany	74%	76%	78%	78%
Denmark	63%	65%	66%	64%
Estonia	66%	62%	66%	65%
Spain	74%	75%	75%	76%
Finland	69%	64%	68%	70%
France	59%	62%	58%	57%
United Kingdom	65%	55%	58%	56%
Greece	60%	63%	61%	65%
Croatia	66%	69%	66%	66%
Hungary	76%	72%	74%	74%
Ireland	66%	66%	66%	67%
Iceland	90%	89%	90%	90%
Italy	60%	65%	65%	64%
Lithuania	67%	72%	80%	71%
Latvia	67%	64%	67%	67%
Netherlands	72%	71%	71%	72%
Norway	65%	62%	66%	64%
Poland	75%	74%	75%	76%
Portugal	65%	69%	65%	67%
Romania	74%	72%	73%	74%
Serbia	65%	63%	61%	65%
Sweden	66%	60%	61%	59%
Slovenia	74%	73%	71%	69%
Slovakia	75%	72%	72%	72%

Table 11: Annual load factor of European countries

Based on the above data, a heatmap for average load factor of individual countries mentioned in above table is also shown in figure given below:

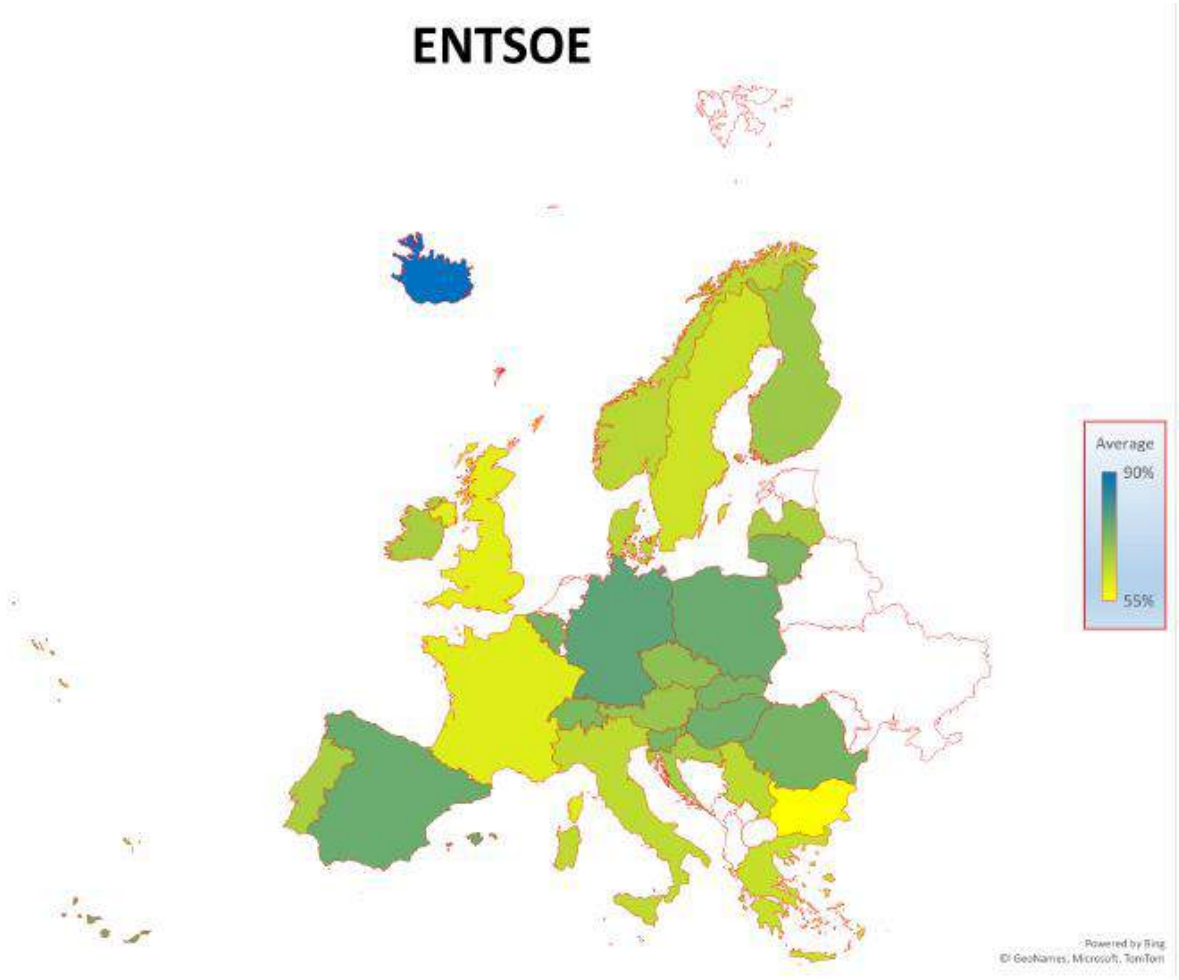


Figure 12:Heatmap of average load factor of major countries of ENTSO-E from 2015-2018

Source: Energy and peak demand data for countries under ENTSOE has been taken from "**ENTSO-E Statistical Factsheet". Link for the same is given below:**

https://www.entsoe.eu/publications/statistics-and-data/#statistical-factsheet

Similarly, an exercise has been done to observe load factor pattern in other major grids of the world. Literature survey for TEPCO, Japan, Ceylon Electricity Board (CEB), Sri Lanka and California ISO, USA has been carried out and based on the data available on their website, load factor of respective utilities has been calculated and given on next page:

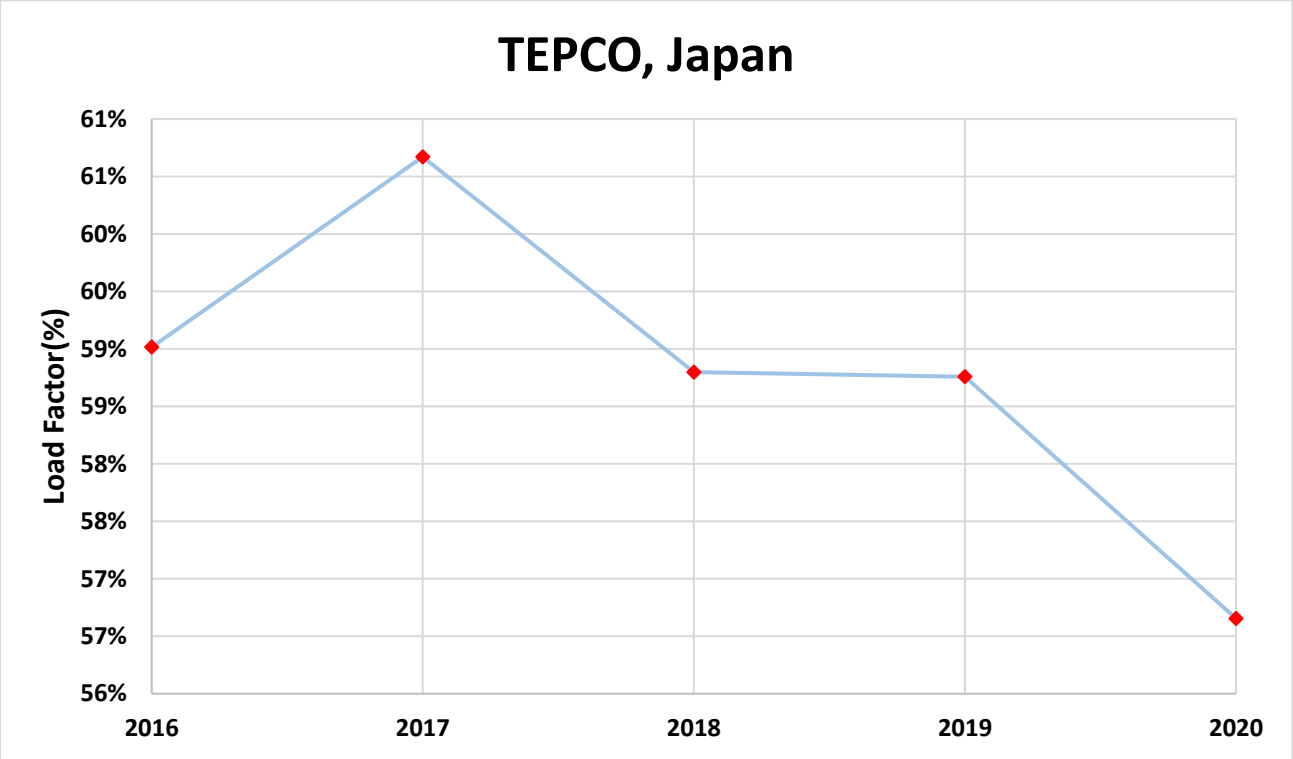


Figure *13*:Load Factor Variation in TEPCO,Japan

Source: https://www.tepco.co.jp/en/forecast/html/download-e.html

*Data for 2016 was available from April onwards.

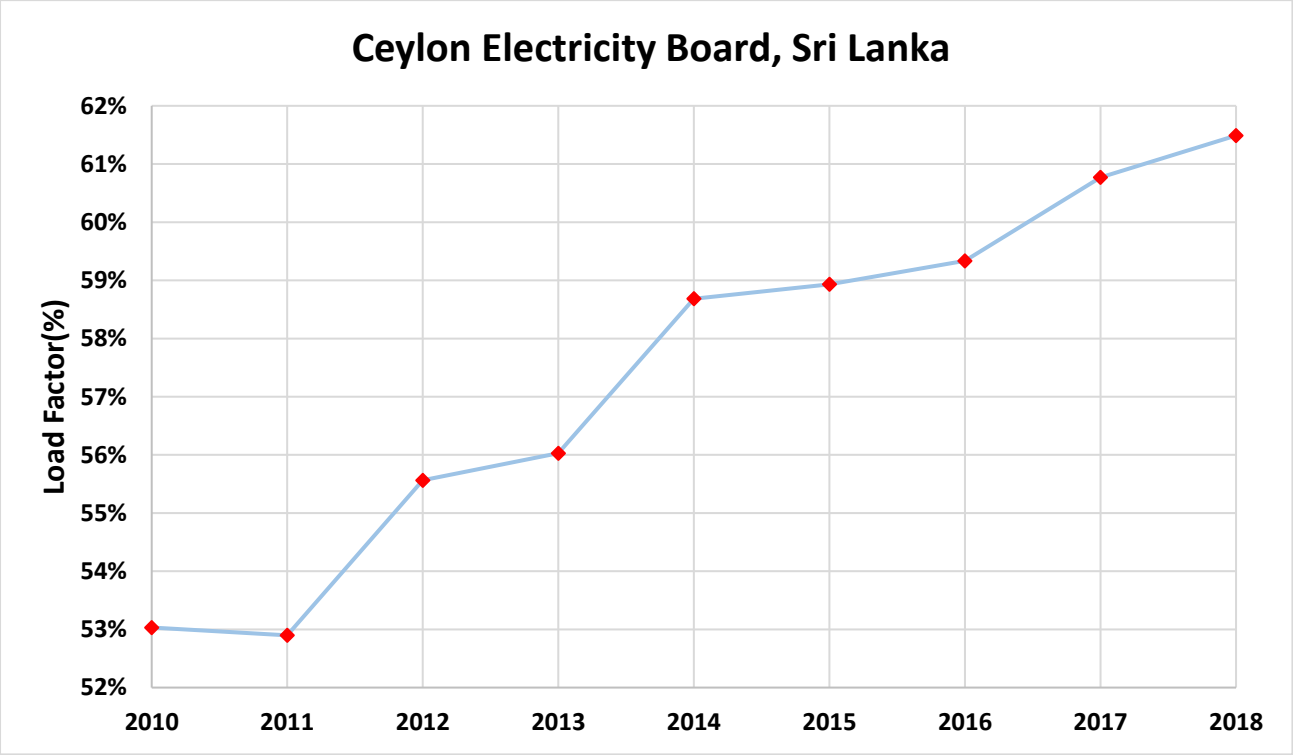


Figure *14*:Load Factor Variation in CEB,Sri Lanka

Source: https://ceb.lk/front_img/img_reports/1605765148CEB_Annual_Report_2018.pdf

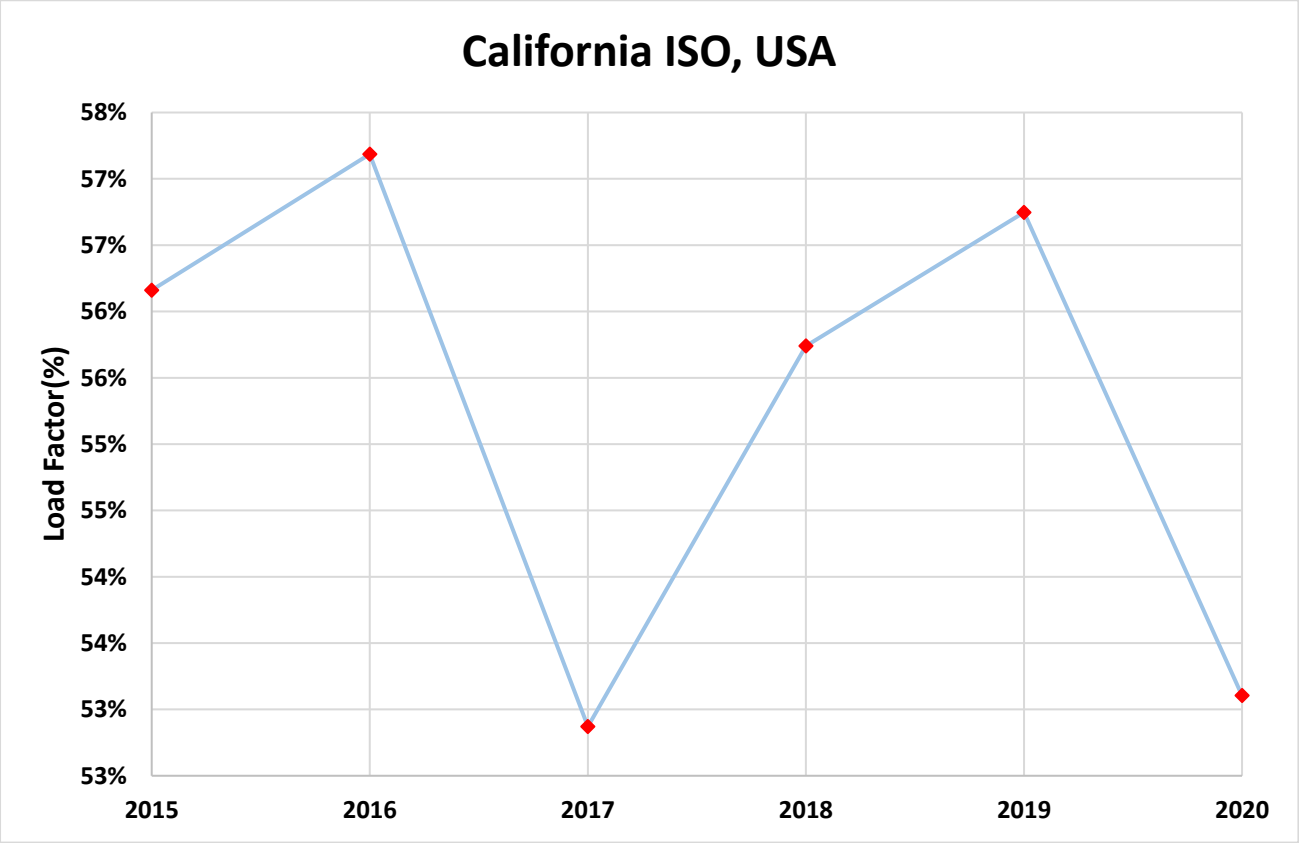


Figure *15*:Load Factor variation in California ISO, USA

Source: http://www.caiso.com/planning/Pages/ReliabilityRequirements/Default.aspx#Historical

8. Findings and Way Forward

Major findings of this report are given below:

- All India demand load factor is decreasing as peak demand growth is surpassing the energy consumption growth over the years.
- High RE penetration and variability, may affect demand load factor profile significantly.
- All India load diversity has been in increasing trend over the years. several factors like increasing RE penetration, agriculture load shifting, rural electrification etc. are having major role in the same.
- Integration of different grids and strengthening of inter-regional transmission network would help in harnessing diversity among the different regions.
- It is expected that formation of SAARC grid in future would also help in harnessing the diversity among the countries and reducing overall cost of supply in the region. More such analysis is required to be done to understand the finer aspects of load factor and its impact on power system.
- Further analysis showing the impact of load factor on cost of supply is required. It is desirable that each state utility should work out load factor of their control area and same needs to be incorporated in to their planning. It is also desirable that provisions for the same may also be included in the regulations along with the future trajectory.
- Increase in penetration of Distributed Energy Resources (DER) and its impact assessment may require a separate analysis for further understanding.

9. Contributing and reviewing members

Contributed by:

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Reviewed by:

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2	Sh. K.V.S. Baba	POSOCO
3	Sh. S. R. Narasimhan	POSOCO
4	Sh. Debasis De	NLDC
5	Sh. R.K. Porwal	NLDC
6	Sh. Vivek Pandey	NLDC
7	Sh. Ashok Kumar	NLDC
8	Sh. Harish Rathour	NLDC

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3. Dmitriy V. Antipov, Oksana M. Syardova, Aliya S. Aytasova, "Building an Additive Model for determining the Seasonal Effect on the Quantity of Products Supplied by the Chemical Industry Enterprises" in 2019 Amity International Conference on Artificial Intelligence (AICAI).
4. G. H. McDaniel and A. F. Gabrielle, ''Load diversity-its role in power system utilization,'' IEEE Trans. Power App. Syst., vol. PAS-84, no. 7, pp. 626–635, Jul. 1965.
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6. USAID webinar on "Load Factor and Unserved Energy", October-2019.
7. Dr. Ron Lembke, "Forecasting with Seasonality" handouts on seasonality, Sept-2015.
8. POSOCO on "Electricity Load Factor in Indian Power System" 2016.
9. Central Electricity Authority report, "18th and 19th Electric Power Survey".
10. Documentation of MATLAB/R.
11. Indzara, Geographic Heat Map India v4.

11. Annexure

11.1. All India

a) Average Load Factor (%):

Average Daily Load Factor from 2009-2020	92
Average Monthly Load Factor from 2009-2020	88
Average Annual Load Factor from 2009-2020	83

b) Highest/Lowest Load Factor Occurrence:

Month/Period of Highest Load Factor	May-June
Month/Period of Lowest Load Factor	Nov-Dec

c) Seasonal decomposition of load factor trend:

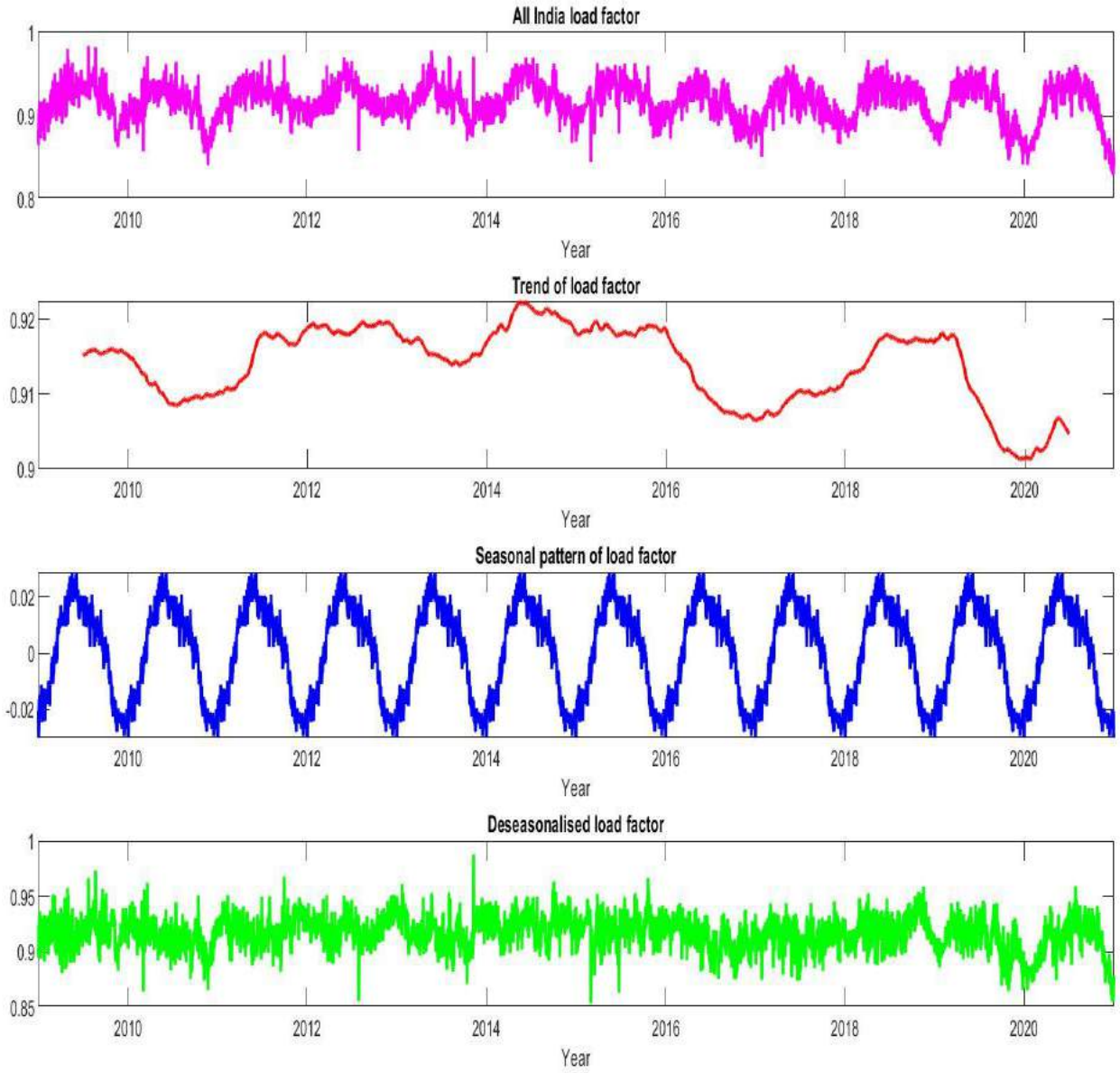


Figure 16:Seasonal decomposition of all India load factor trend

d) Linear fitting of Load factor trend:

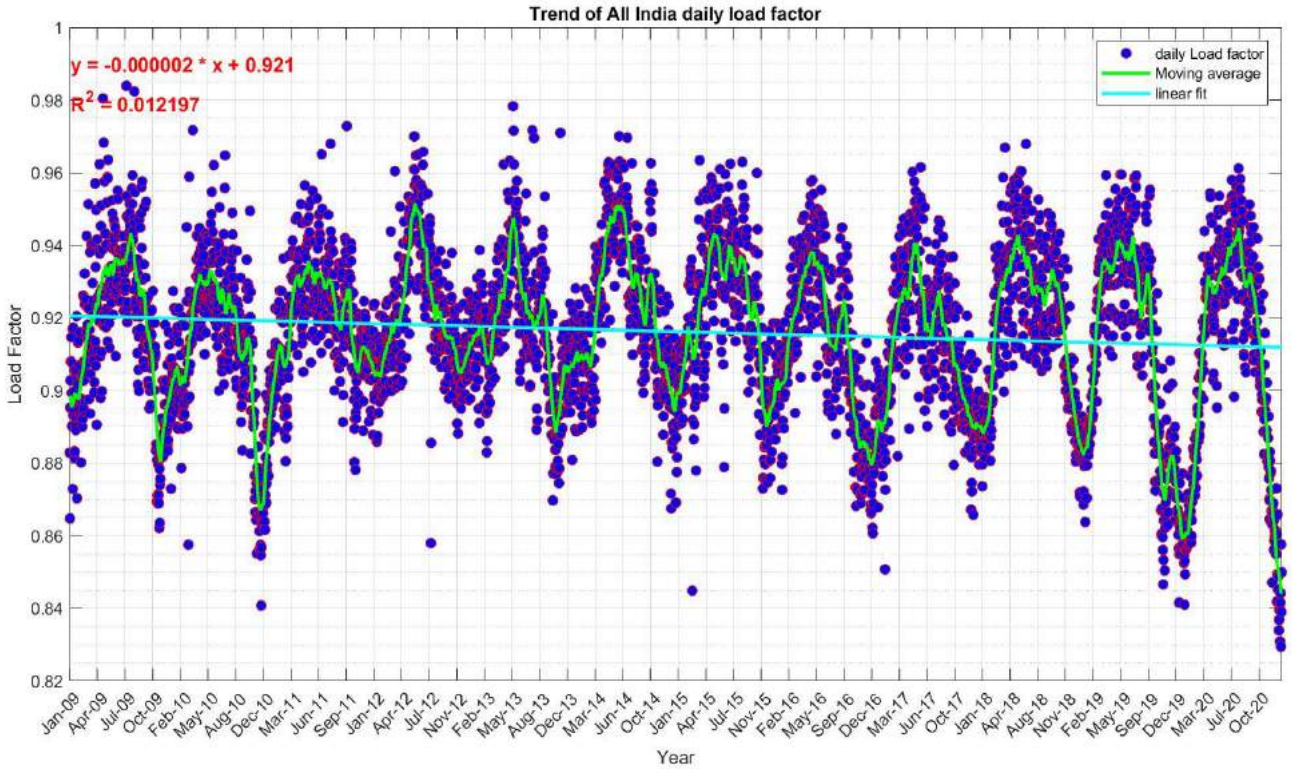


Figure 17:Linear fitting of all India Load factor trend

e) Growth in Maximum, Minimum and Average alongwith Load Factor:

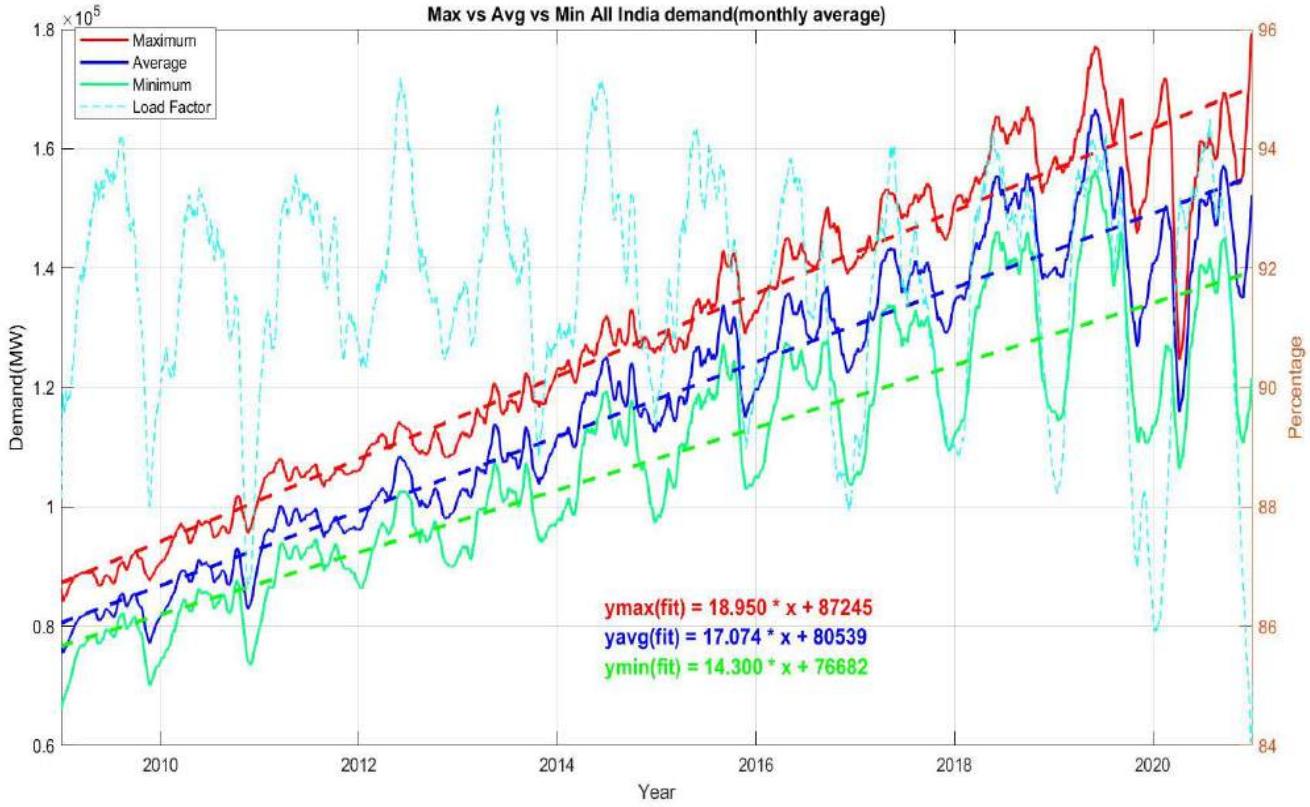


Figure 18:Growth in Maximum, Minimum and Average demand alongwith all India Load Factor

f) Heatmap of monthly average load factor:

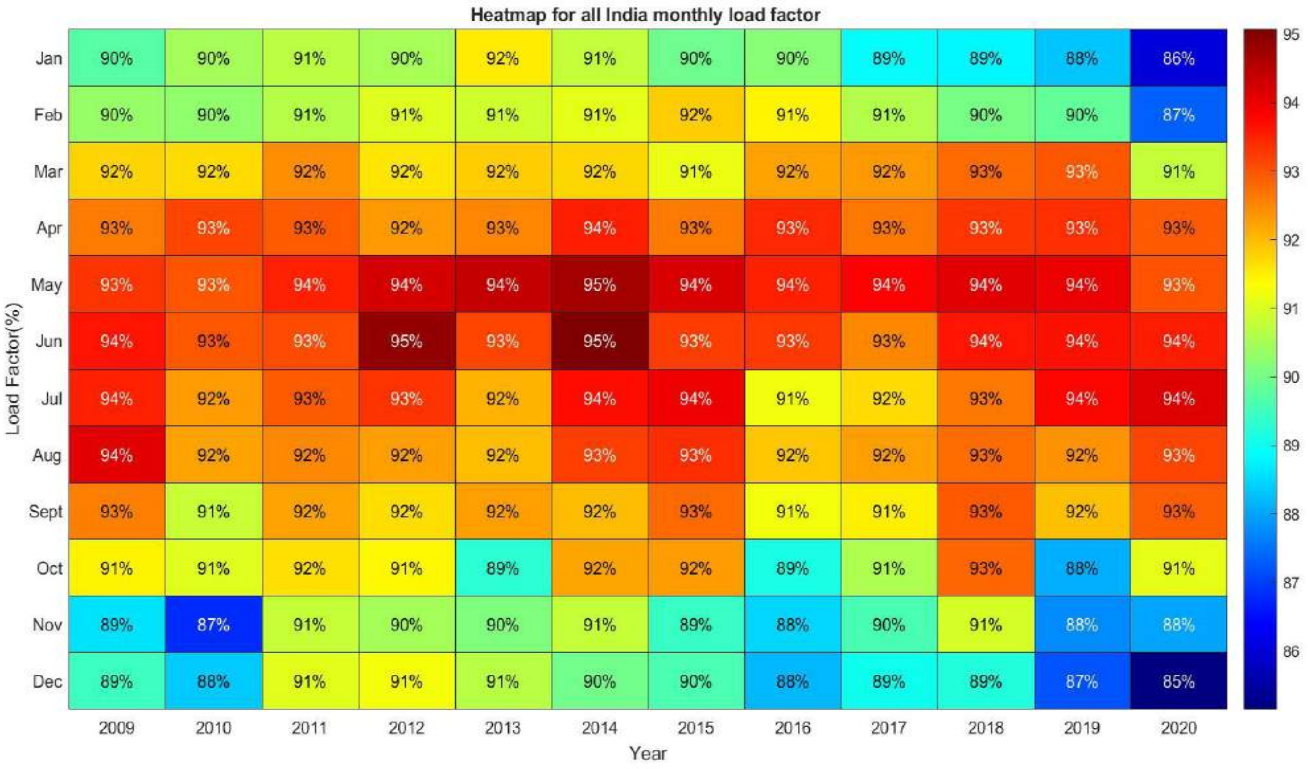


Figure 19:Heatmap of all India monthly average load factor (mean of daily load factor)

g) Duration curve of load factor:

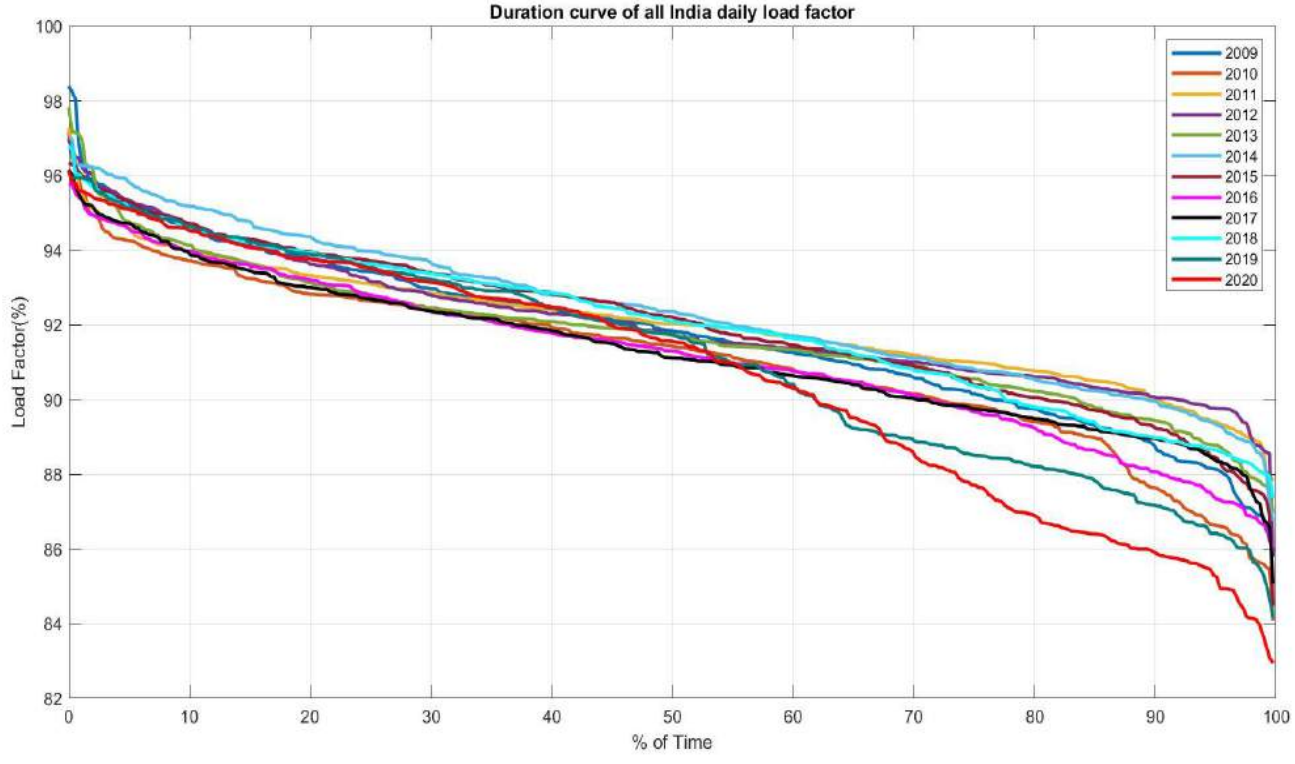


Figure 20:Duration curve of all India load factor

h) Cycle-Sub series plot of Load Factor:

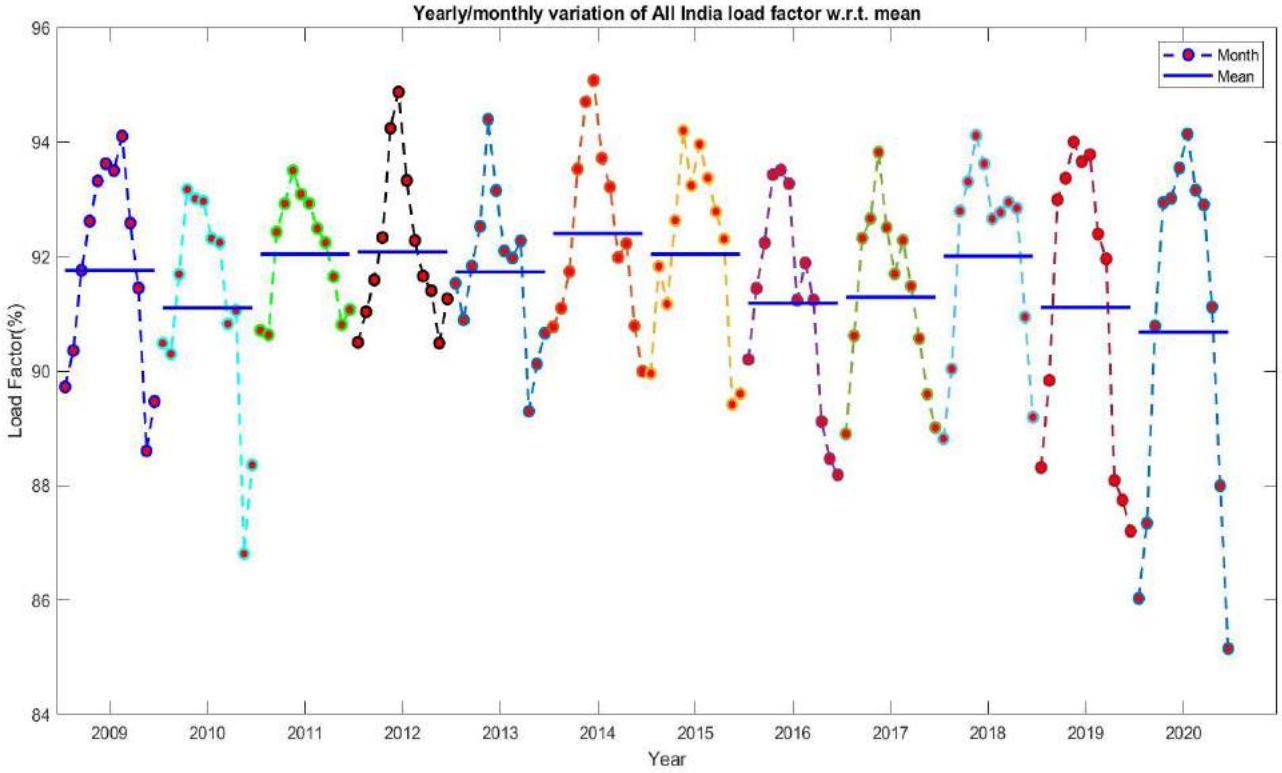


Figure 21: Cycle-Sub series plot for Yearly/Monthly variation of all India Load Factor

i) Concentration of Load factor:

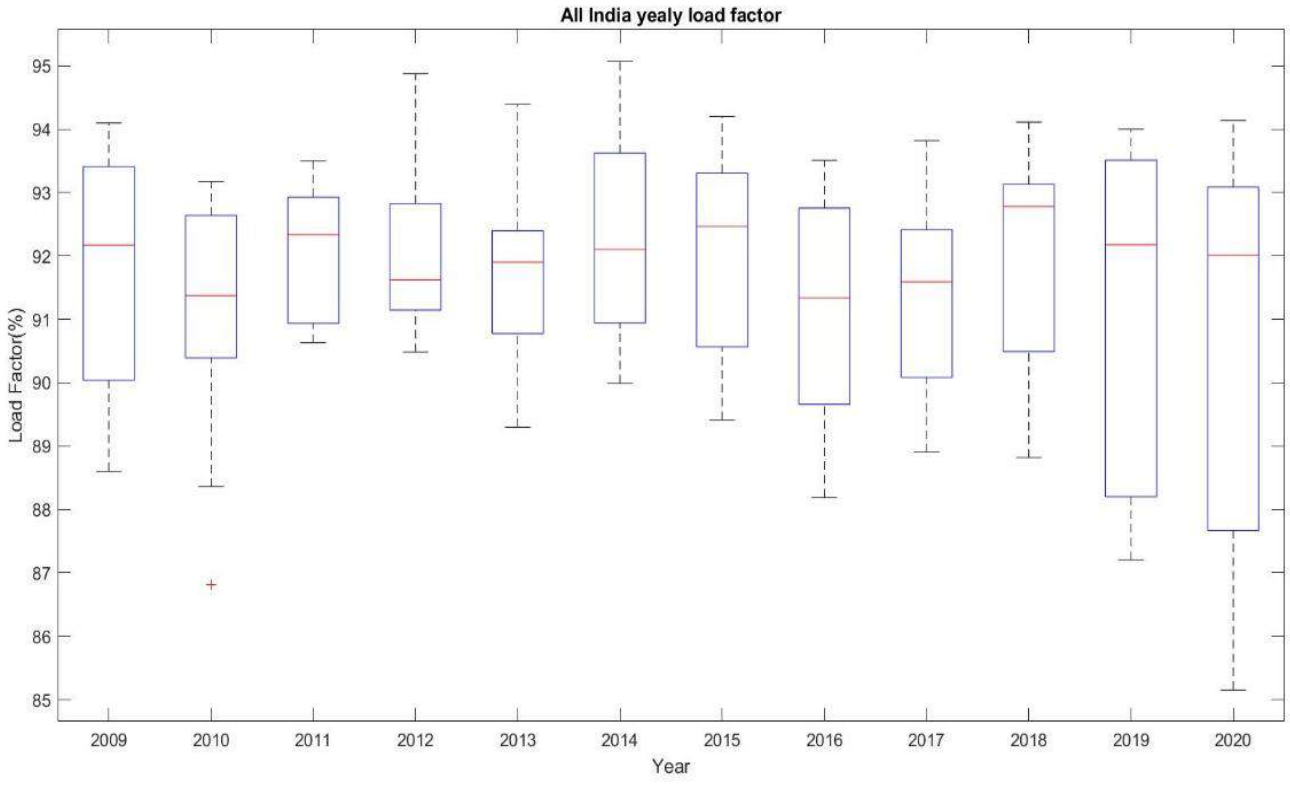
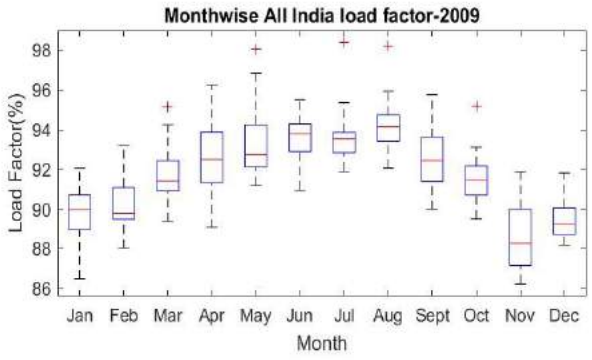
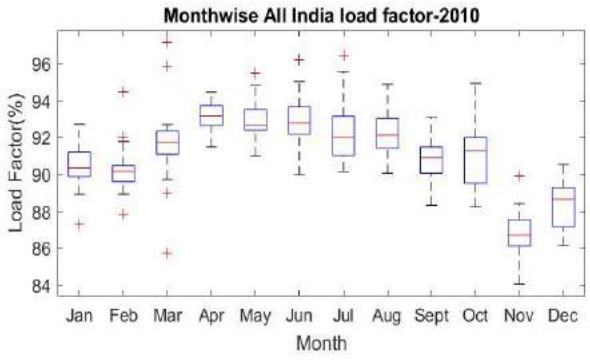
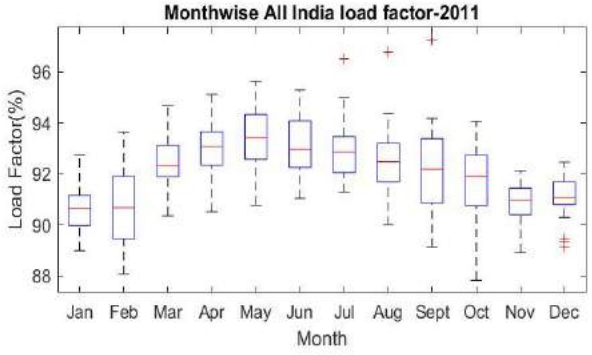


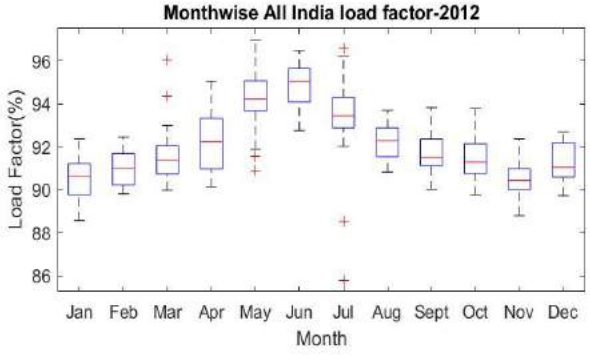
Figure 22:Concentration of all India Load factor

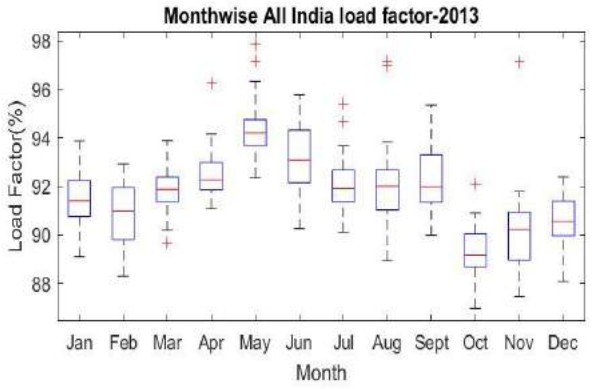
j) Monthly Variation of Load Factor over the years:

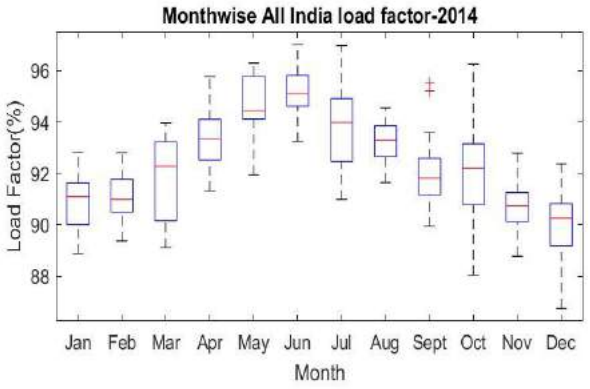


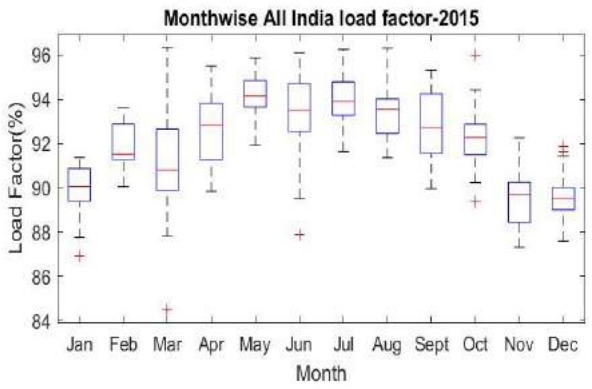


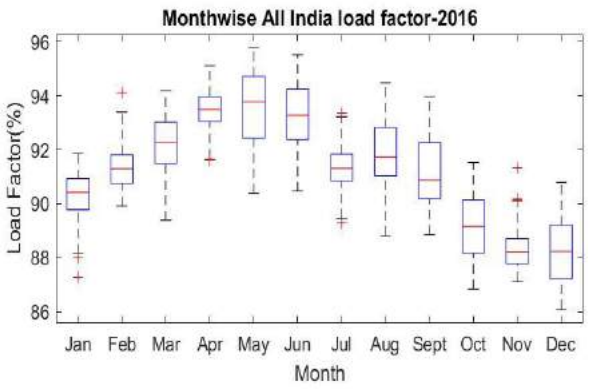












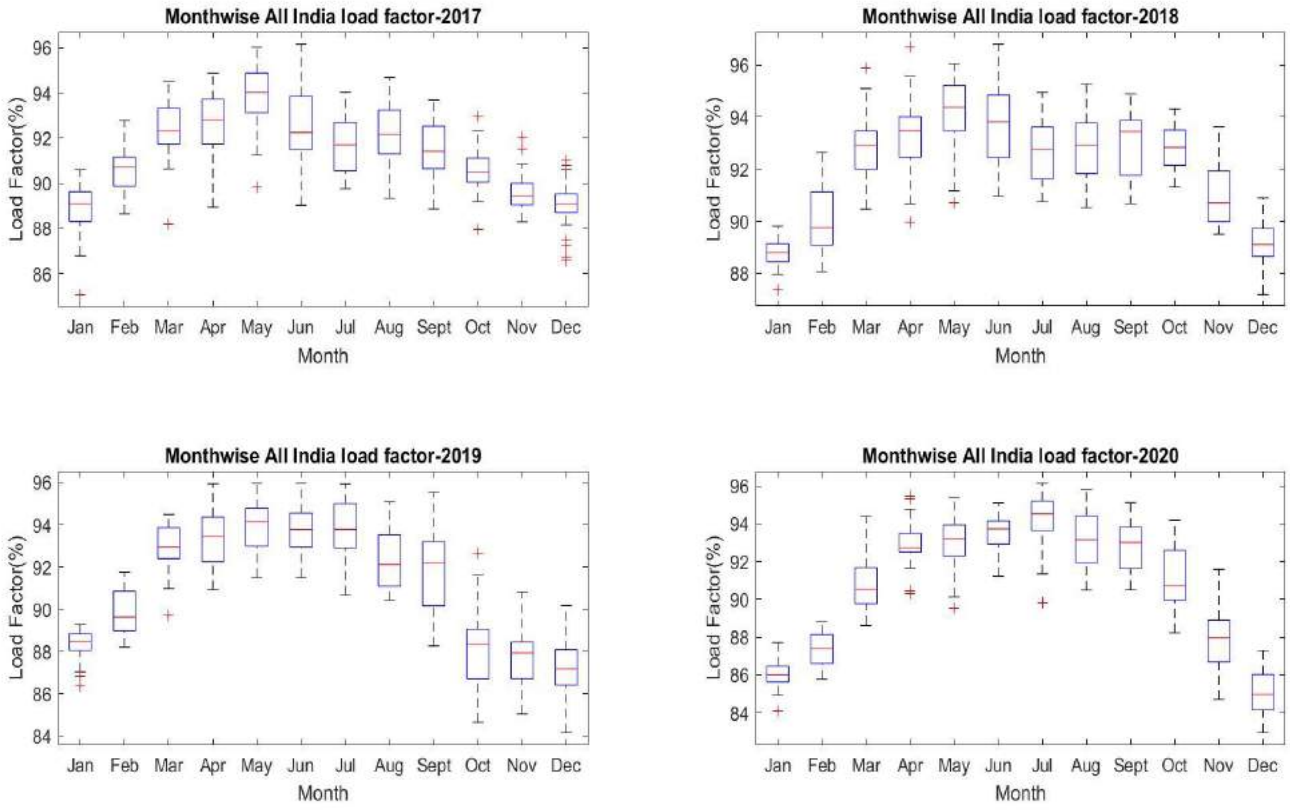


Figure 23:Monthly Variation of Load Factor over the years for all India

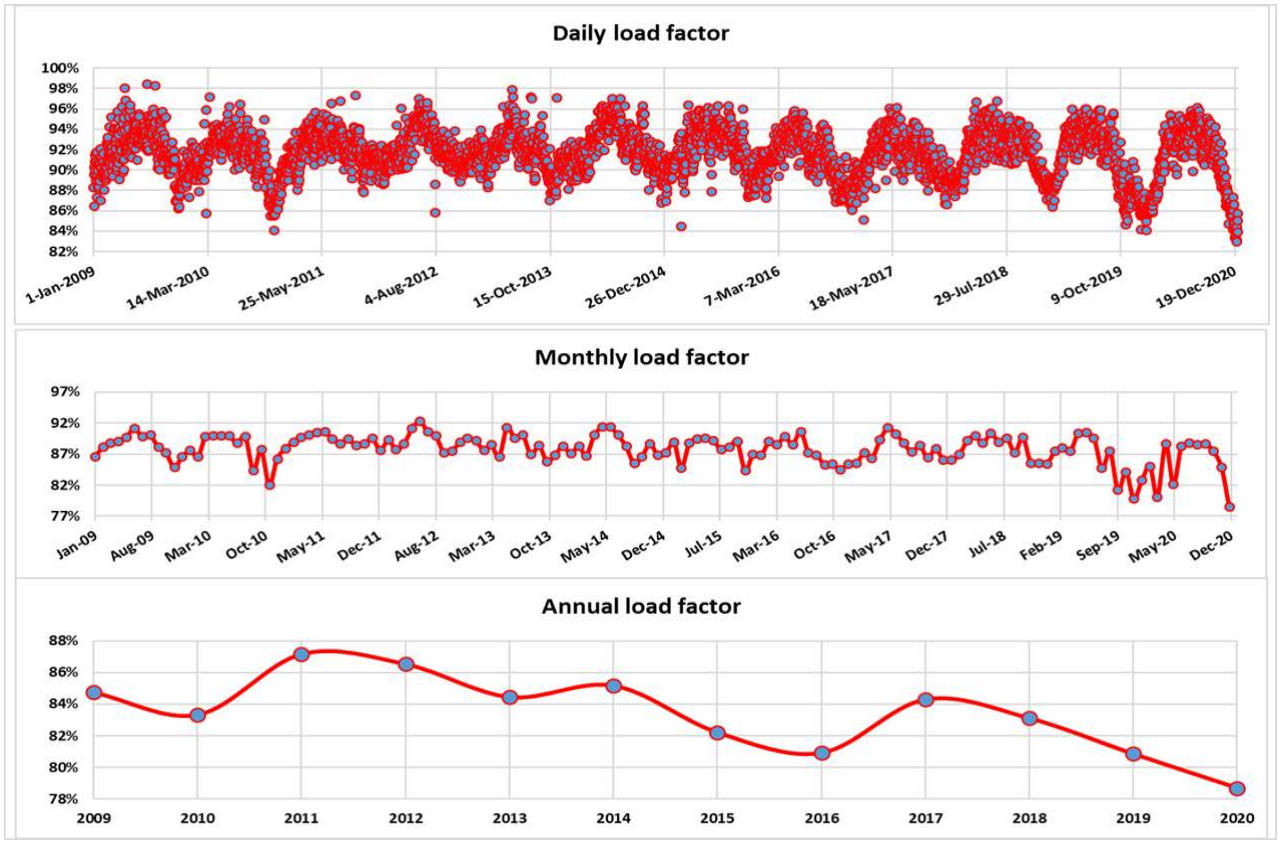


Figure 24:Variation of all India load factor

11.2. Northern Region

a) Average Load Factor (%):

Average Daily Load Factor from 2009-2020	90
Average Monthly Load Factor from 2009-2020	84
Average Annual Load Factor from 2009-2020	73

b) Highest/Lowest Load Factor Occurrence:

Month/Period of Highest Load Factor	Jul-Aug
Month/Period of Lowest Load Factor	Dec-Jan

c) Seasonal decomposition of load factor trend:

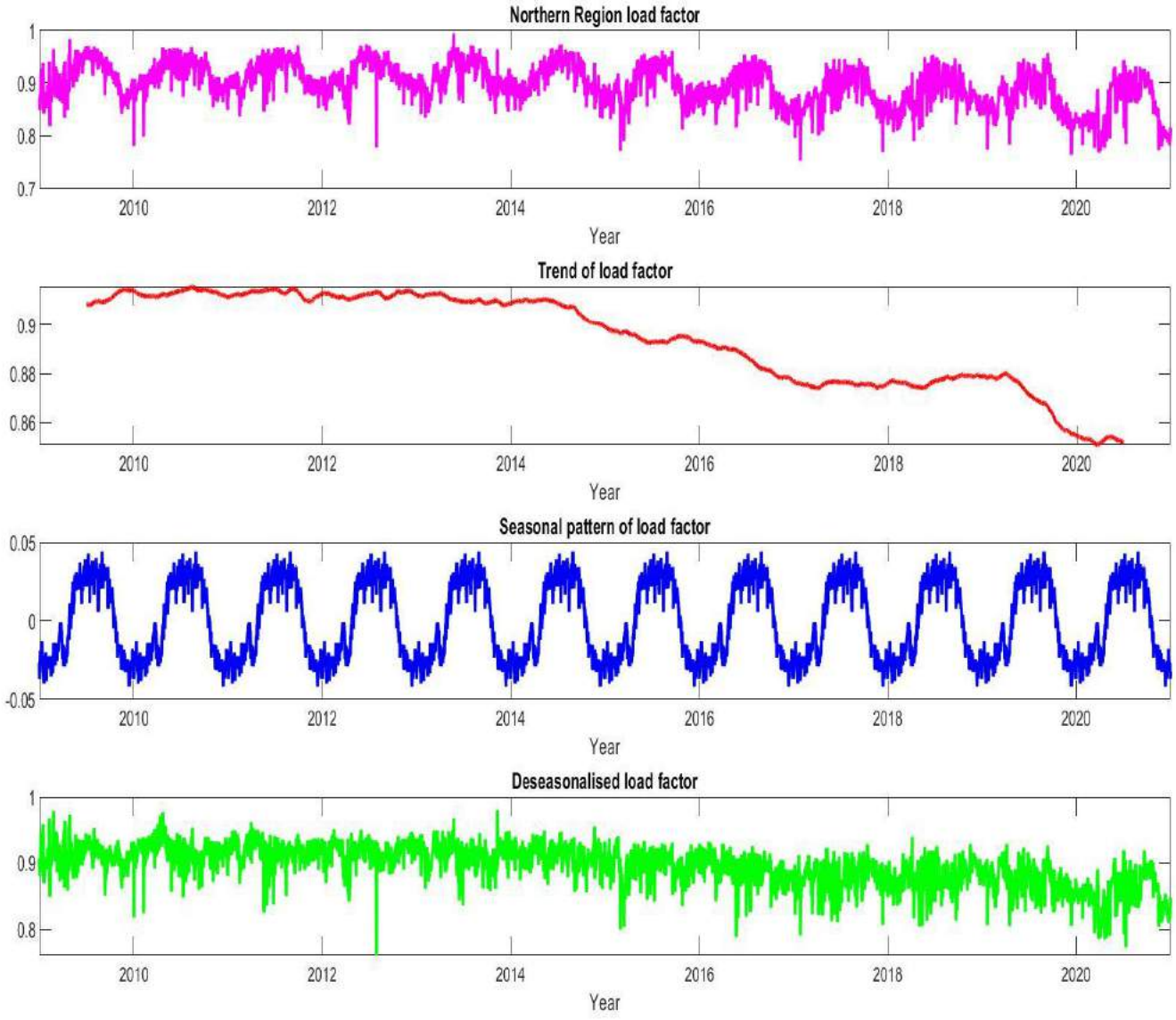


Figure 25:Seasonal decomposition of NR load factor trend

d) Linear fitting of Load factor trend:

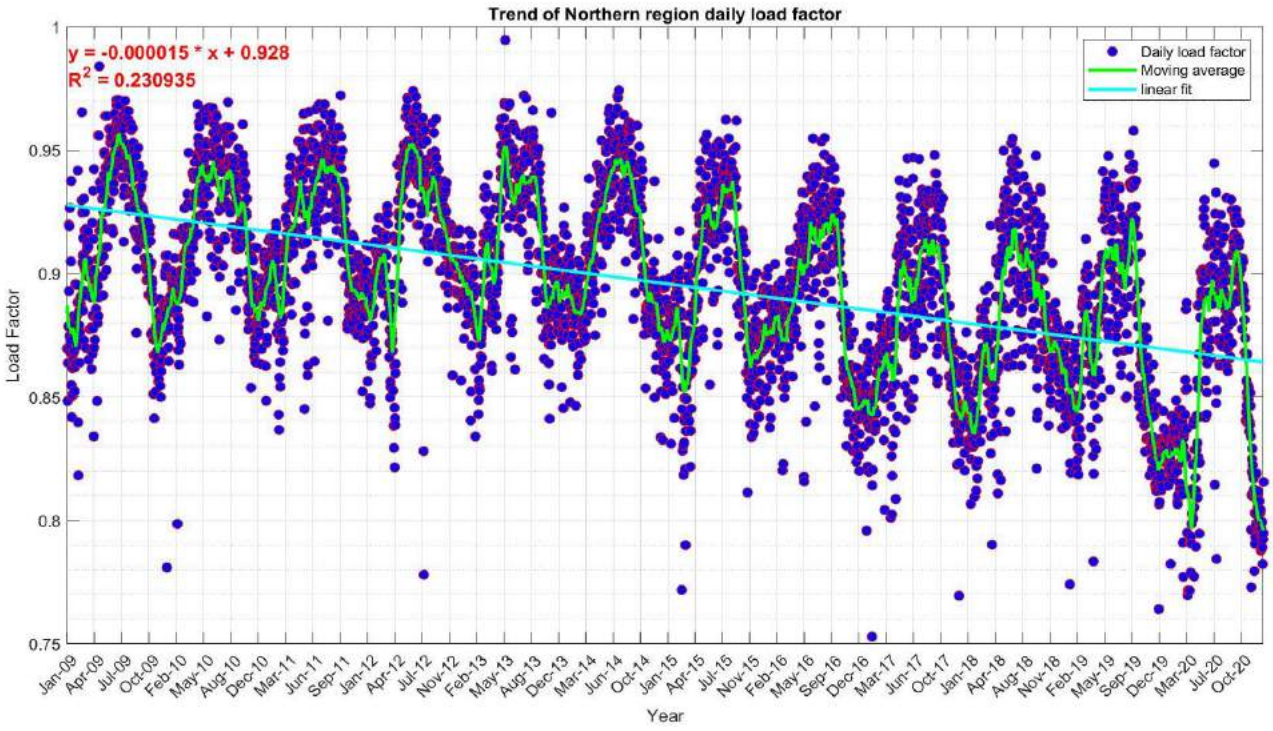


Figure 26:Linear fitting of NR Load factor trend

e) Growth in Maximum, Minimum and Average alongwith Load Factor:

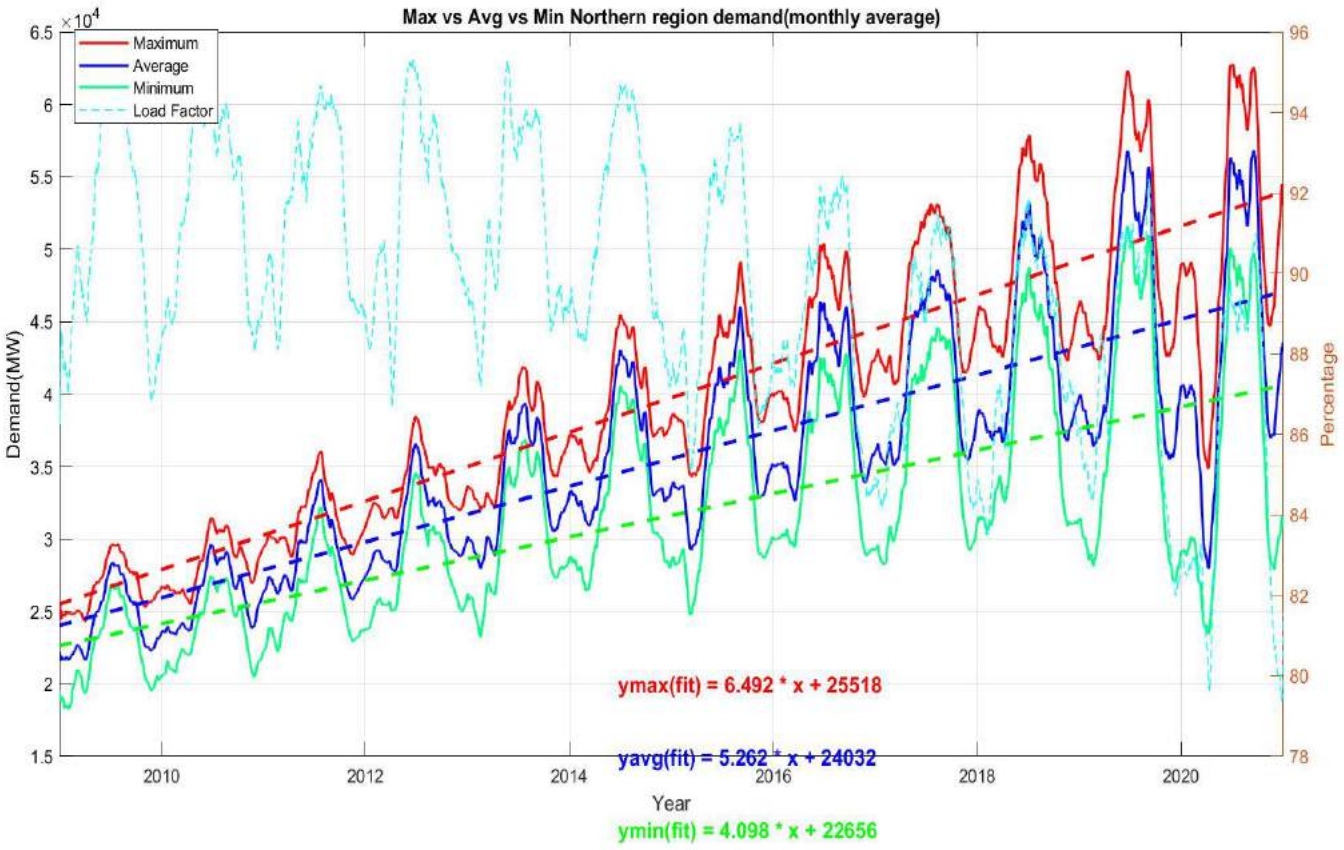


Figure 27:Growth in Maximum, Minimum and Average demand alongwith NR Load Factor

f) Heatmap of monthly average load factor:

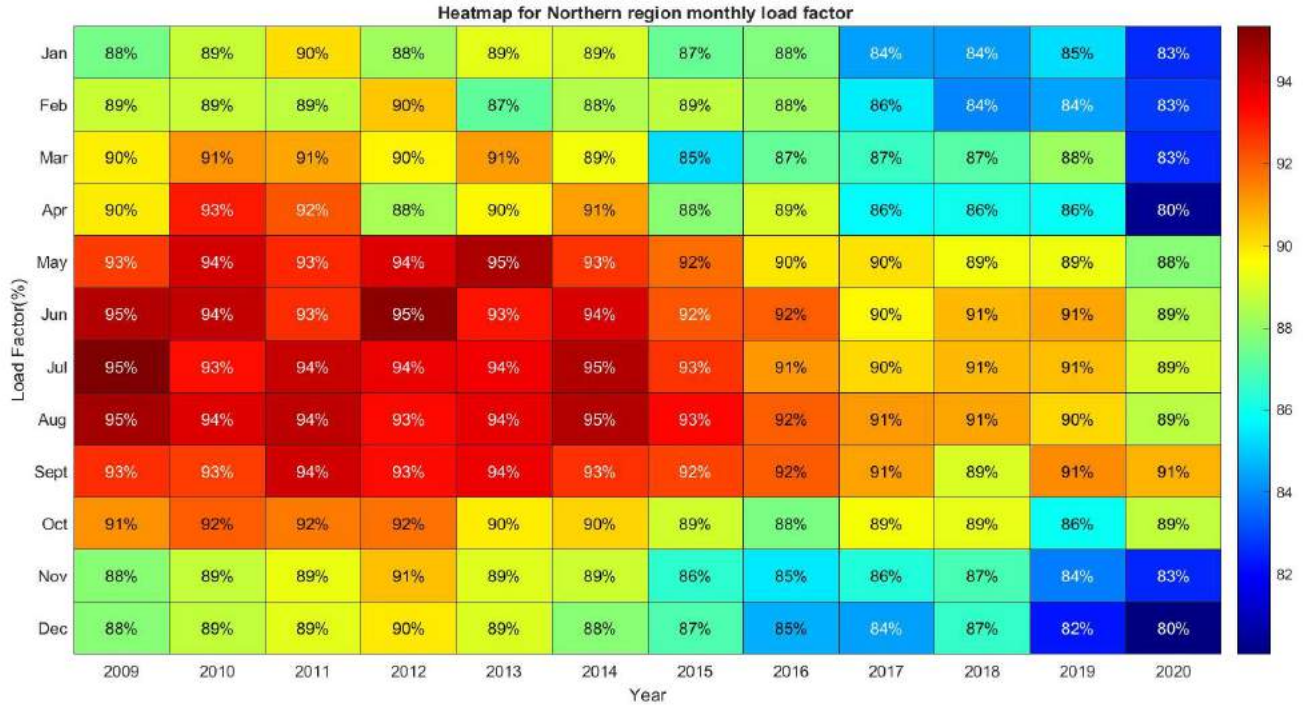


Figure 28:Heatmap of NR monthly average load factor (mean of daily load factor)

g) Duration curve of load factor:

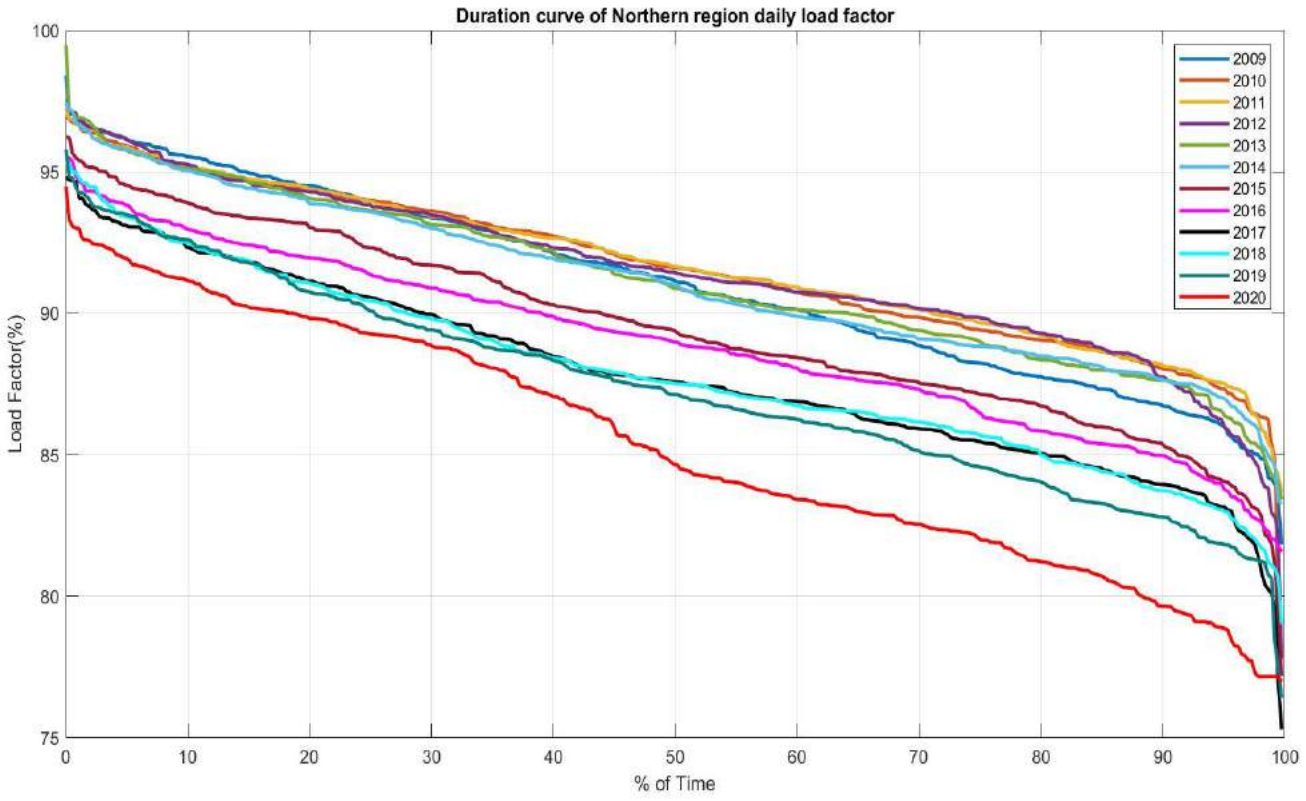


Figure 29:Duration curve of NR load factor

h) Cycle-Sub series plot of Load Factor:

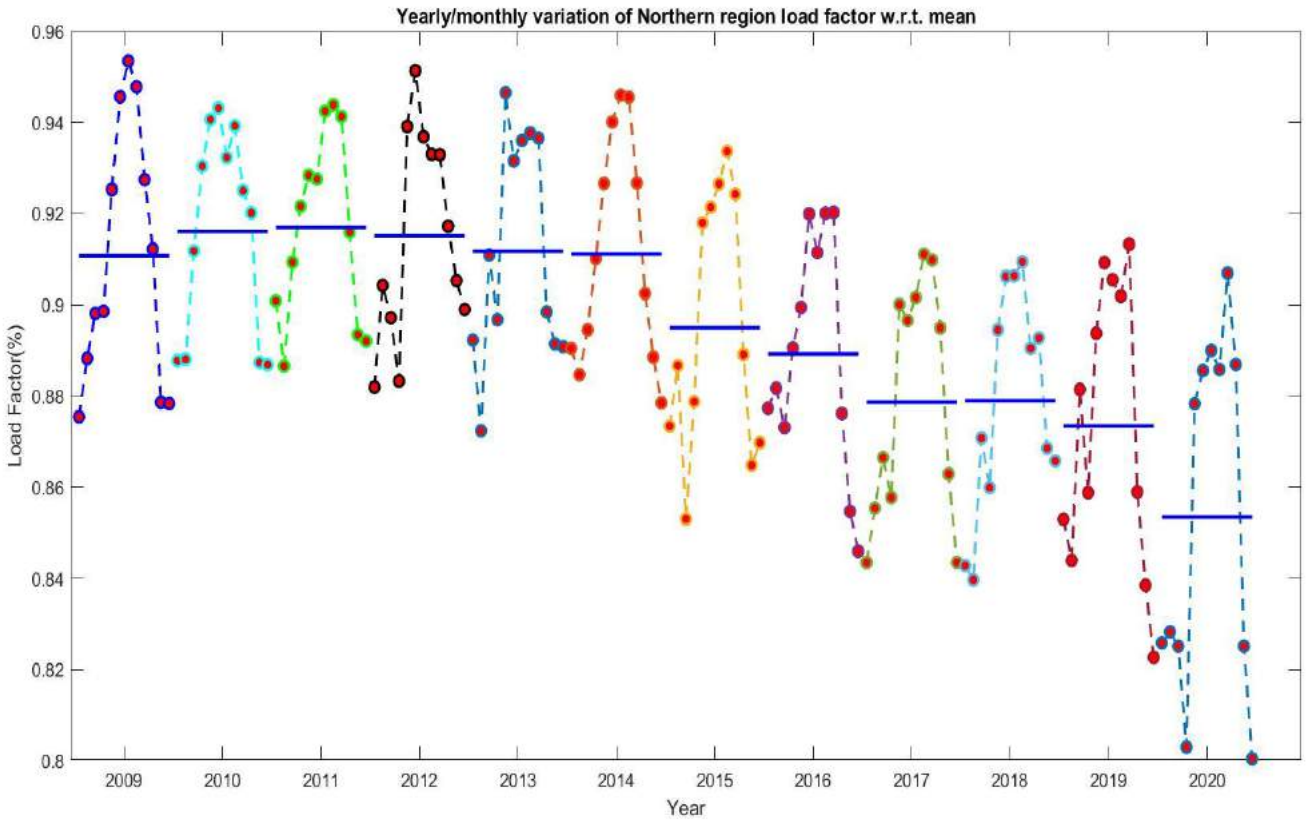


Figure 30:Cycle-Sub series plot for Yearly/Monthly variation of NR Load Factor

i) Concentration of Load factor:

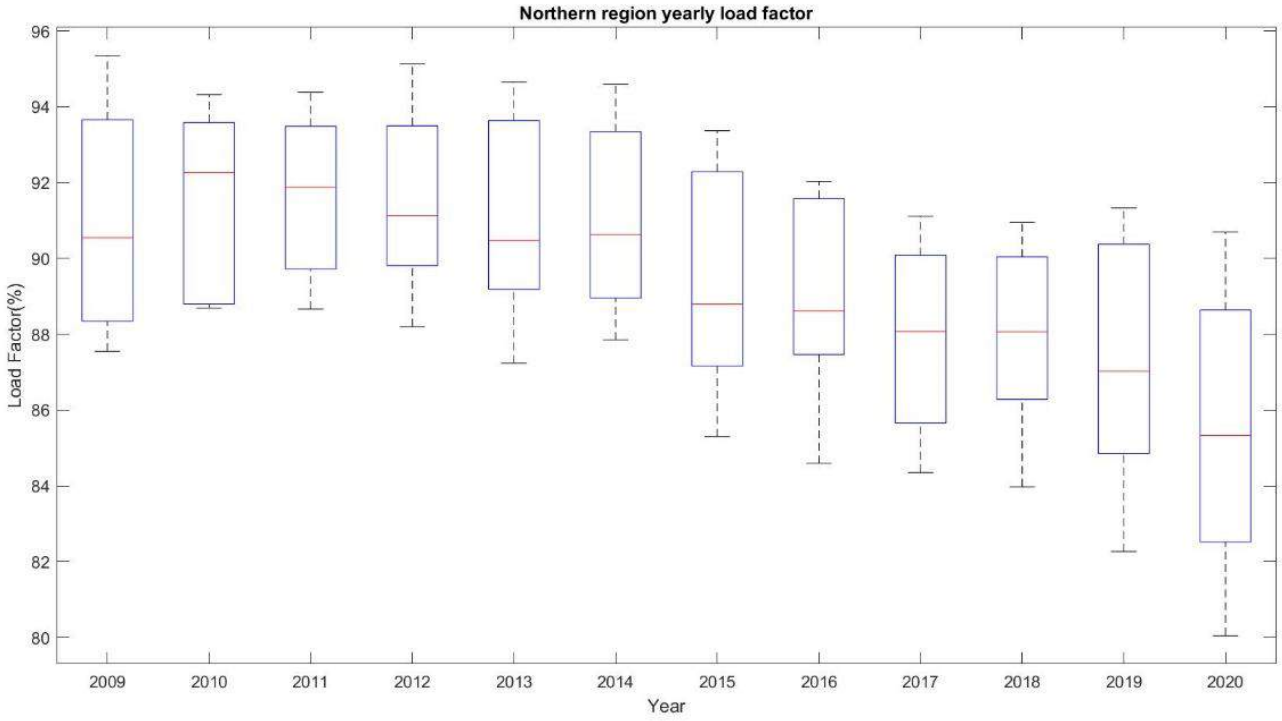
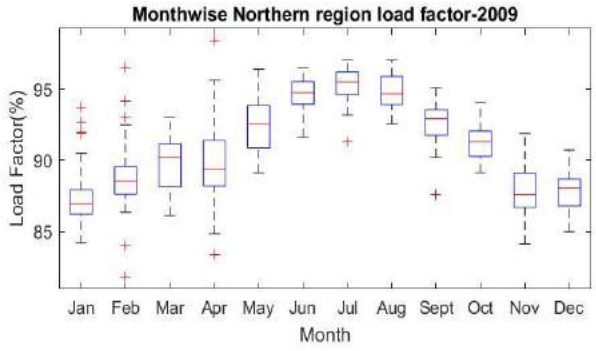
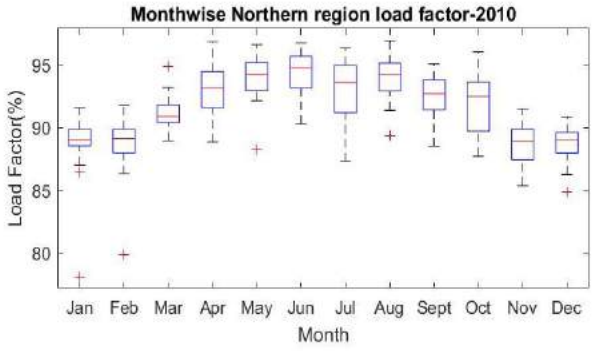
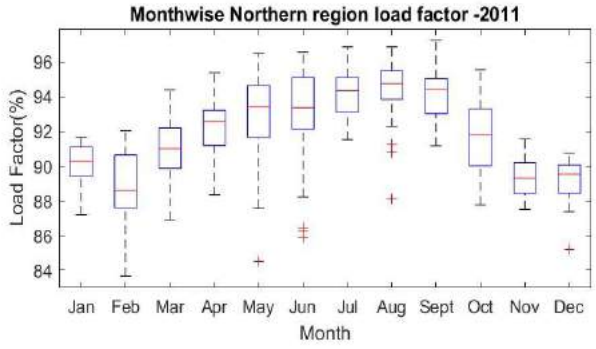


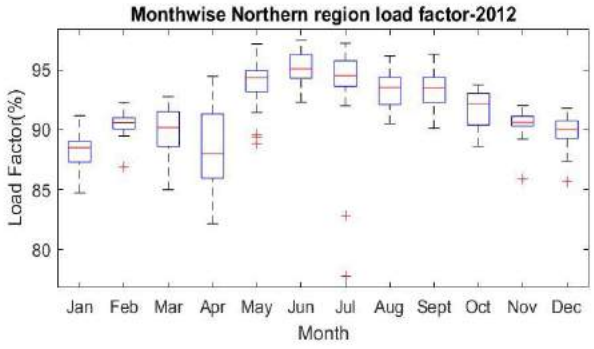
Figure 31:Concentration of NR Load factor

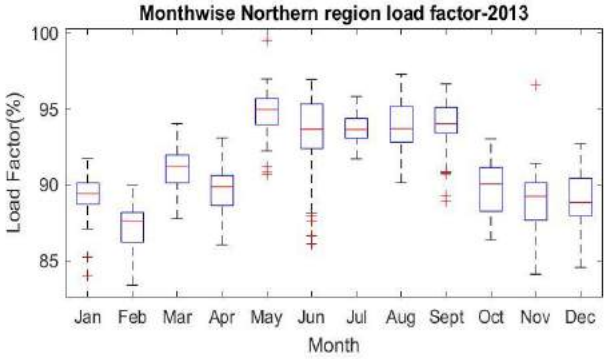
j) Monthly Variation of Load Factor over the years:

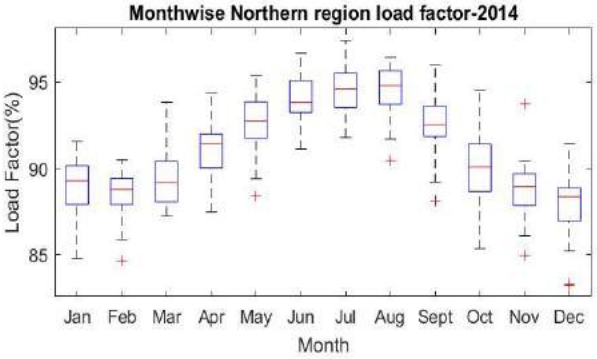


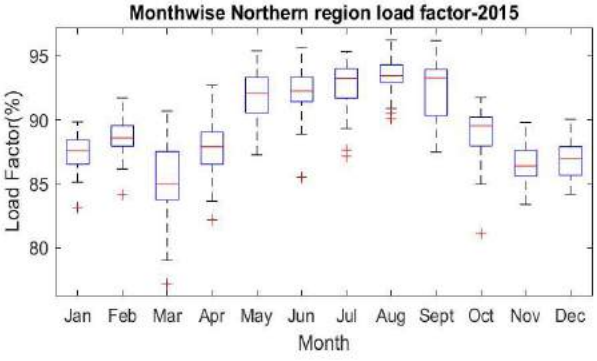


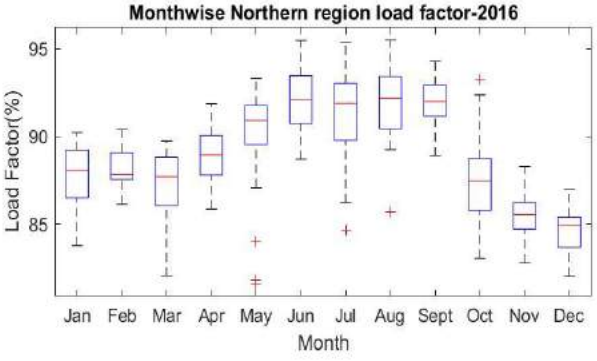












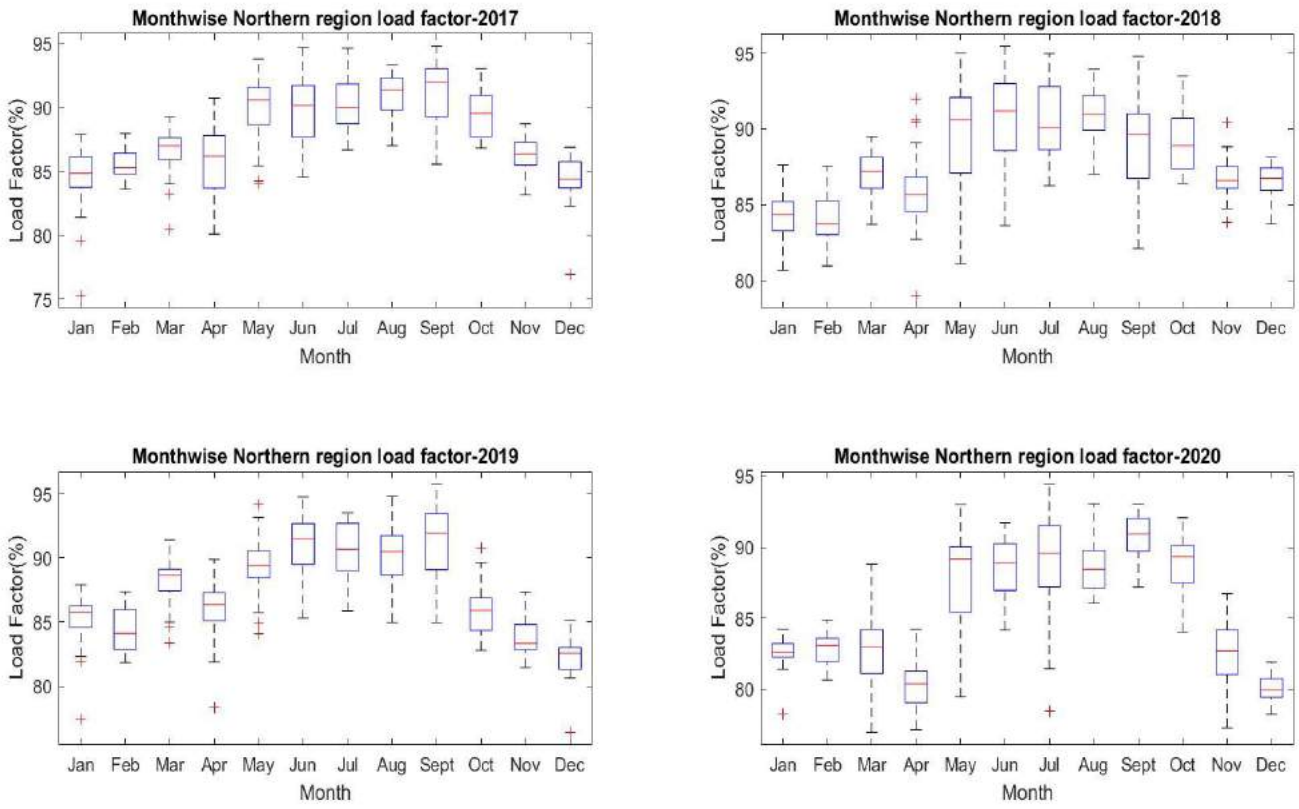


Figure 32:Monthly Variation of Load Factor over the years for NR

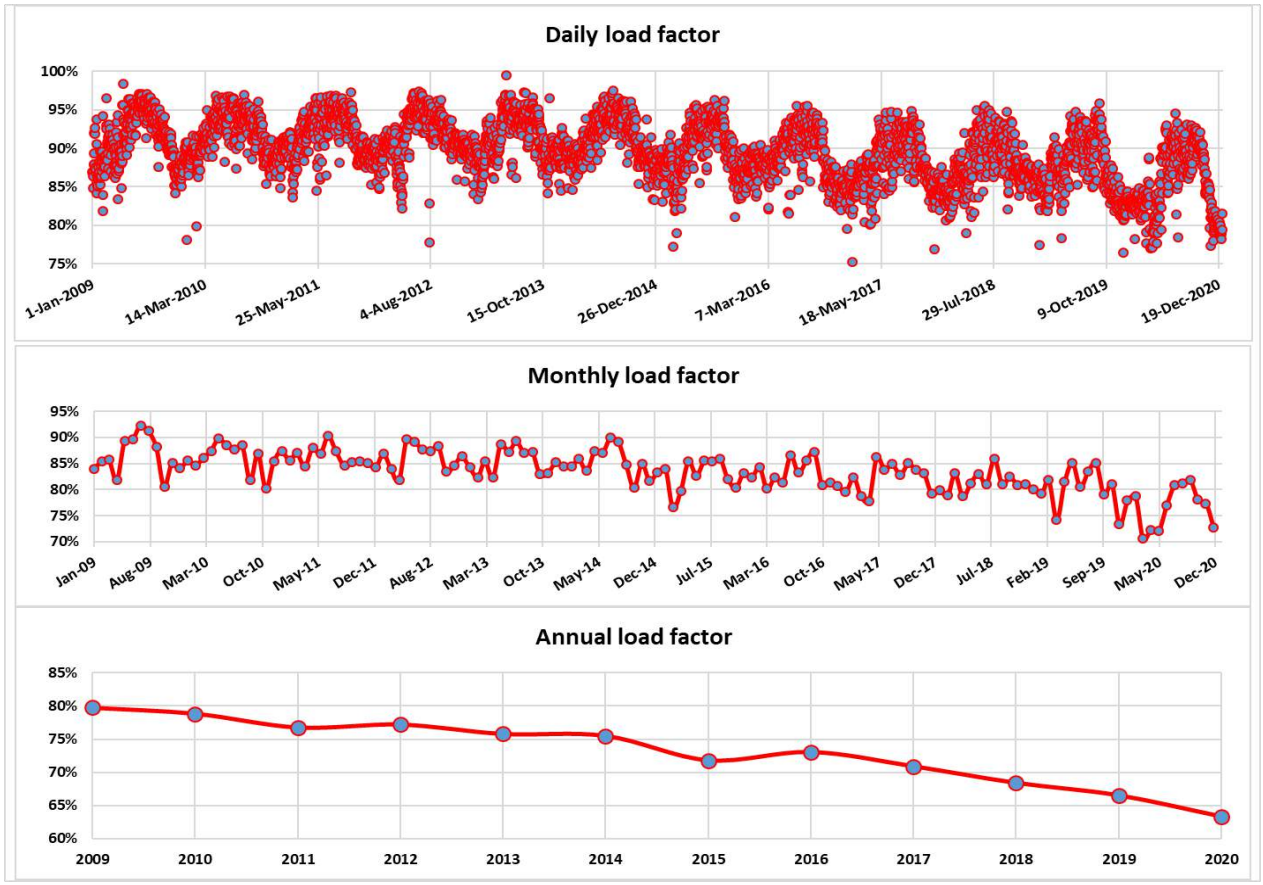


Figure 33:Variation of Northern Region load factor

11.3. Western Region

a) Average Load Factor (%):

Average Daily Load Factor from 2009-2020	92
Average Monthly Load Factor from 2009-2020	86
Average Annual Load Factor from 2009-2020	79

b) Highest/Lowest Load Factor Occurrence:

Month/Period of Highest Load Factor	Apr-May
Month/Period of Lowest Load Factor	Dec-Jan

c) Seasonal decomposition of load factor trend:

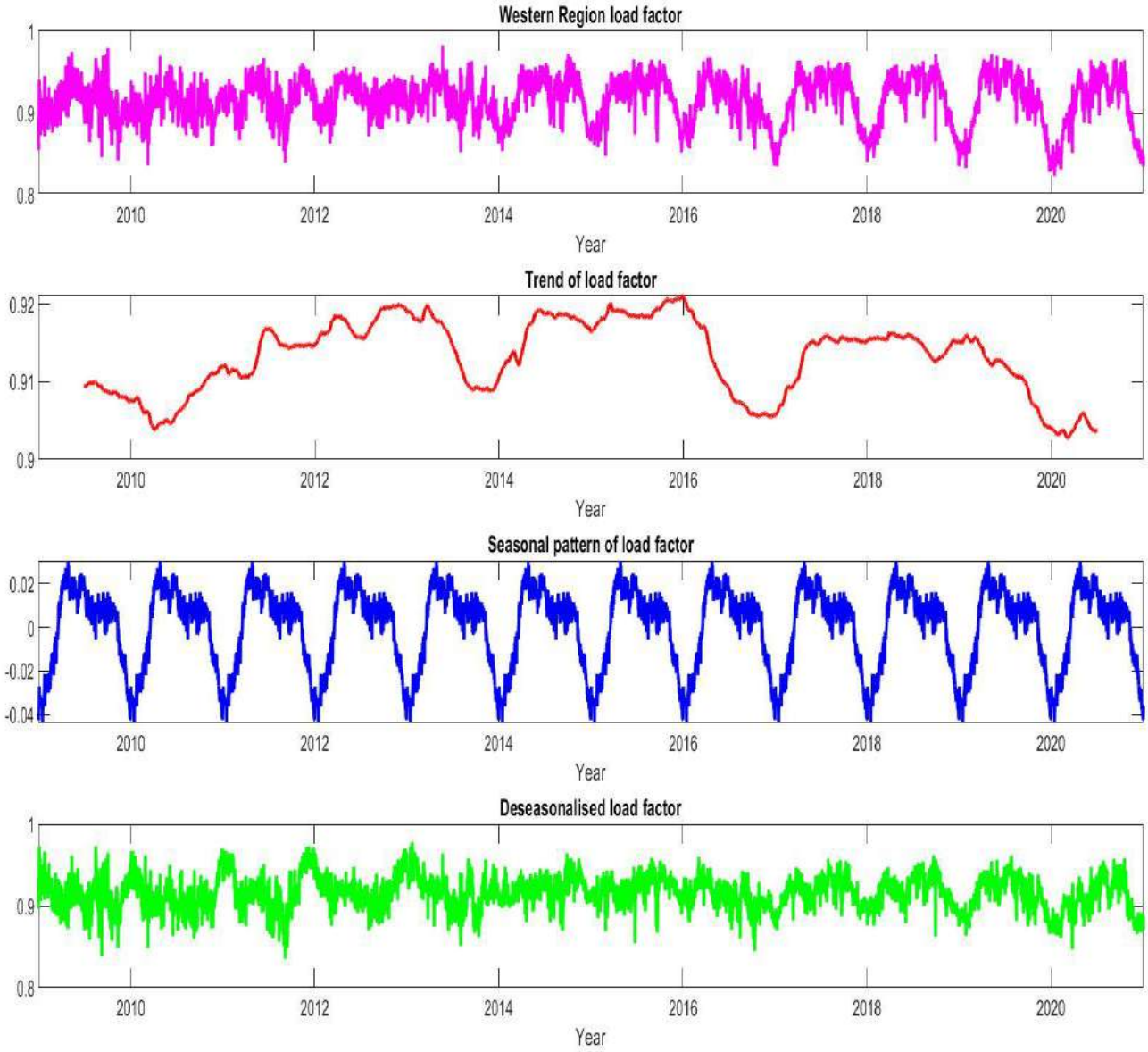


Figure 34:Seasonal decomposition of WR load factor trend

d) Linear fitting of Load factor trend:

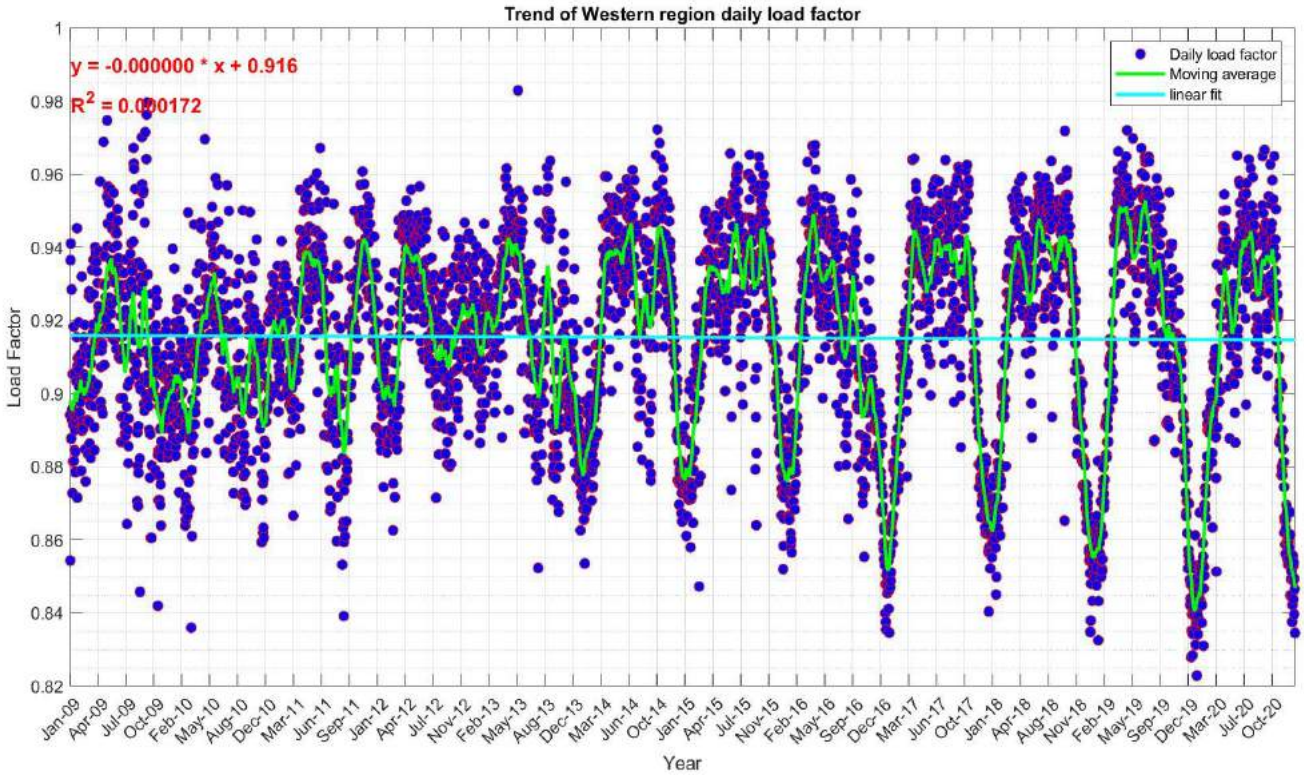


Figure 35:Linear fitting of WR Load factor trend

e) Growth in Maximum, Minimum and Average alongwith Load Factor:

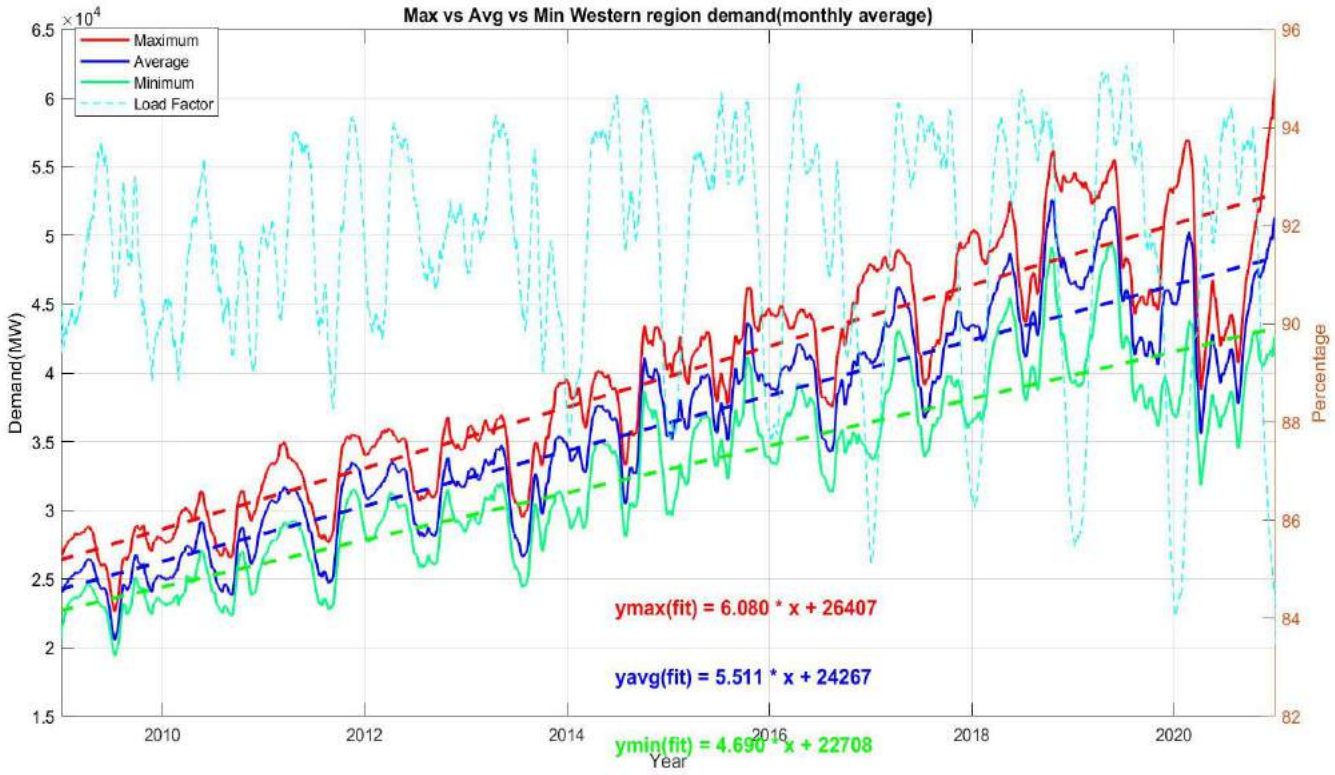


Figure 36:Growth in Maximum, Minimum and Average demand alongwith WR Load Factor

f) Heatmap of monthly average load factor:

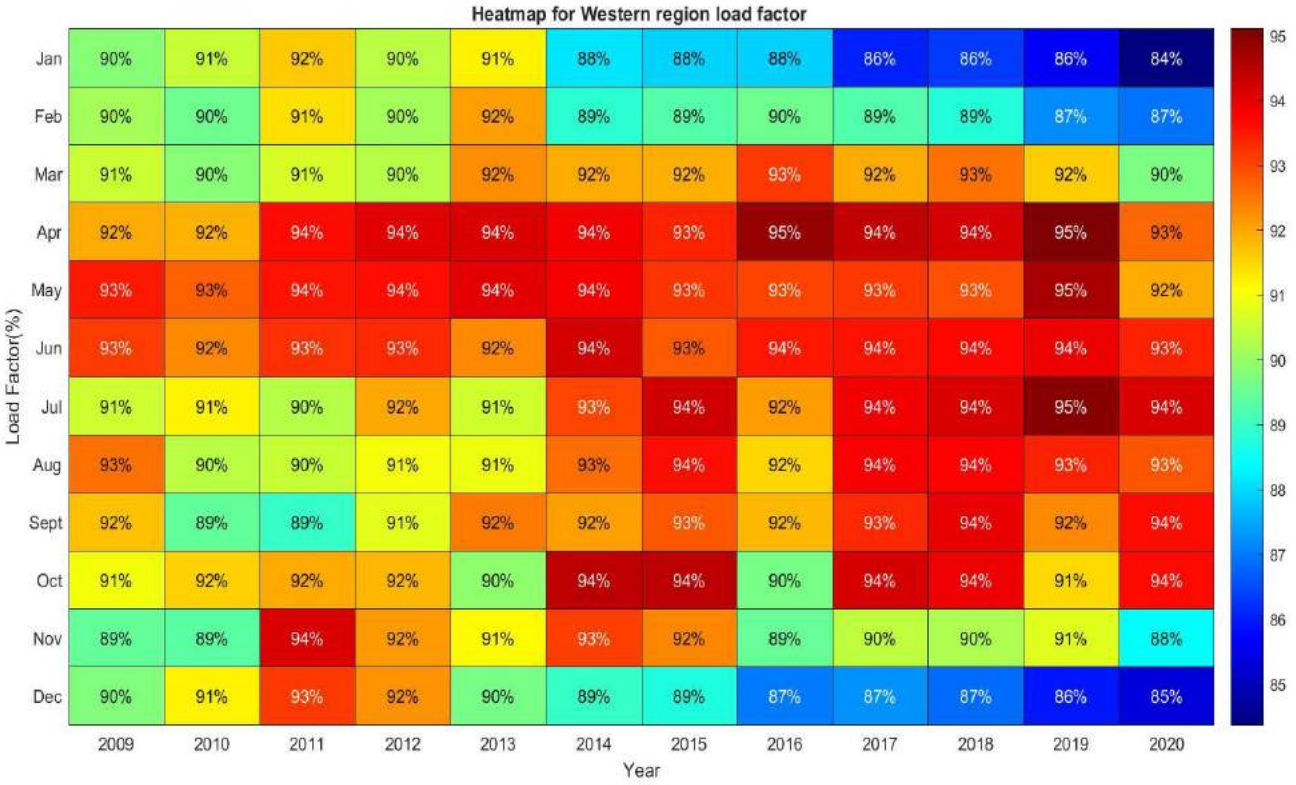


Figure 37:Heatmap of WR monthly average load factor (mean of daily load factor)

g) Duration curve of load factor:

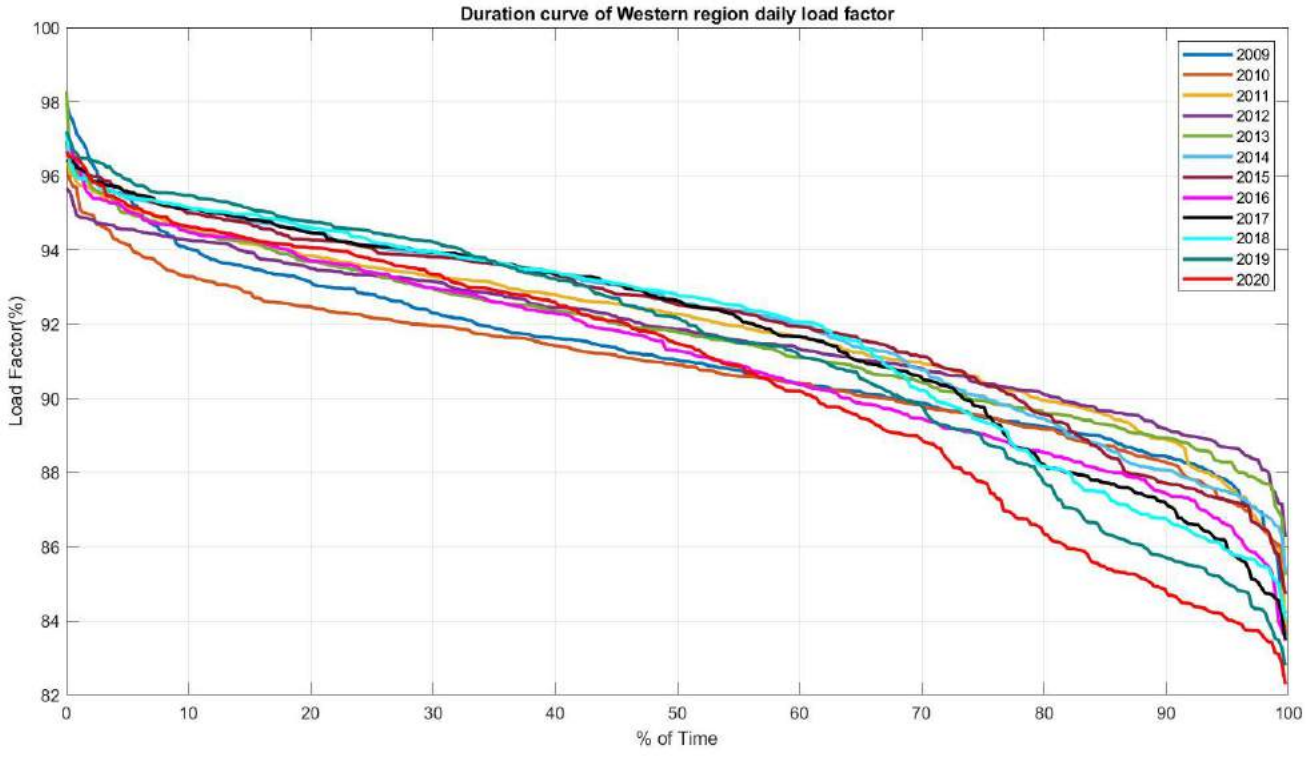


Figure 38:Duration curve of WR load factor

h) Cycle-Sub series plot of Load Factor:

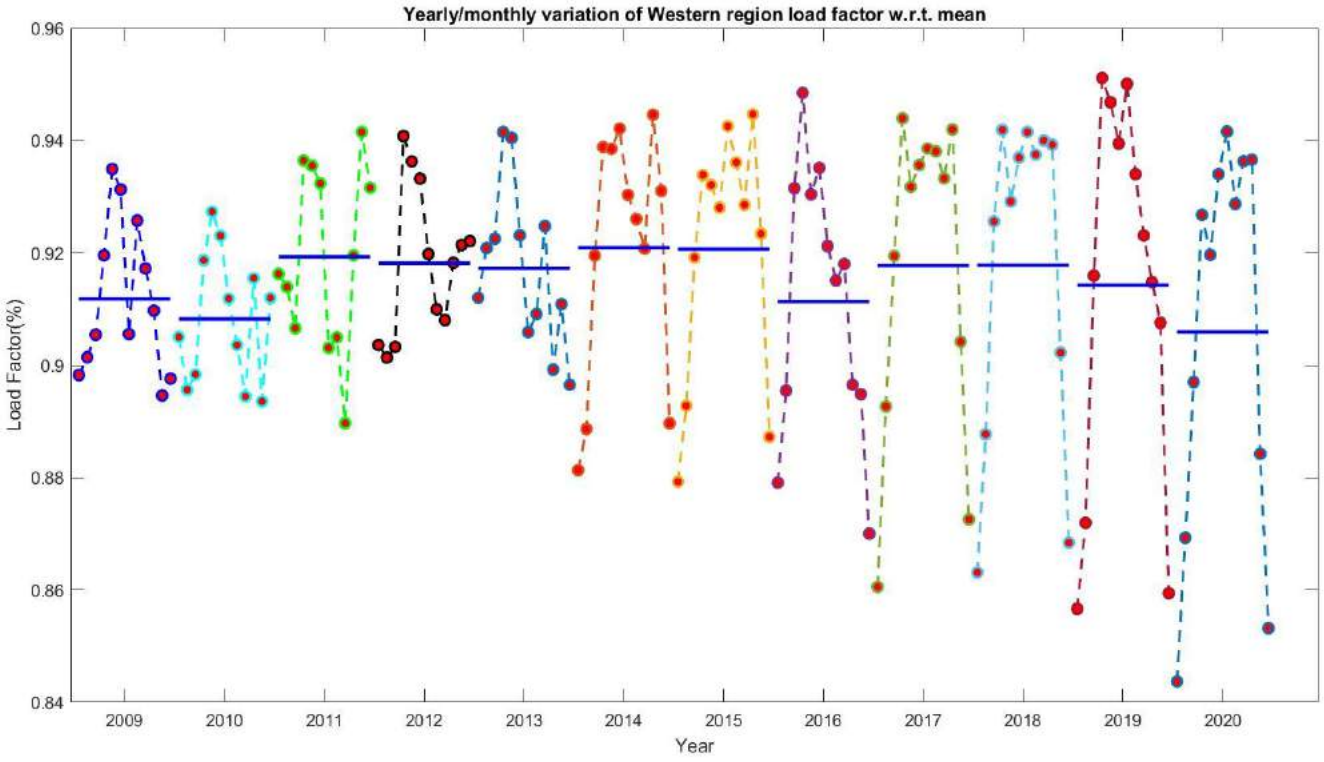


Figure 39:Cycle-Sub series plot for Yearly/Monthly variation of WR Load Factor

i) Concentration of Load factor:

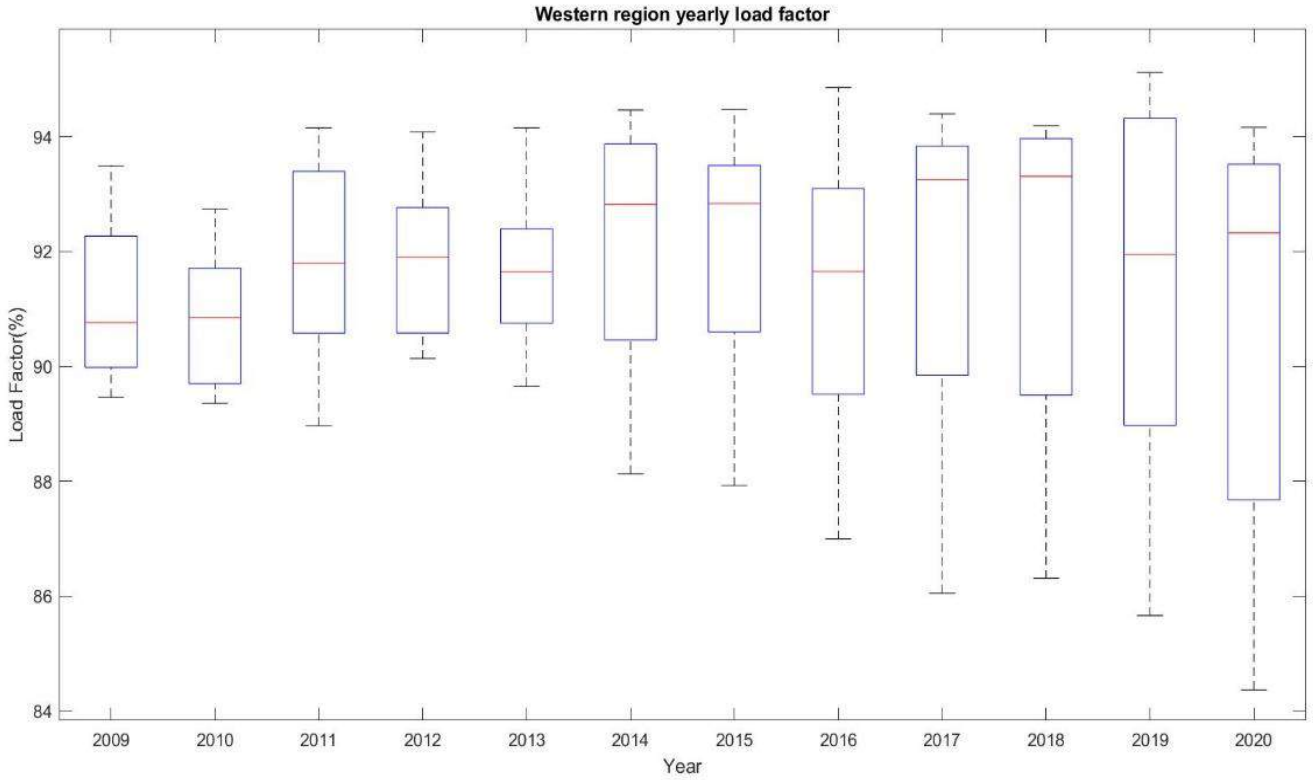
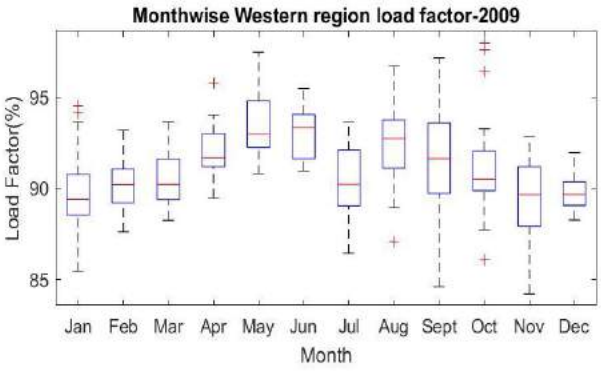
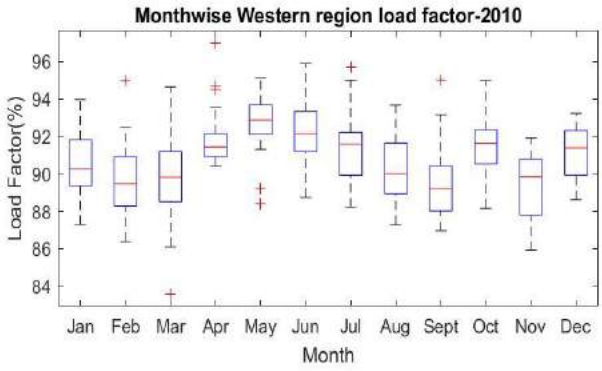
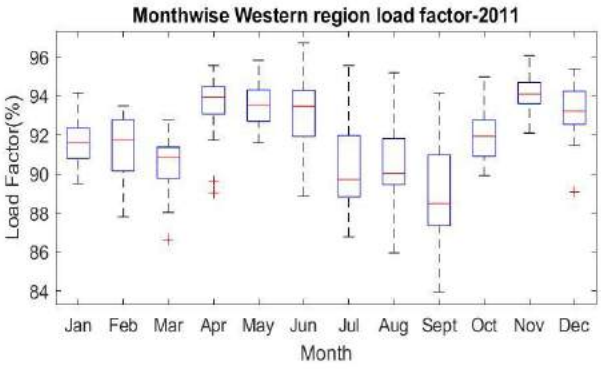


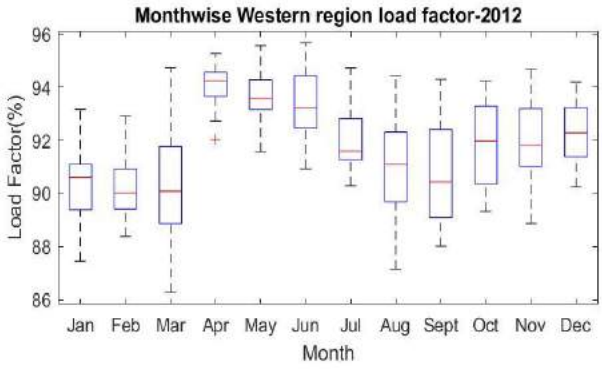
Figure 40:Concentration of WR Load factor

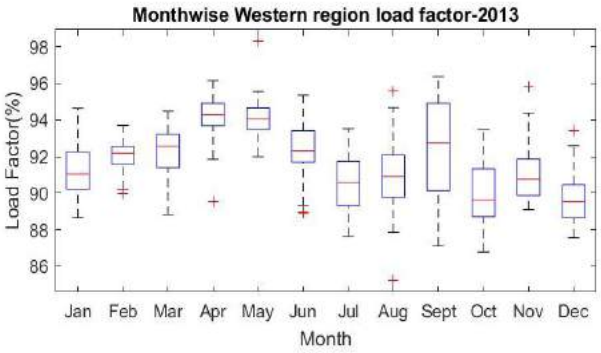
j) Monthly Variation of Load Factor over the years:

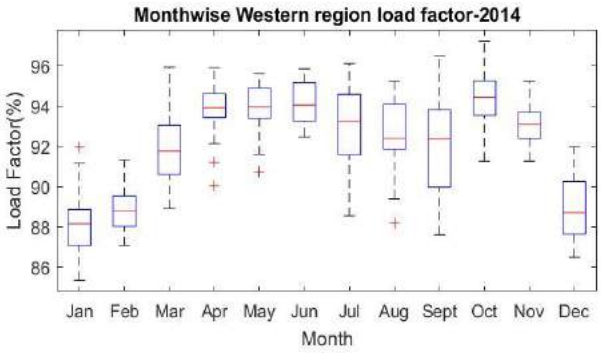


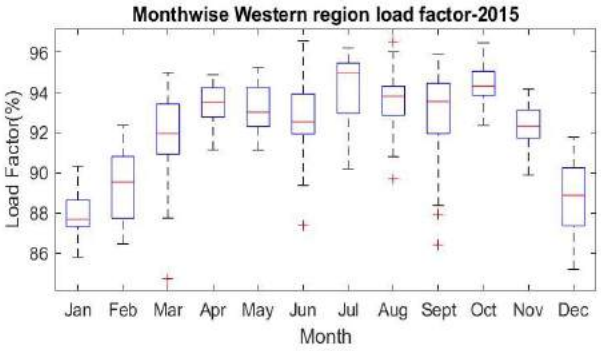


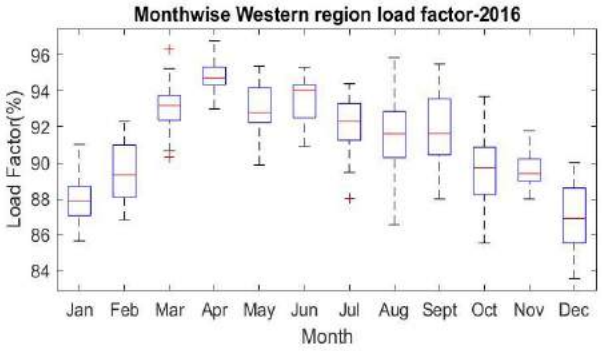












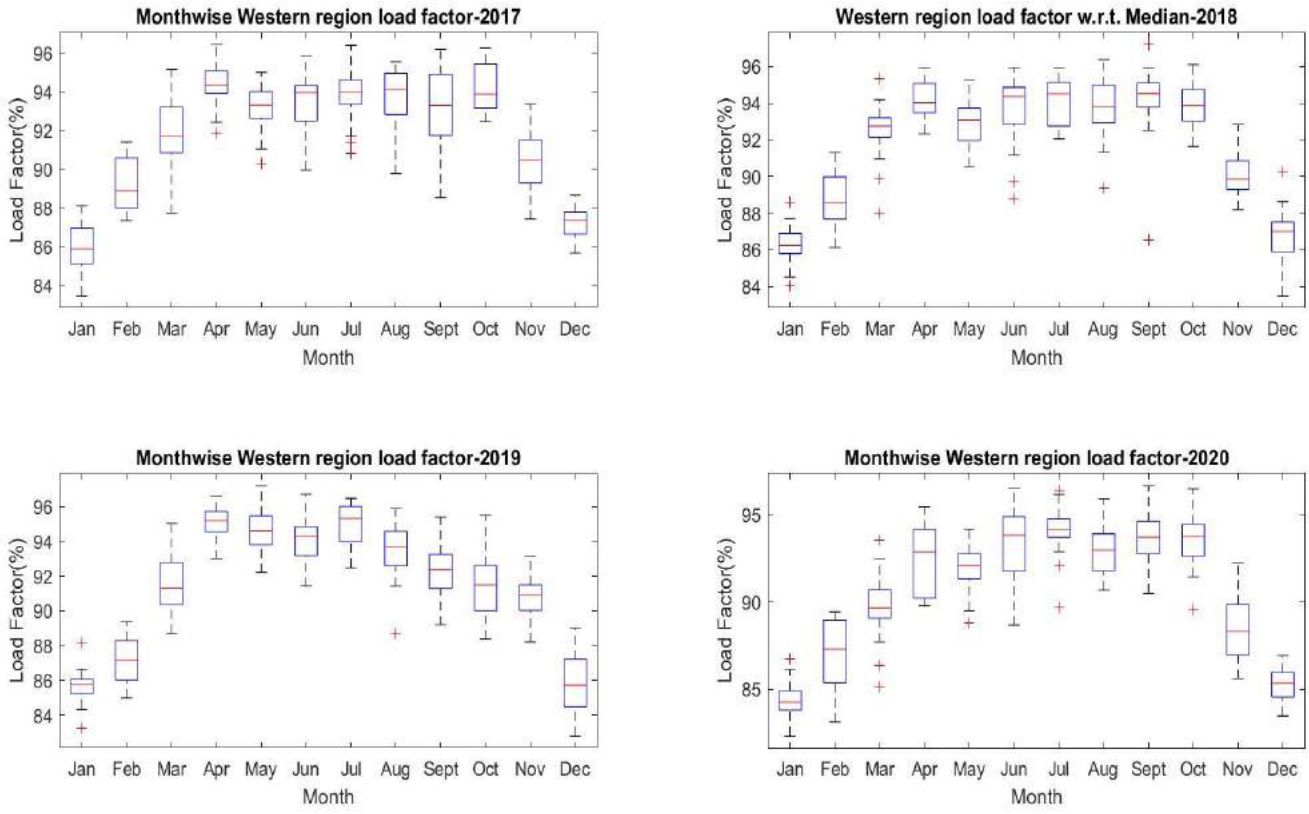


Figure 41:Monthly Variation of Load Factor over the years for WR

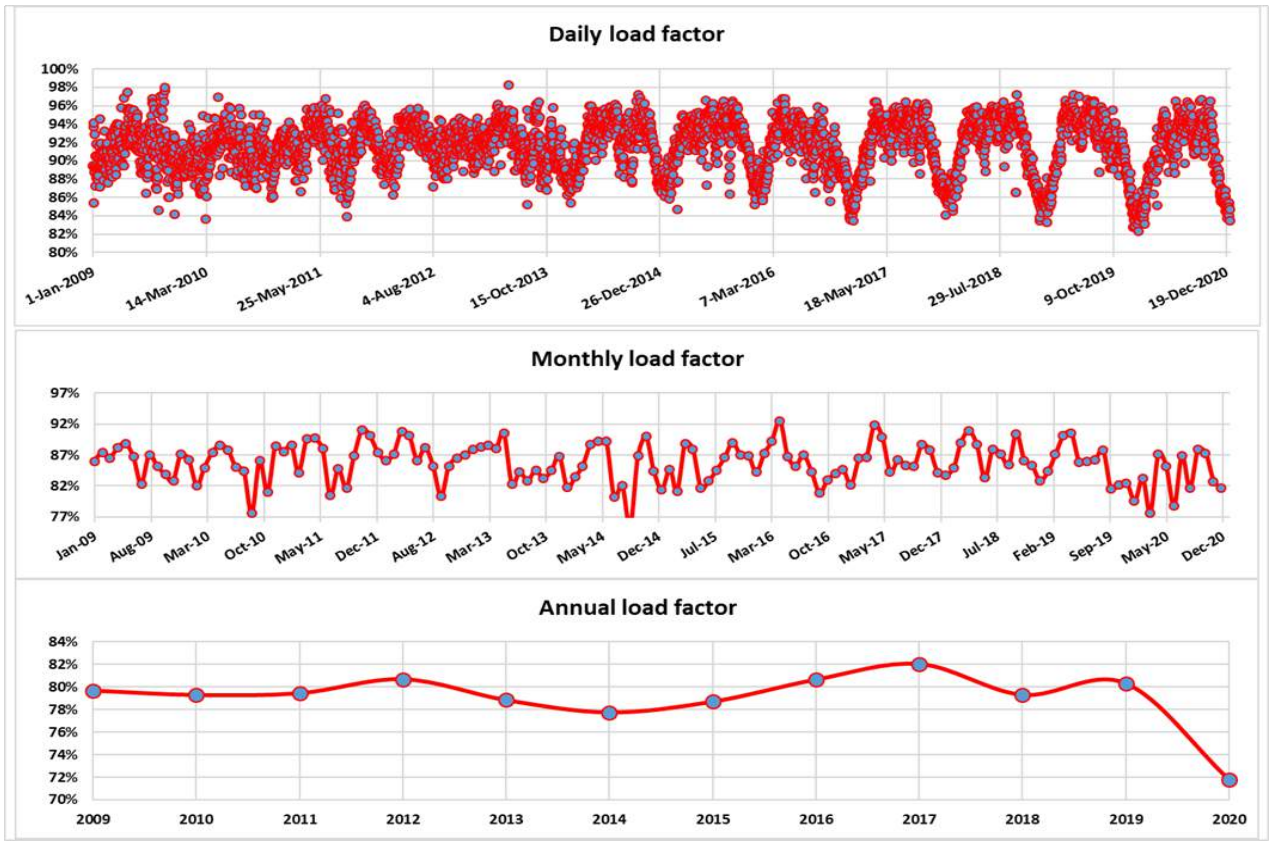


Figure 42:Variation of Western Region load factor

11.4. Southern Region

a) Average Load Factor (%):

Average Daily Load Factor from 2009-2020	91
Average Monthly Load Factor from 2009-2020	86
Average Annual Load Factor from 2009-2020	81

b) Highest/Lowest Load Factor Occurrence:

Month/Period of Highest Load Factor	Mar-Apr
Month/Period of Lowest Load Factor	Dec-Jan

c) Seasonal decomposition of load factor trend:

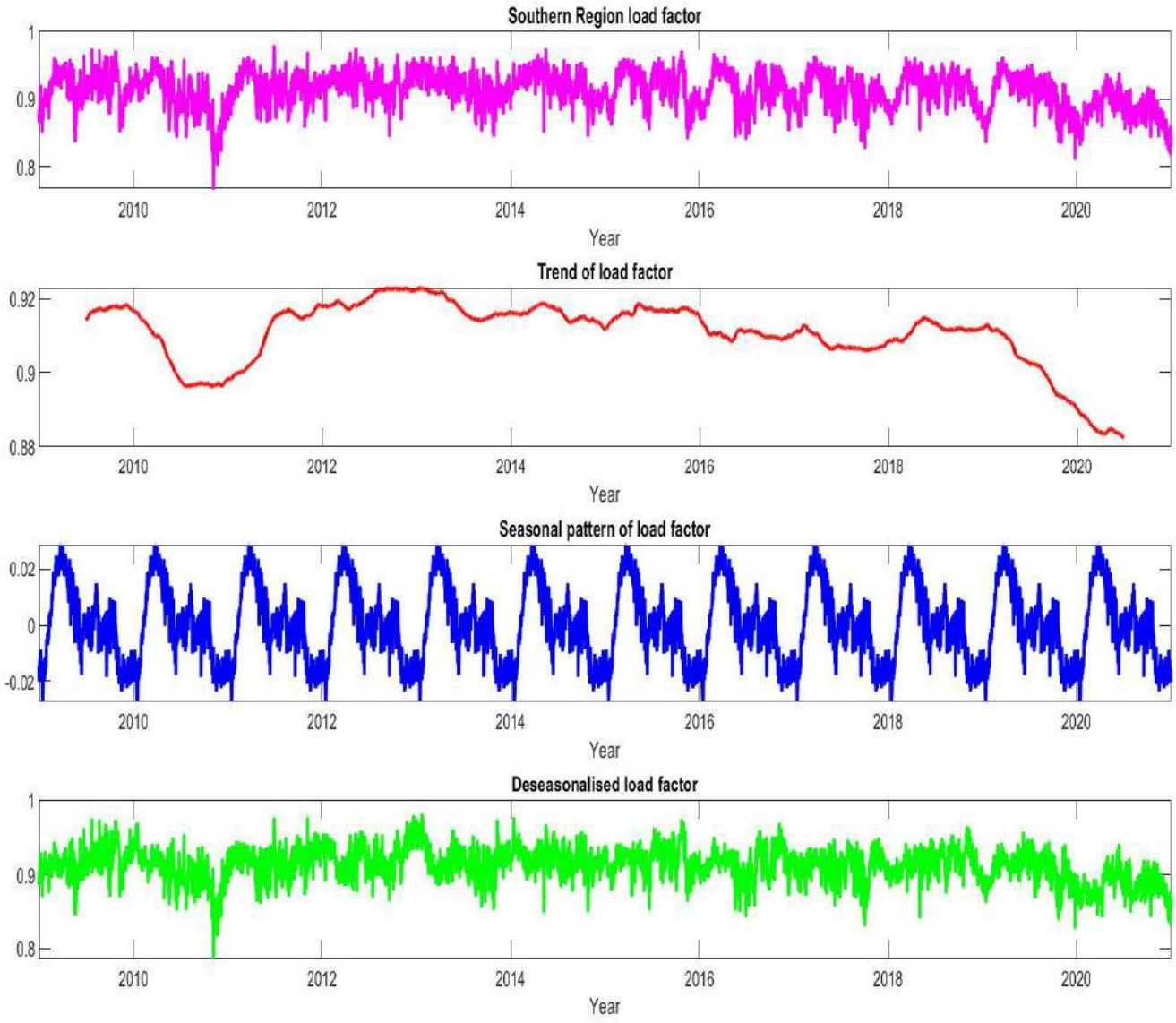


Figure 43:Seasonal decomposition of SR load factor trend

d) Linear fitting of Load factor trend:

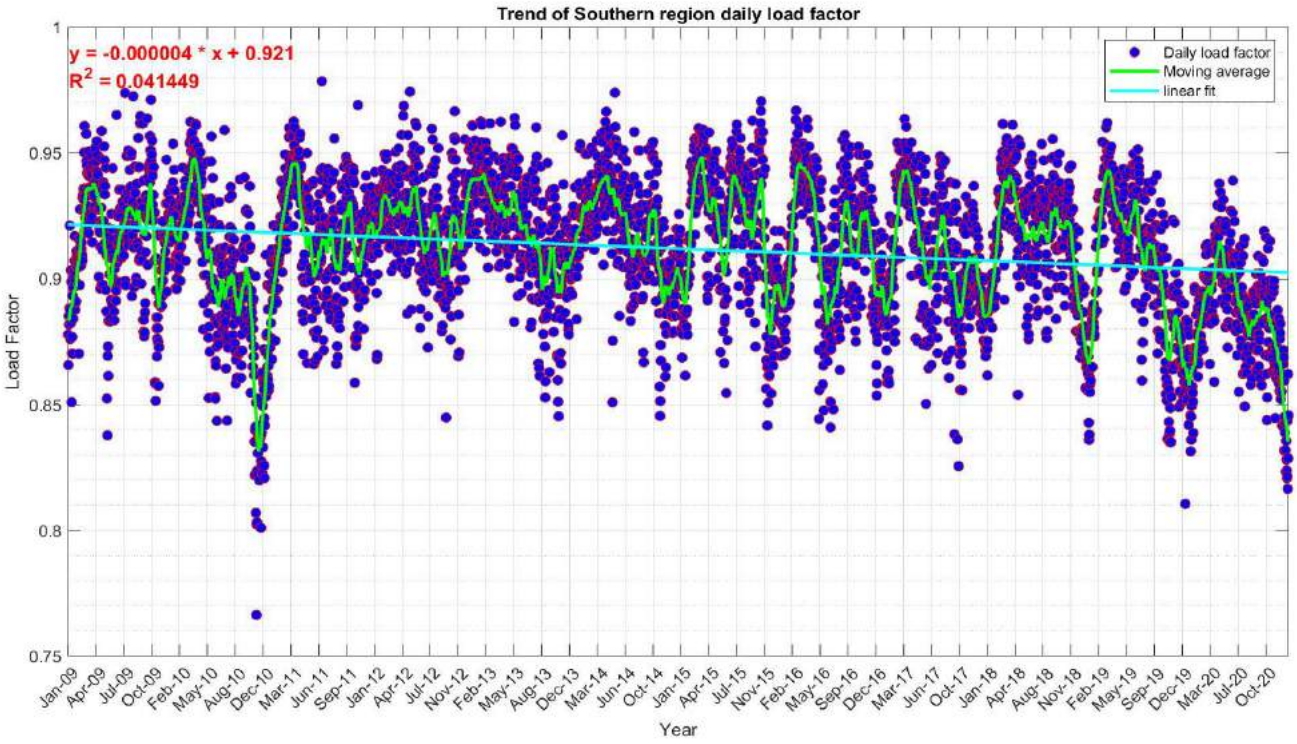


Figure 44:Linear fitting of SR Load factor trend:

e) Growth in Maximum, Minimum and Average alongwith Load Factor:

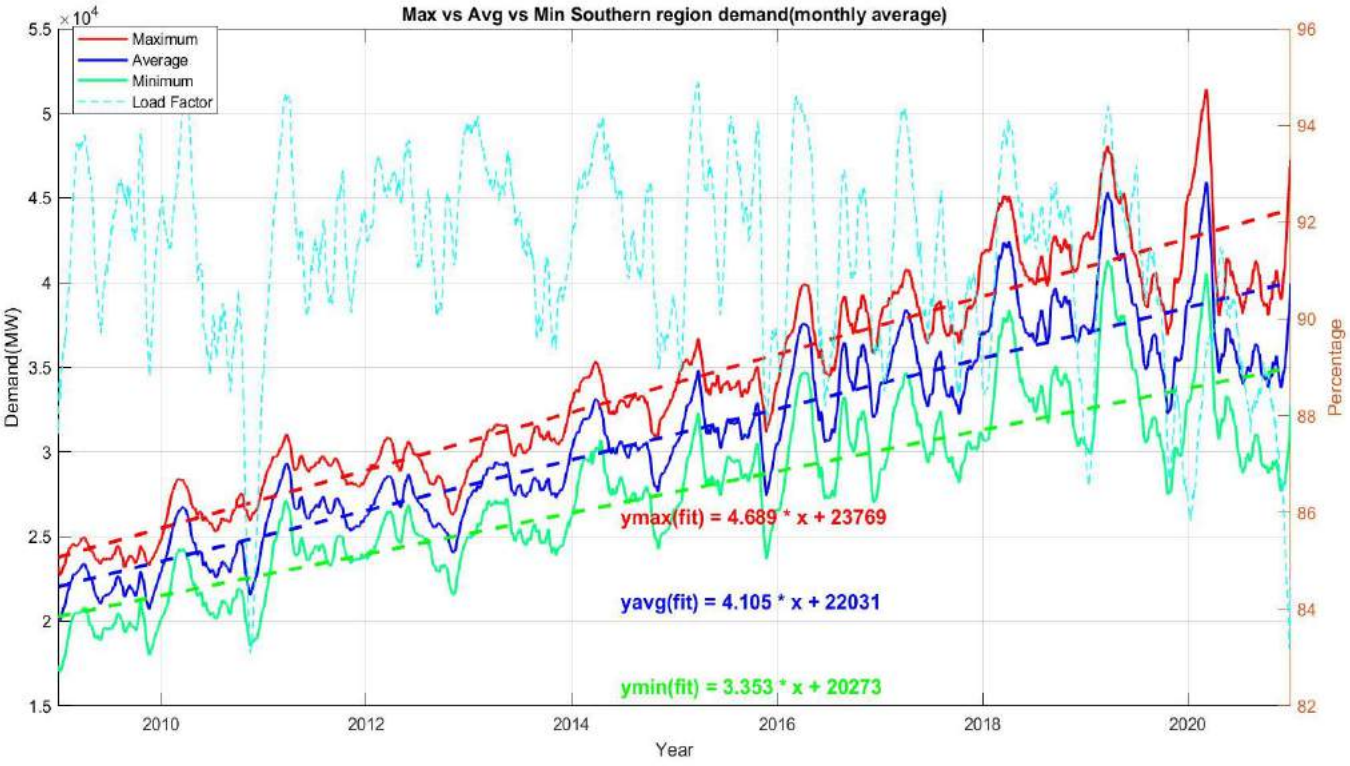


Figure 45:Growth in Maximum, Minimum and Average demand alongwith SR Load Factor

f) Heatmap of monthly average load factor:

Figure 46:Heatmap of SR monthly average load factor (mean of daily load factor)

g) Duration curve of load factor:

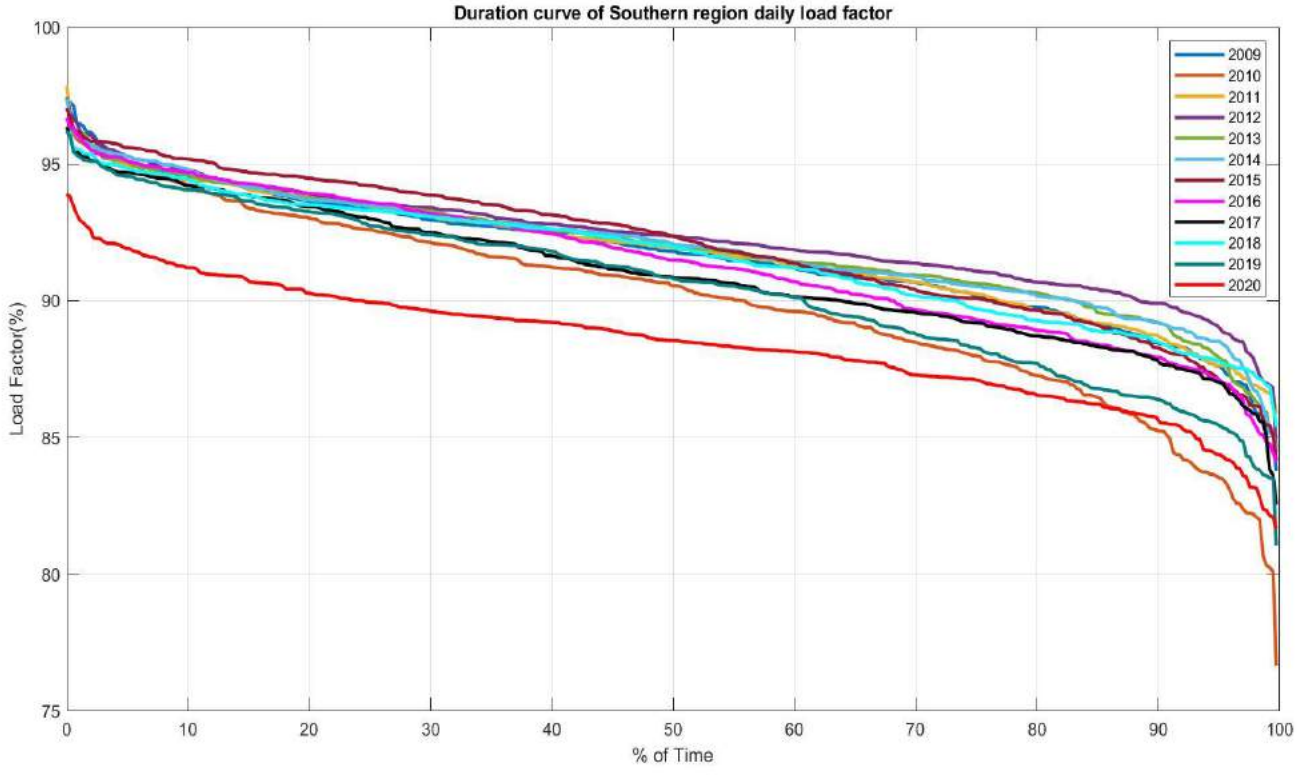


Figure 47:Duration curve of SR load factor

h) Cycle-Sub series plot of Load Factor:

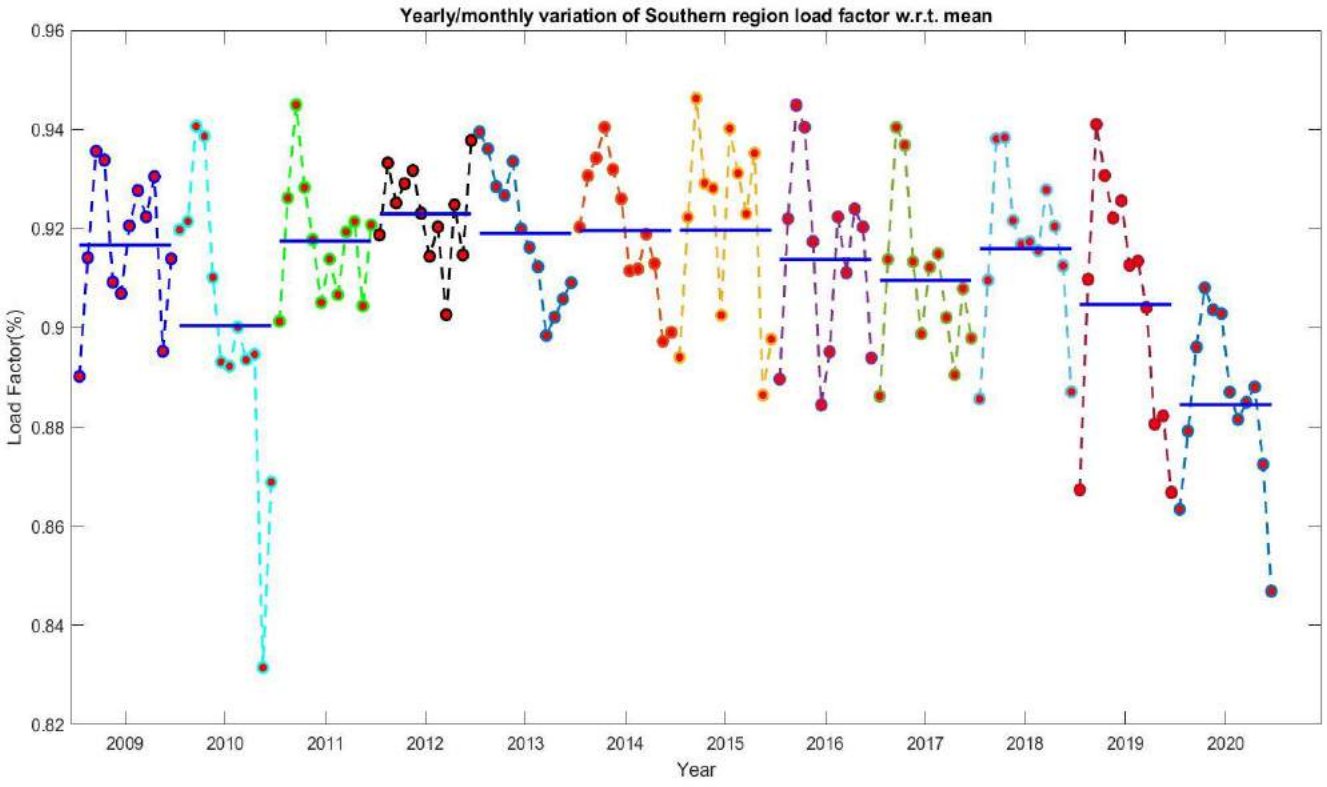


Figure 48:Cycle-Sub series plot for Yearly/Monthly variation of SR Load Factor

i) Concentration of Load factor:

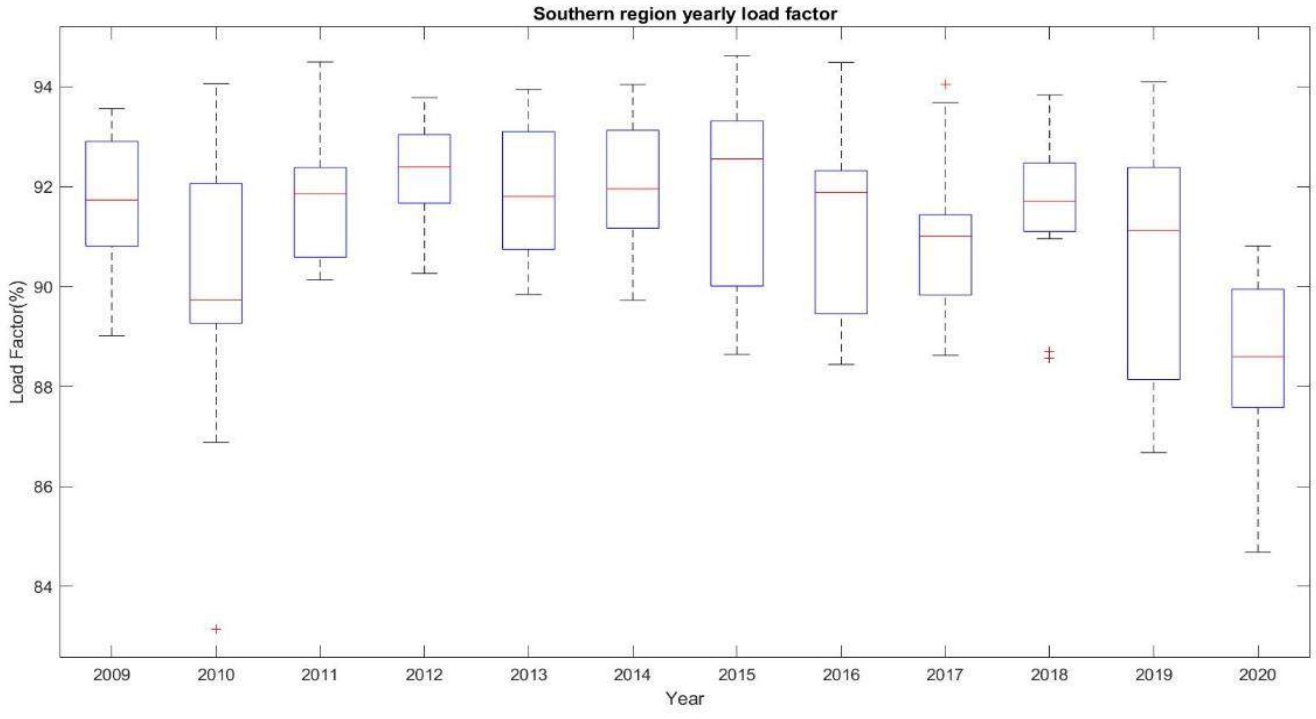
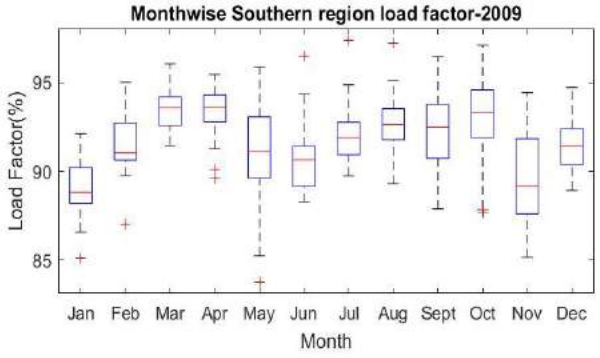
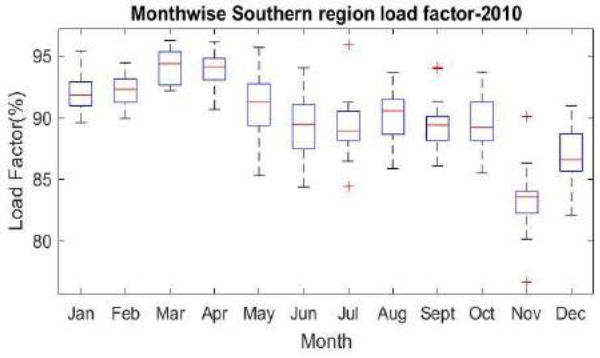
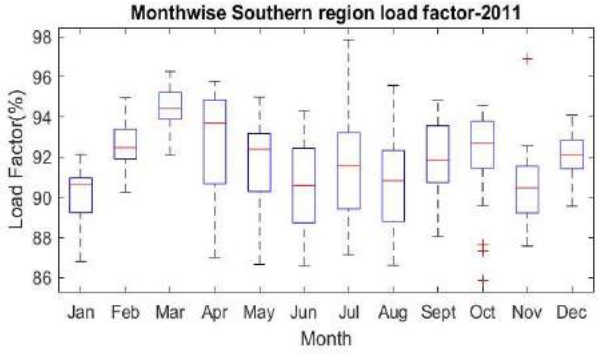


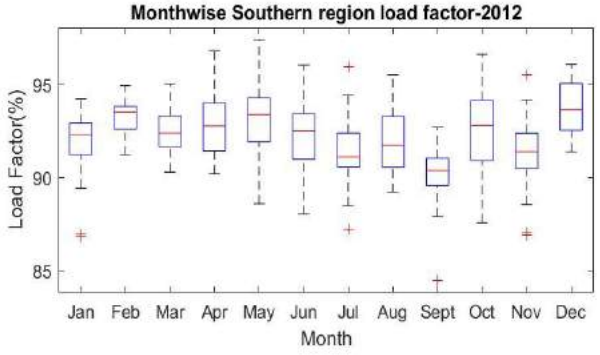
Figure 49:Concentration of SR Load factor

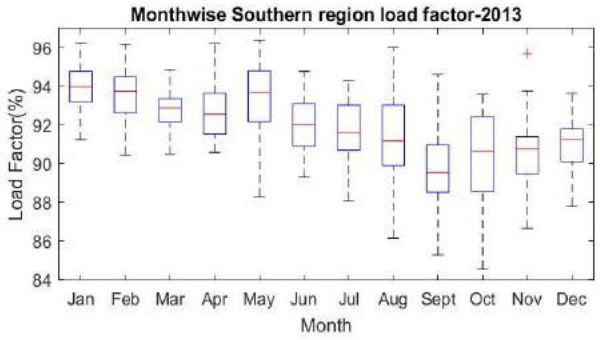
j) Monthly Variation of Load Factor over the years:

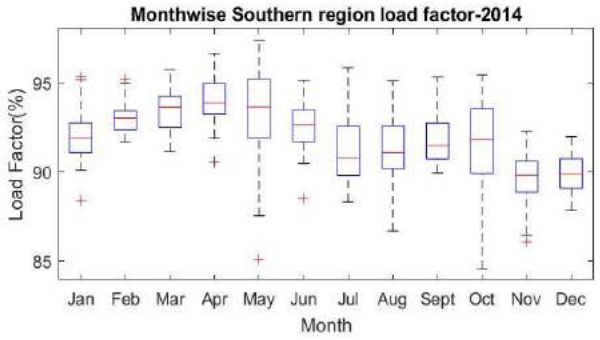


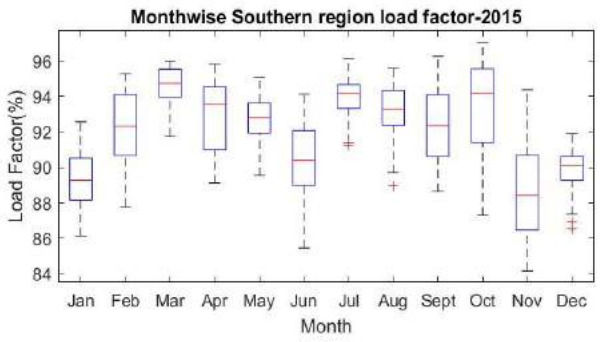


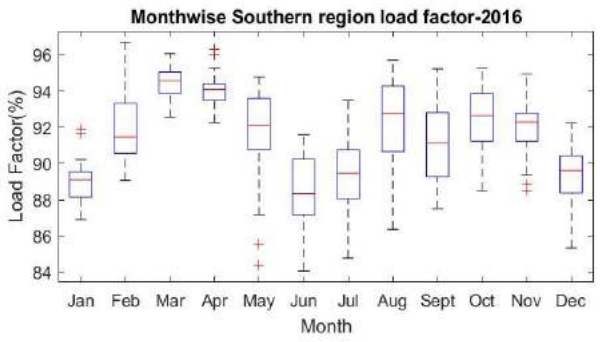












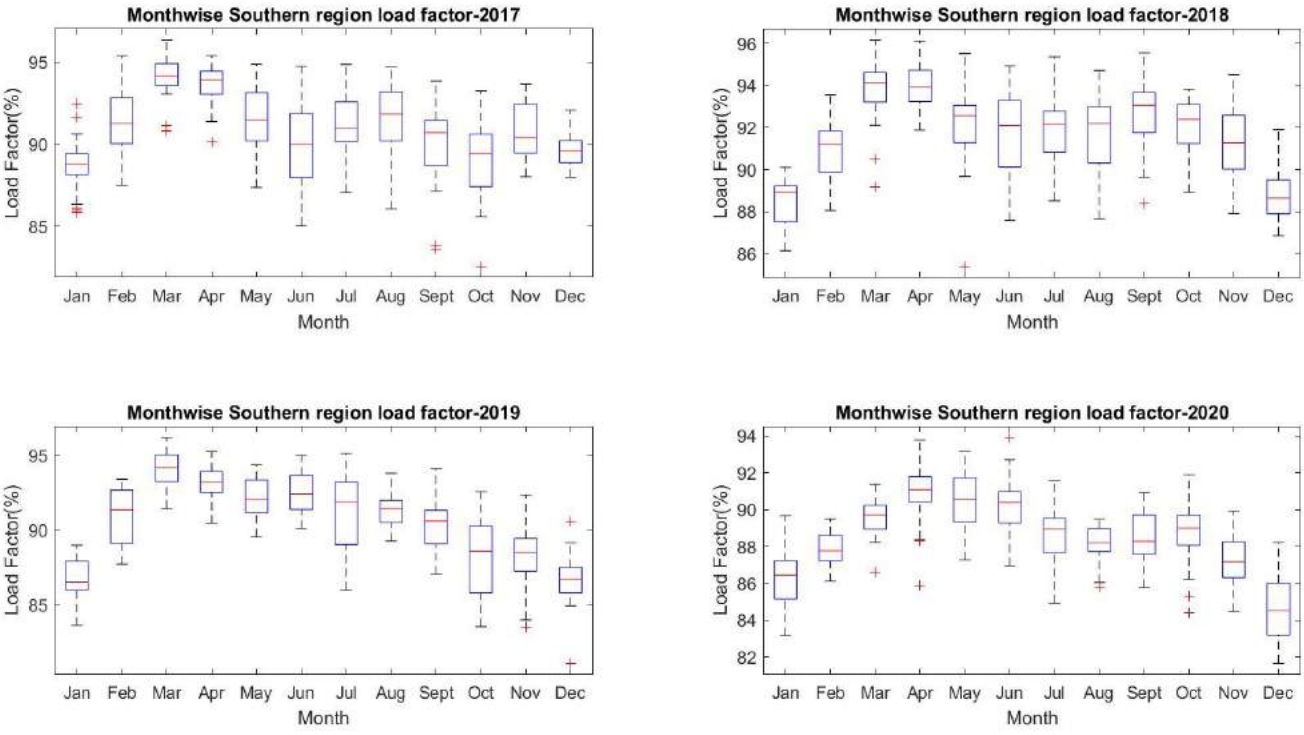


Figure 50:Monthly Variation of Load Factor over the years for SR

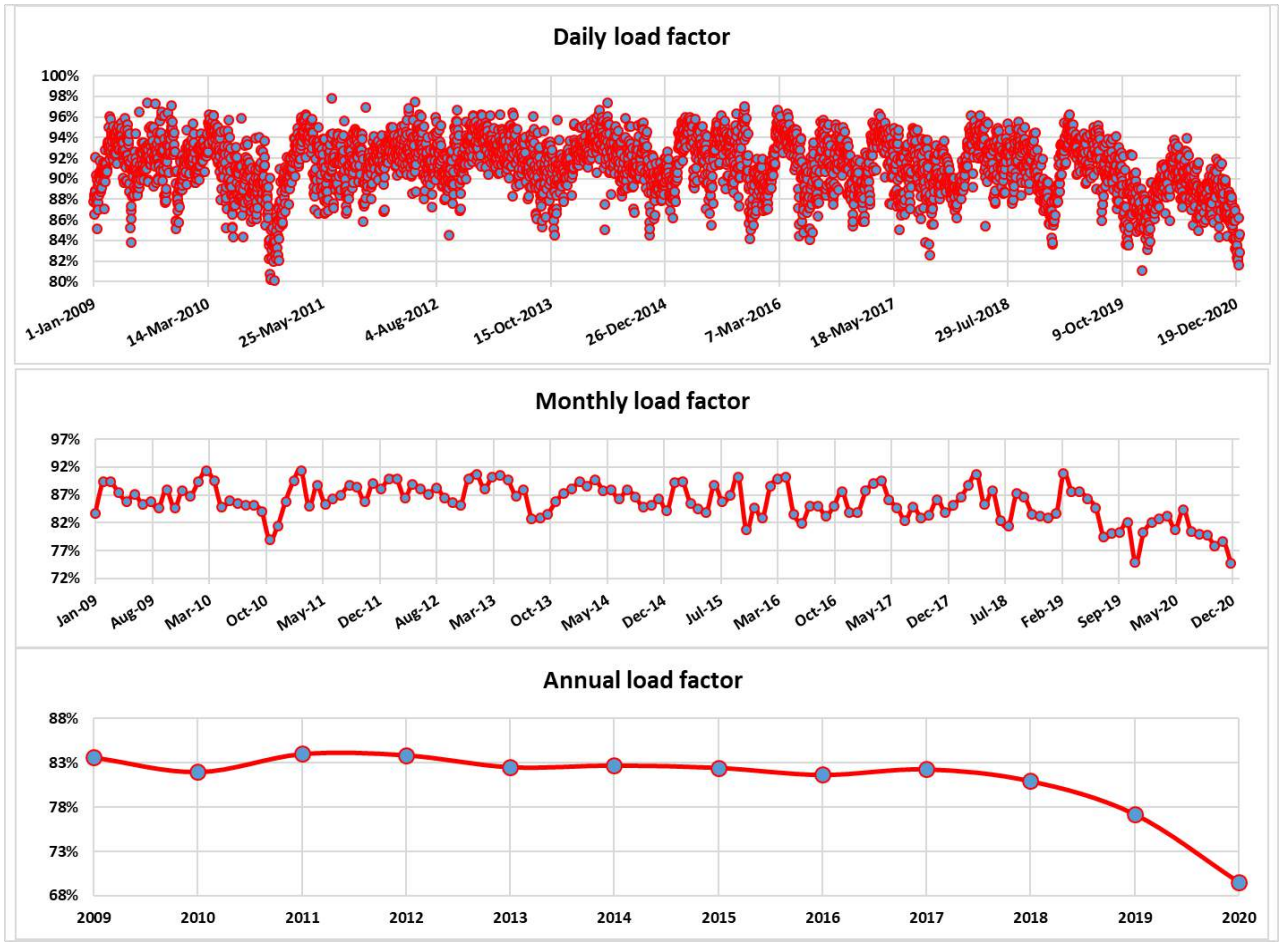


Figure 51:Variation of Southern Region load factor

11.5. Eastern Region

a) Average Load Factor (%):

Average Daily Load Factor from 2009-2020	85
Average Monthly Load Factor from 2009-2020	79
Average Annual Load Factor from 2009-2020	73

b) Highest/Lowest Load Factor Occurrence:

Month/Period of Highest Load Factor	Apr-May
Month/Period of Lowest Load Factor	Nov-Dec

c) Seasonal decomposition of load factor trend:

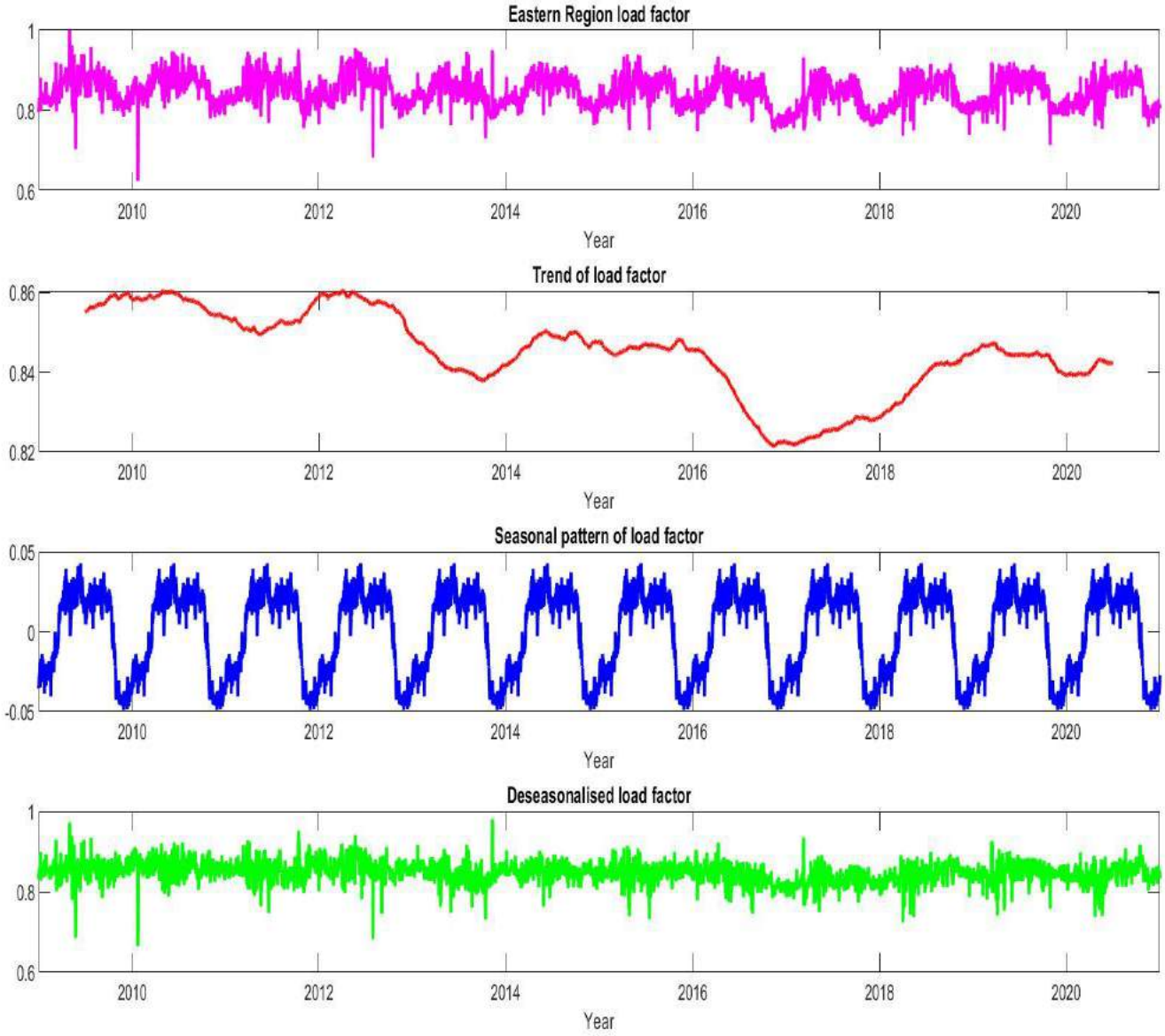


Figure 52:Seasonal decomposition of ER load factor trend

d) Linear fitting of Load factor trend:

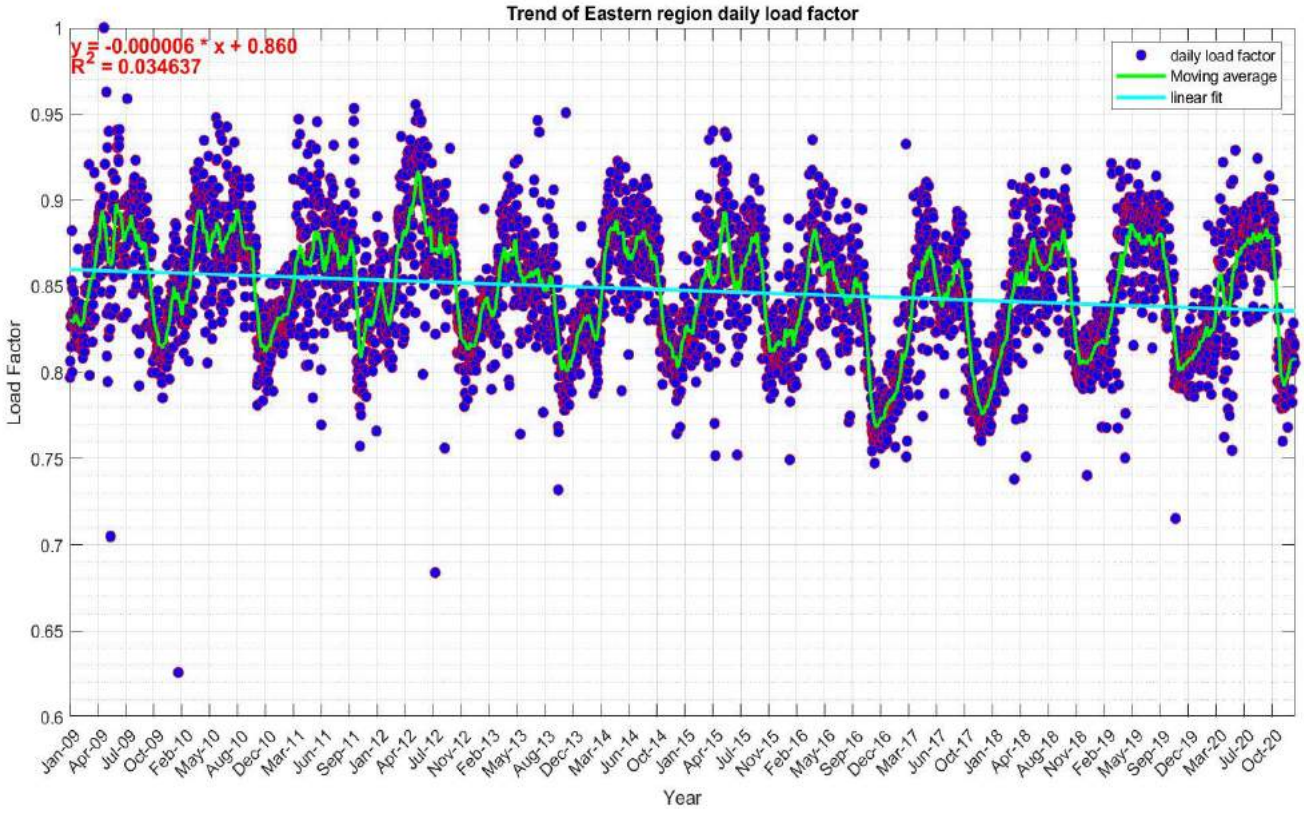


Figure 53:Linear fitting of ER Load factor trend

e) Growth in Maximum, Minimum and Average alongwith Load Factor:

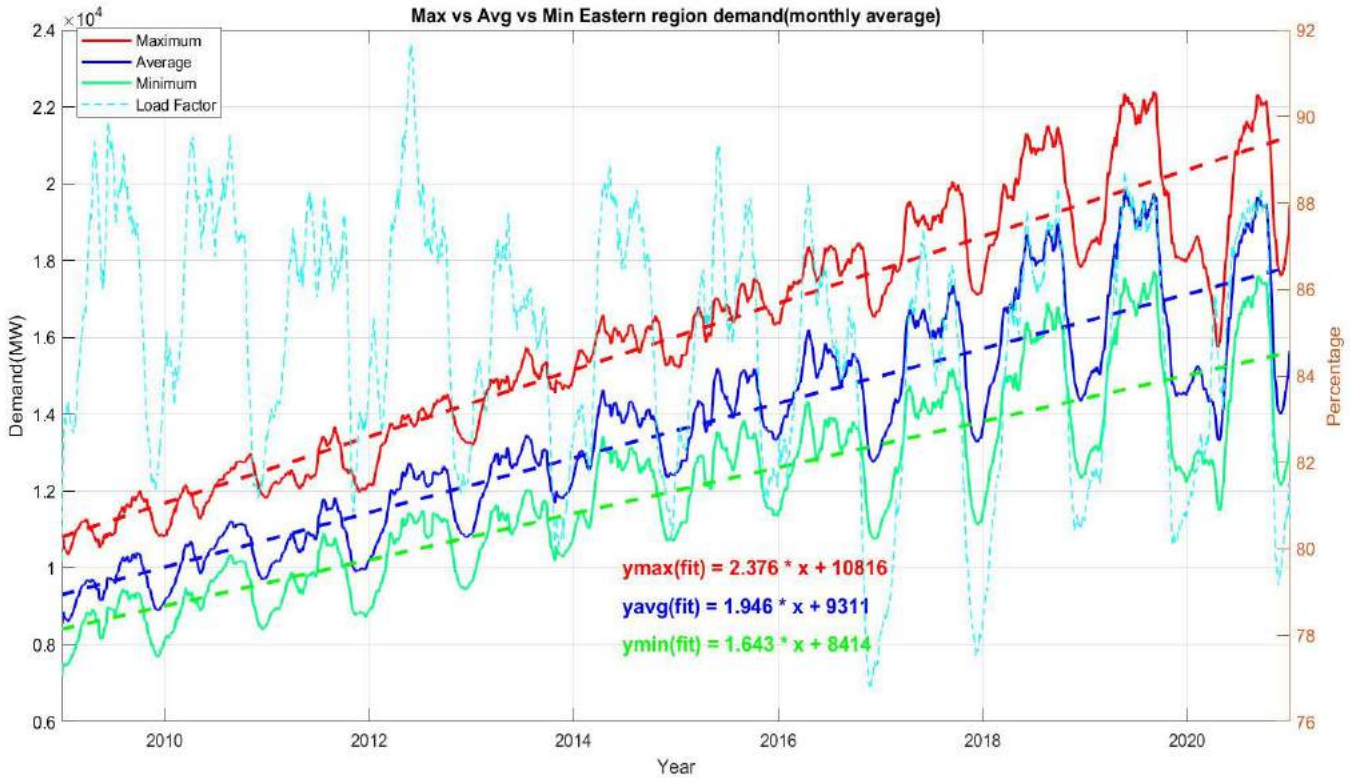


Figure 54:Growth in Maximum, Minimum and Average demand alongwith ER Load Factor

f) Heatmap of monthly average load factor:

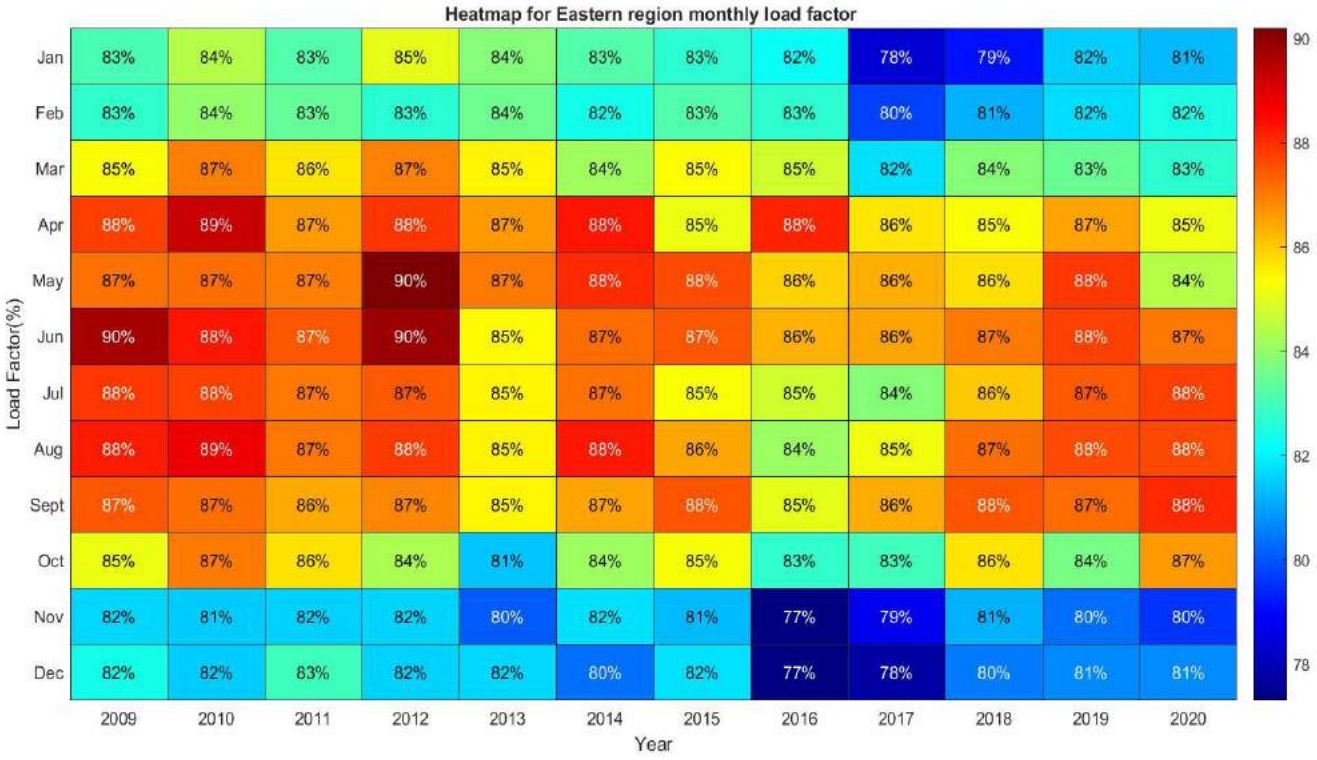


Figure 55:Heatmap of ER monthly average load factor (mean of daily load factor)

g) Duration curve of load factor:

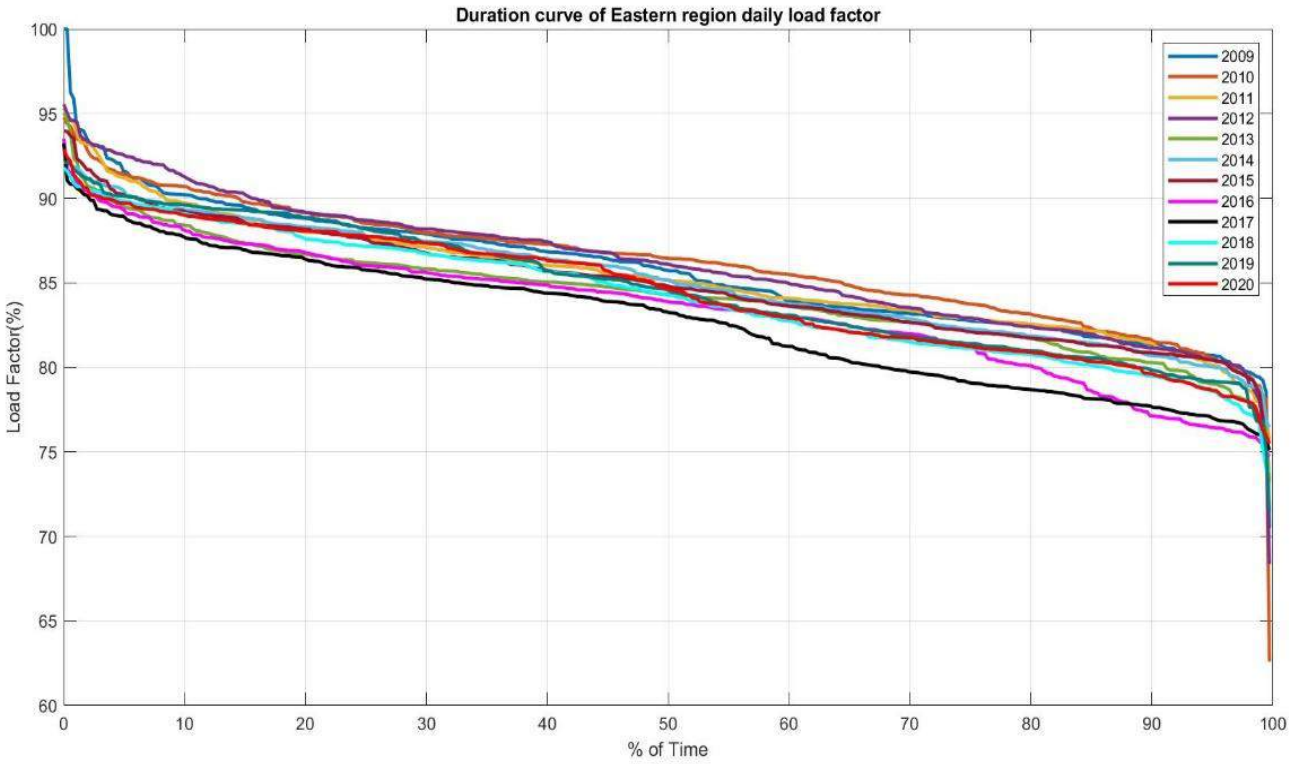


Figure 56:Duration curve of ER load factor

h) Cycle-Sub series plot of Load Factor:

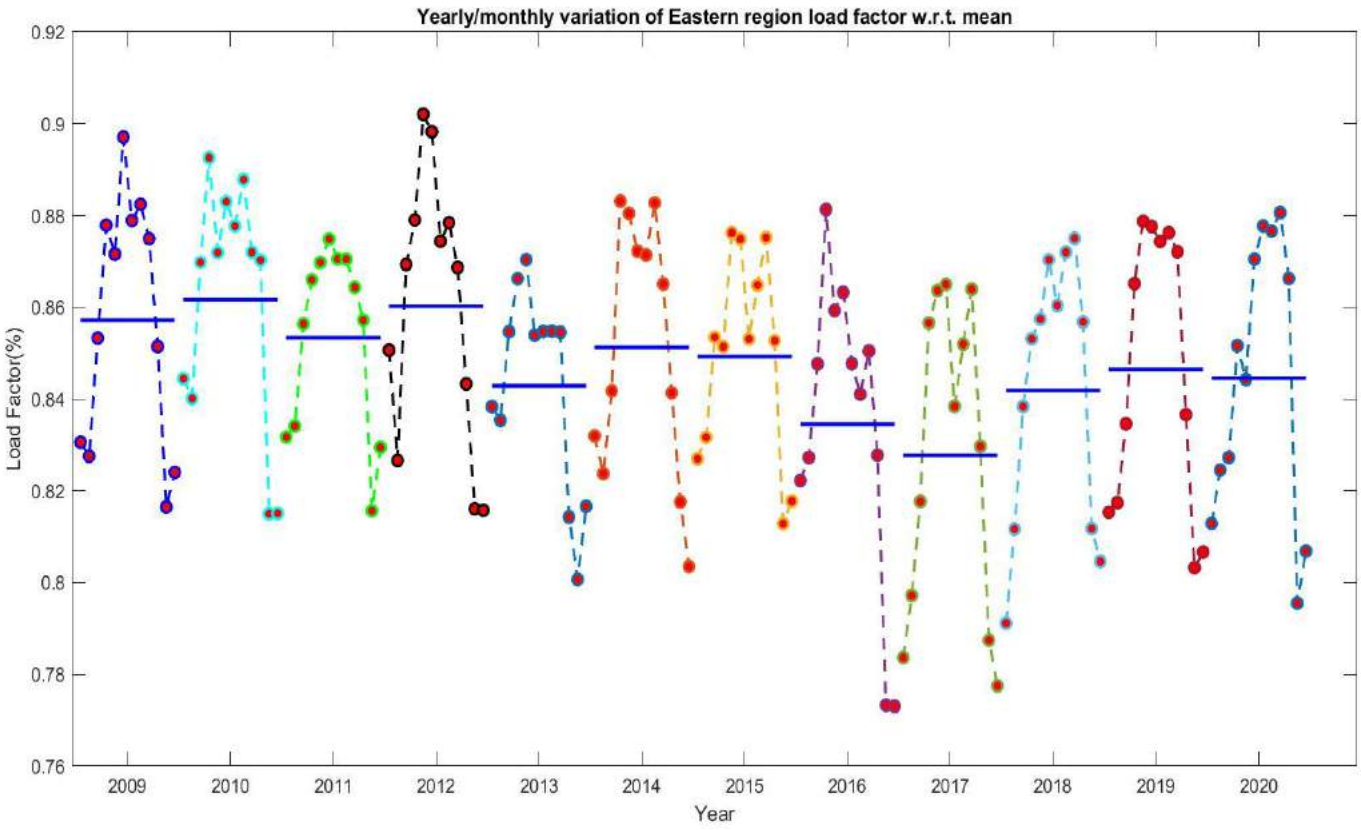


Figure 57:Cycle-Sub series plot for Yearly/Monthly variation of ER Load Factor

i) Concentration of Load factor:

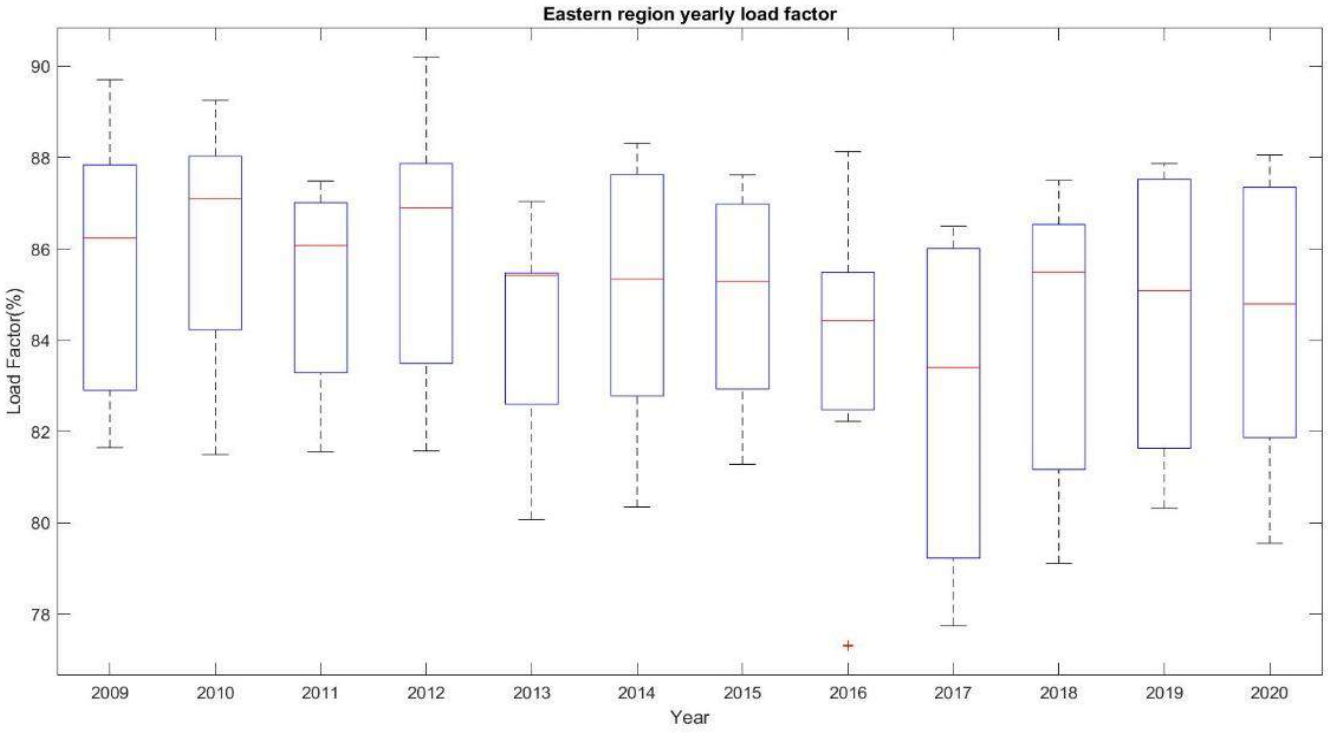
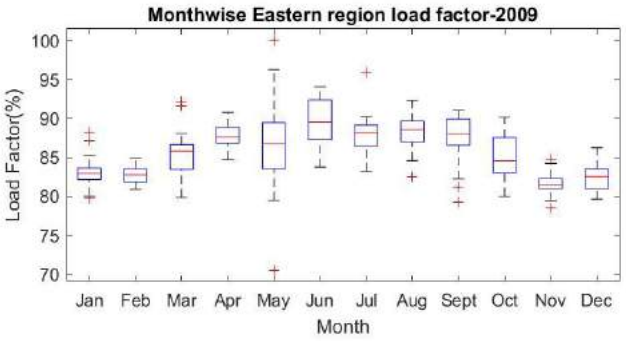
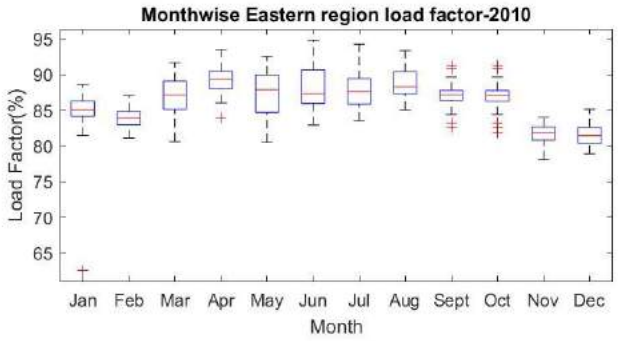
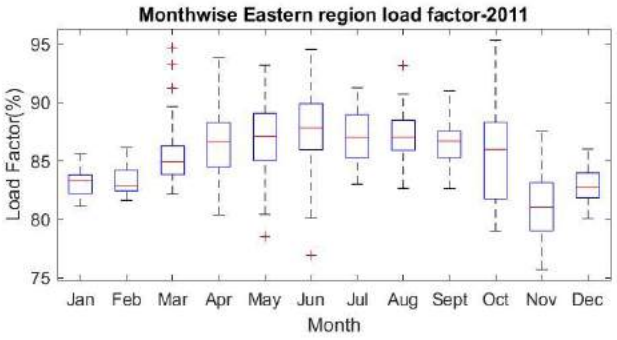


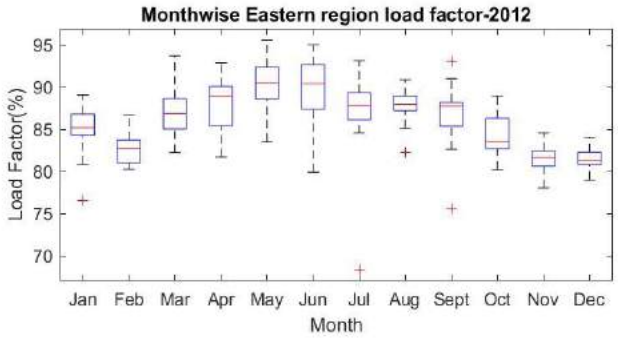
Figure 58:Concentration of ER Load factor

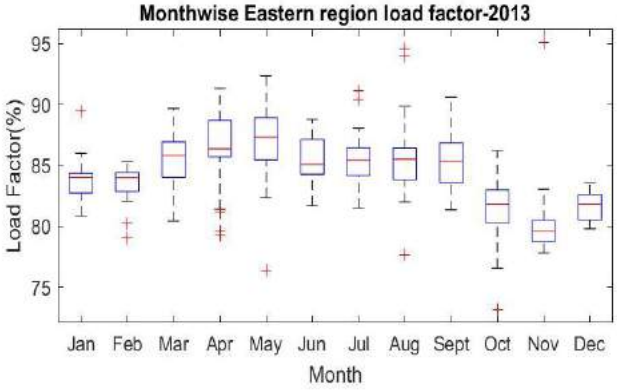
j) Monthly Variation of Load Factor over the years:

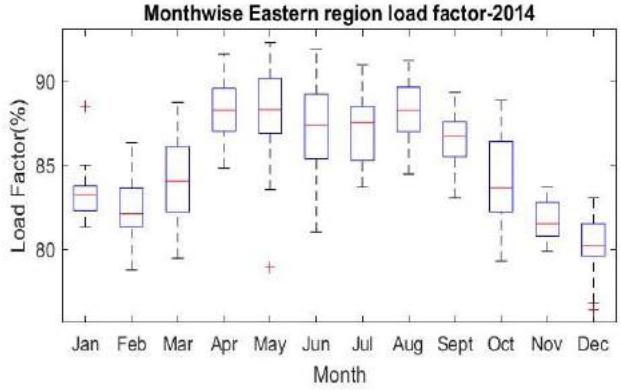


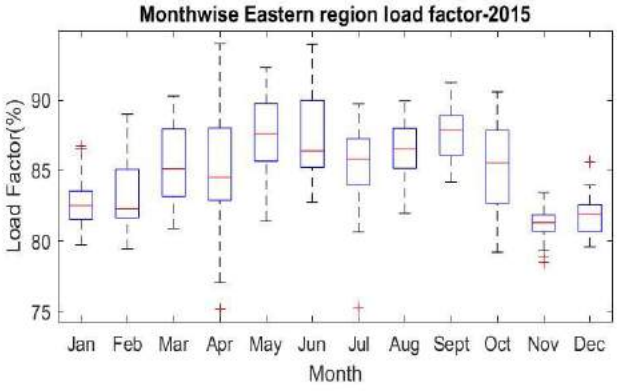


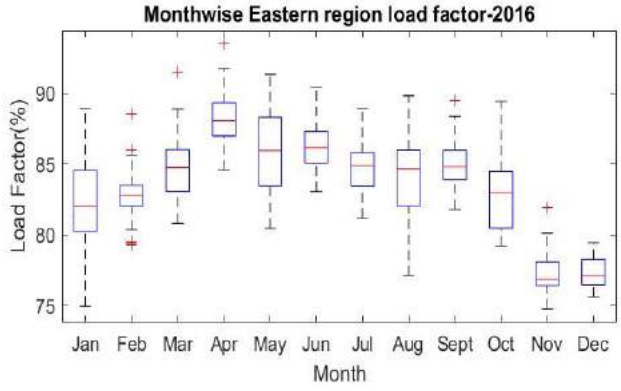












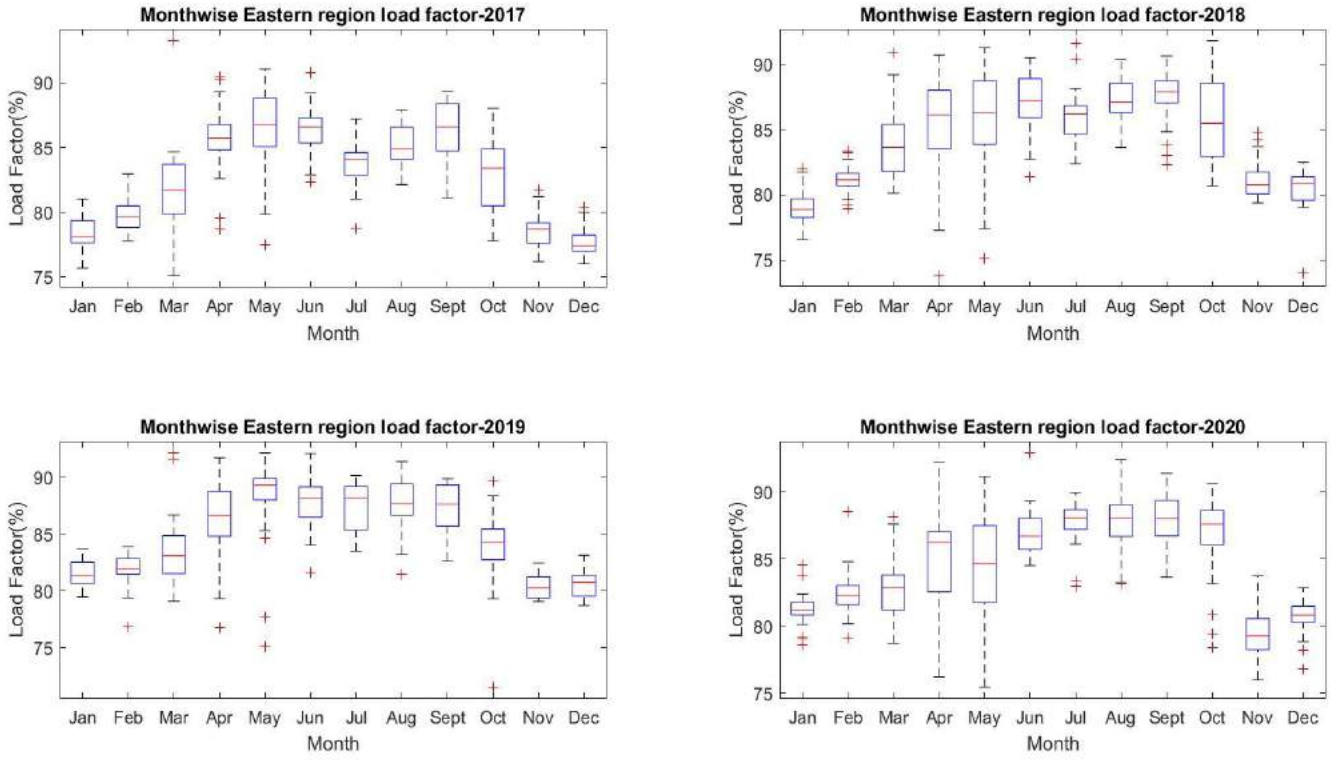


Figure 59:Monthly Variation of Load Factor over the years for ER

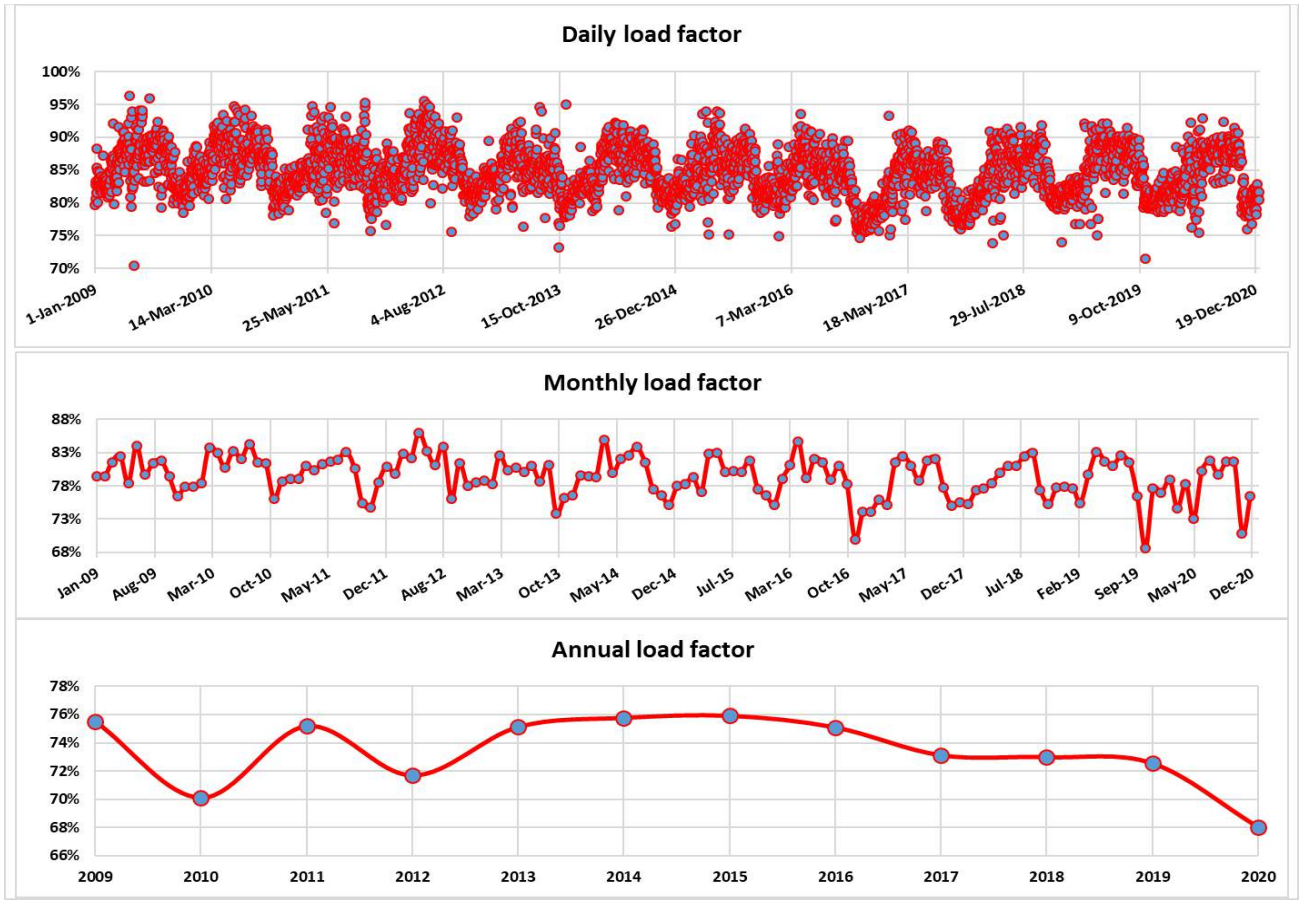


Figure 60:Variation of Eastern Region load factor

11.6. North Eastern Region

a) Average Load Factor (%):

l Factor from 2009-2020	73
.oad Factor from 2009-2020	67
ad Factor from 2009-2020	59

b) Highest/Lowest Load Factor Occurrence:

Month/Period of Highest Load Factor	Jul-Aug
Month/Period of Lowest Load Factor	Mar-Apr

c) Seasonal decomposition of load factor trend:

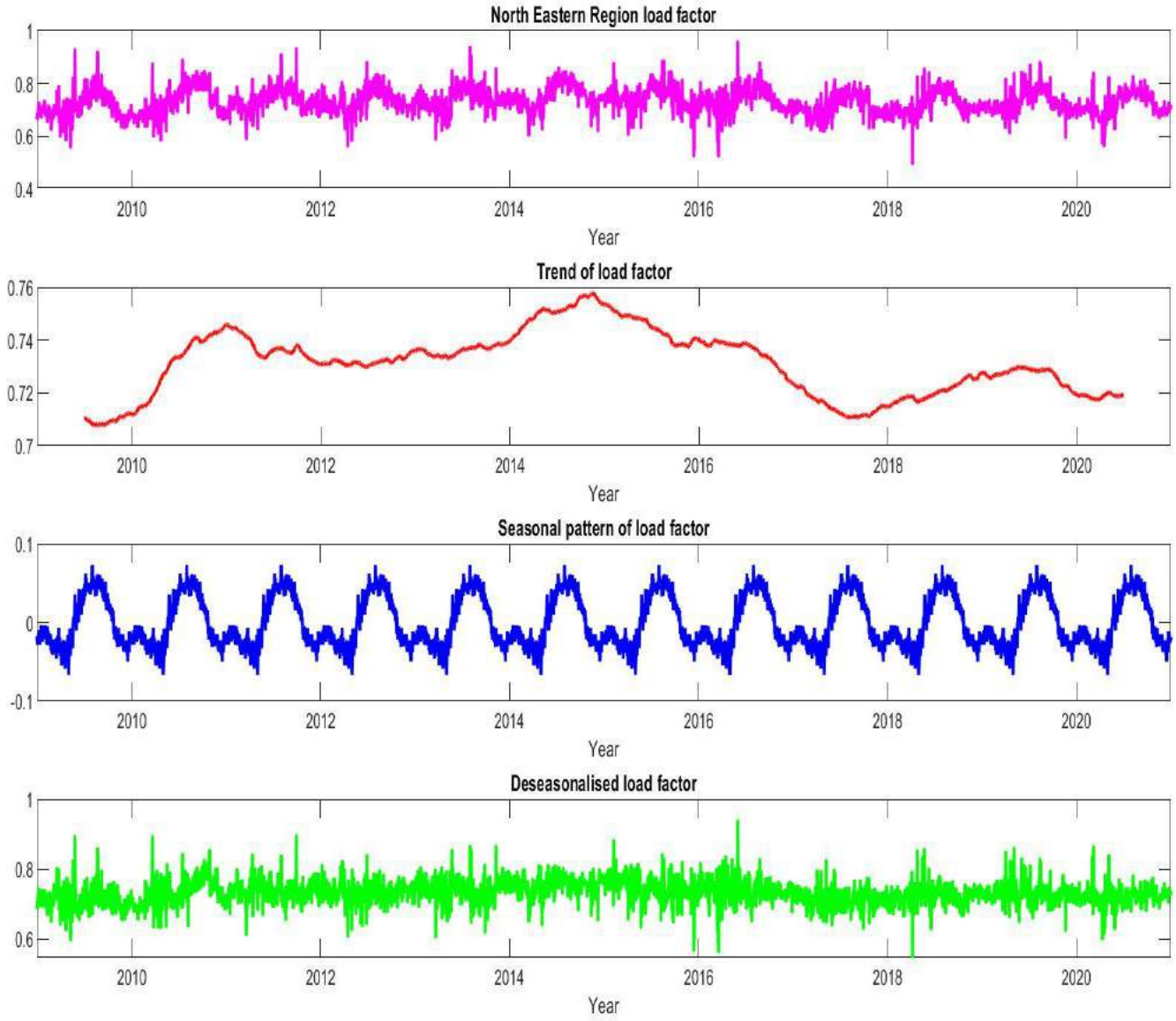


Figure 61:Seasonal decomposition of NER load factor trend

d) Linear fitting of Load factor trend:

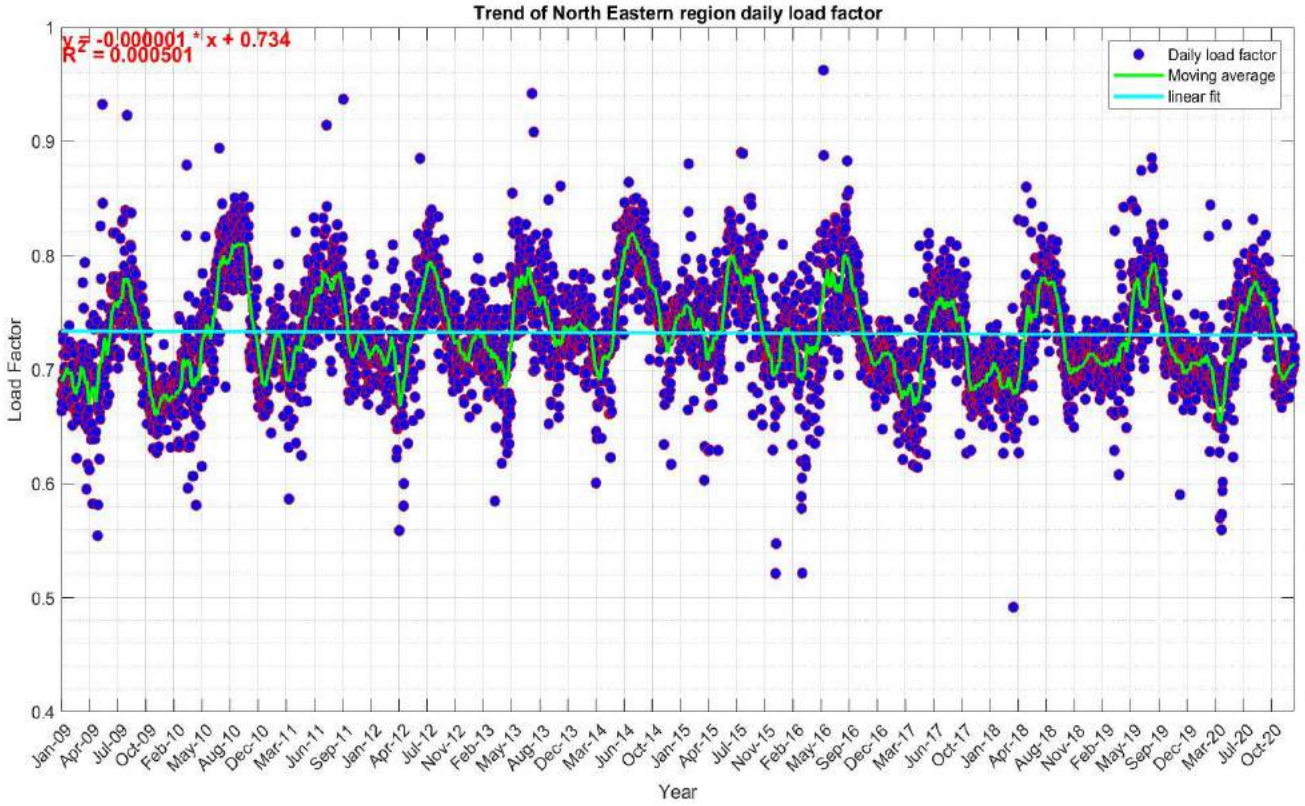


Figure 62:Linear fitting of NER Load factor trend

e) Growth in Maximum, Minimum and Average alongwith Load Factor:

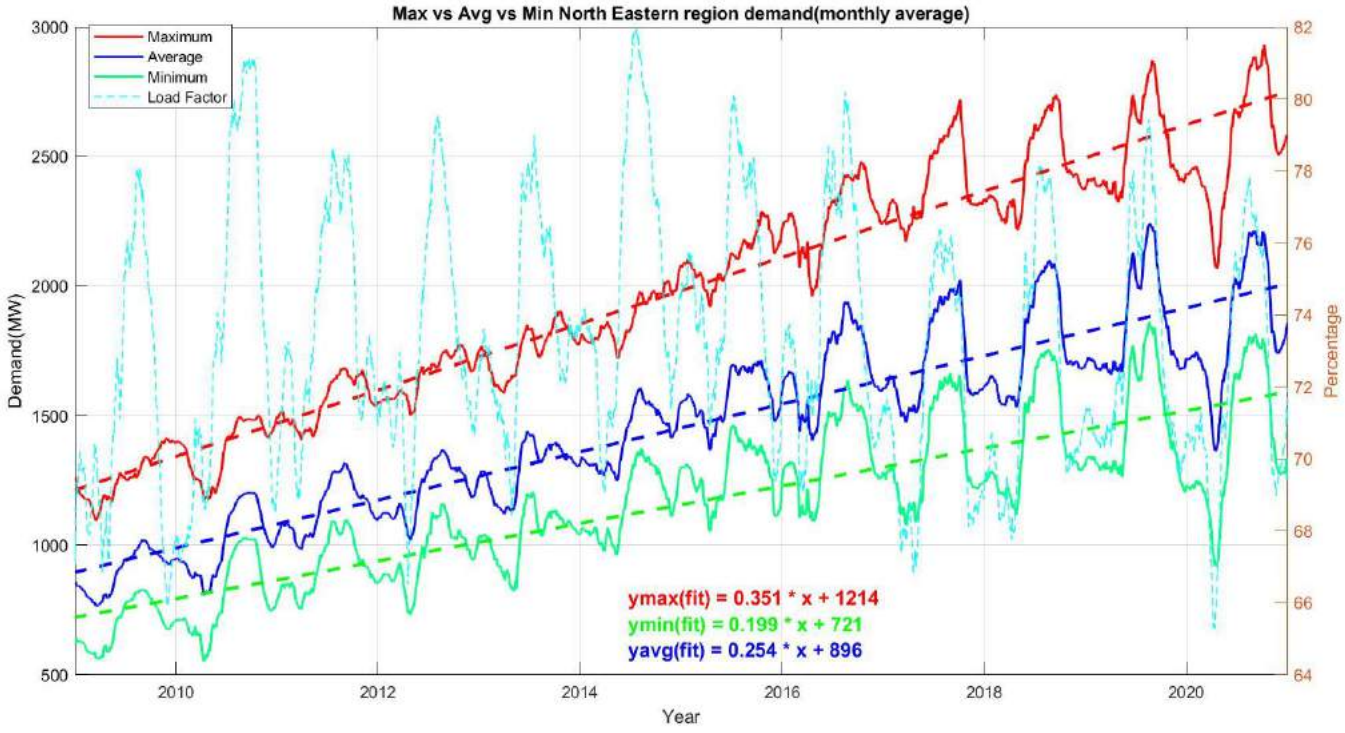


Figure 63:Growth in Maximum, Minimum and Average demand alongwith NER Load Factor

f) Heatmap of monthly average load factor:

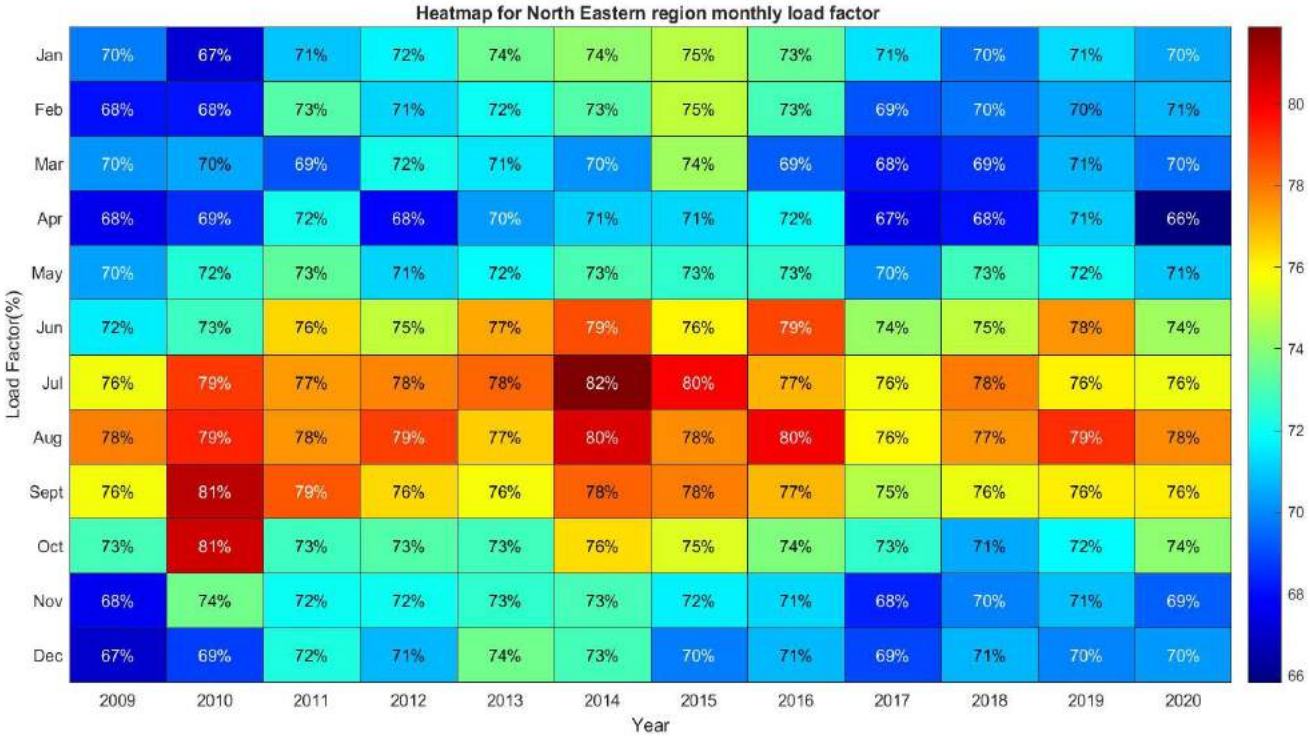


Figure 64:Heatmap of NER monthly average load factor (mean of daily load factor)

g) Duration curve of load factor:

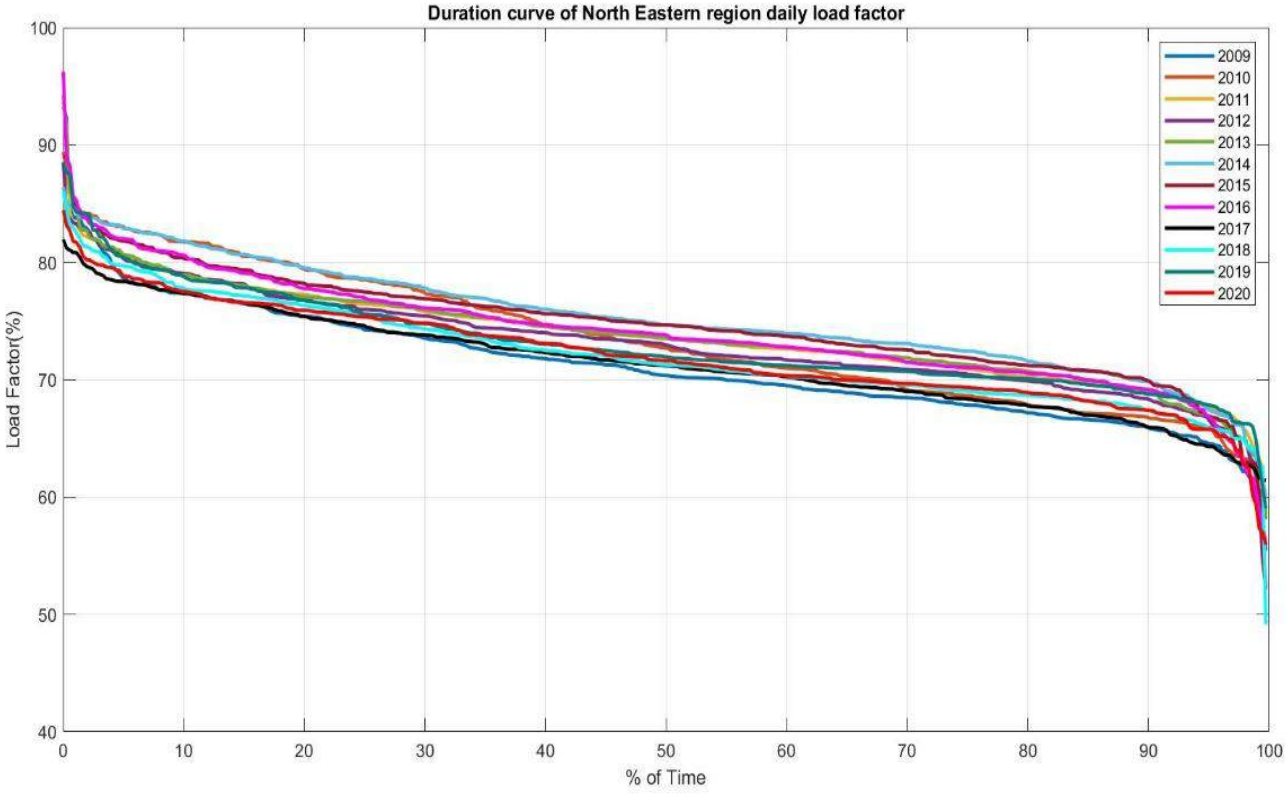


Figure 65:Duration curve of NER load factor:

h) Cycle-Sub series plot of Load Factor:

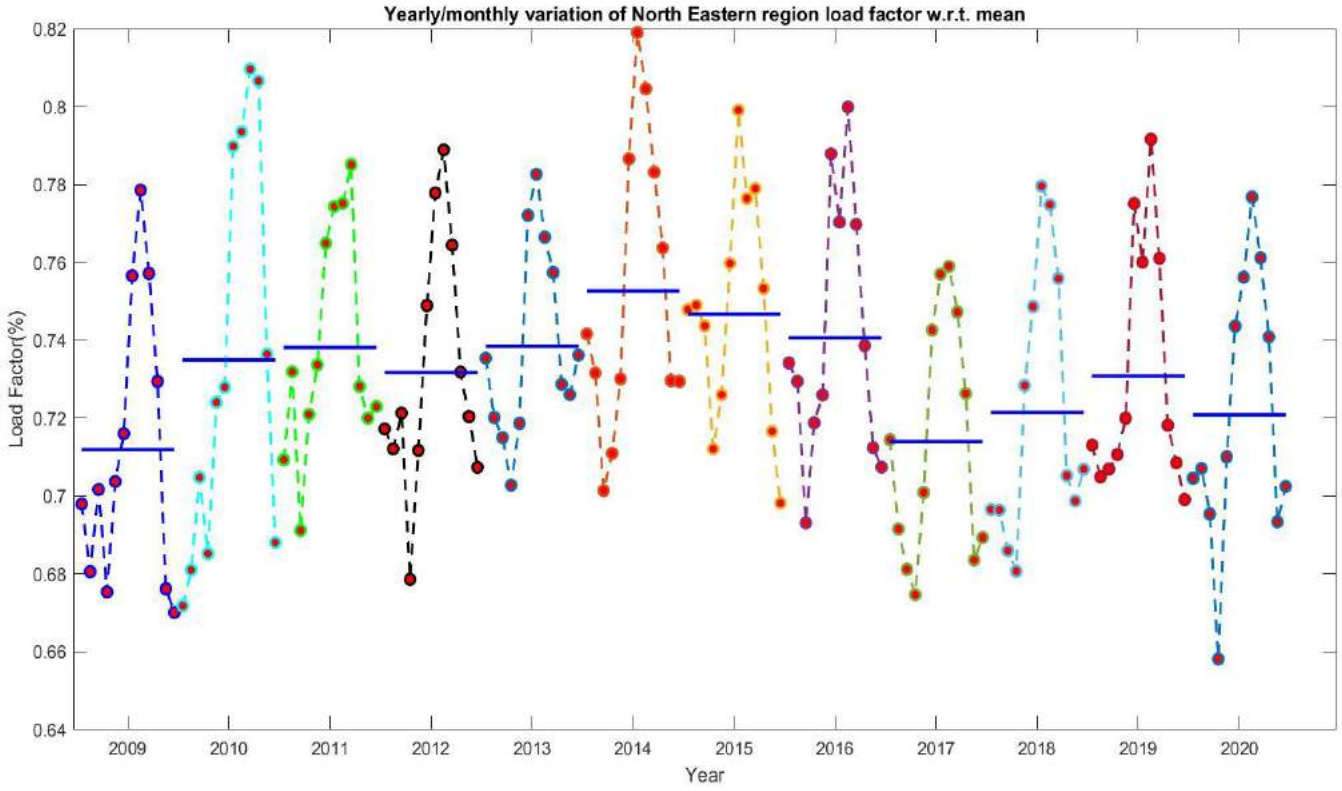


Figure 66:Cycle-Sub series plot for Yearly/Monthly variation of NER Load Factor:

i) Concentration of Load factor:

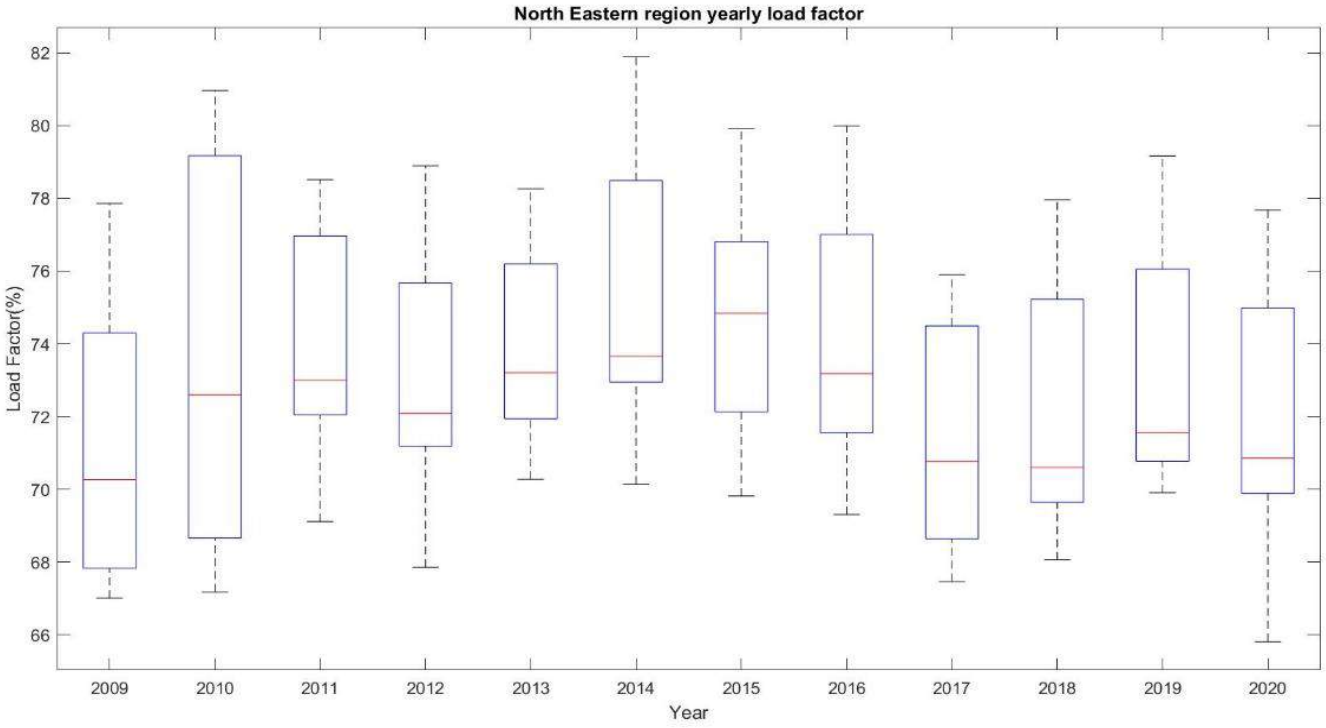
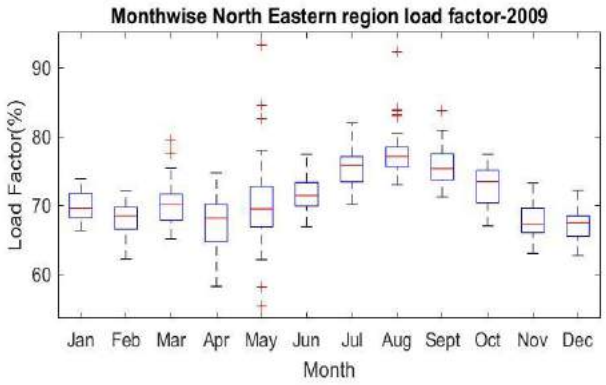
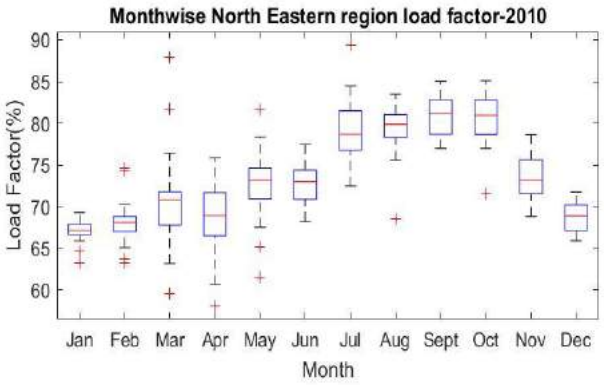
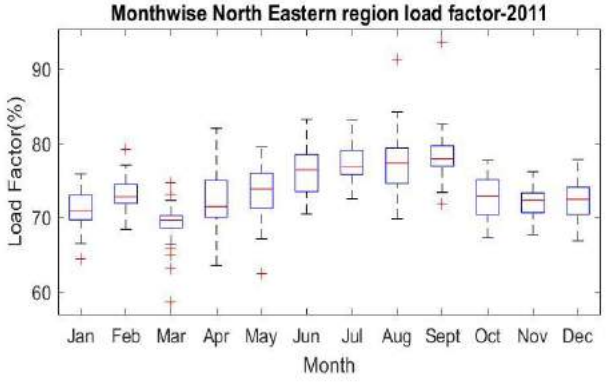


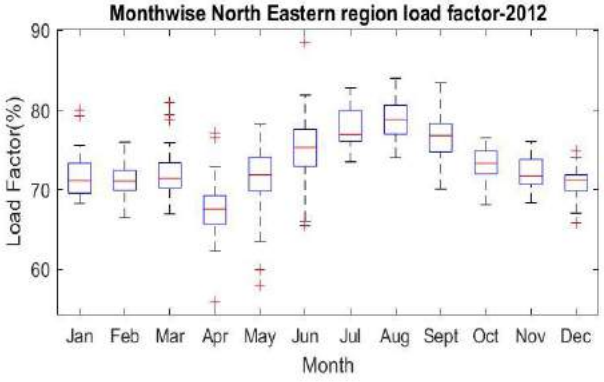
Figure 67:Concentration of NER Load factor

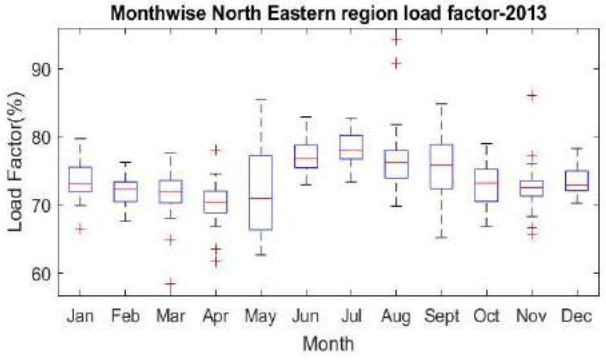
j) Monthly Variation of Load Factor over the years:

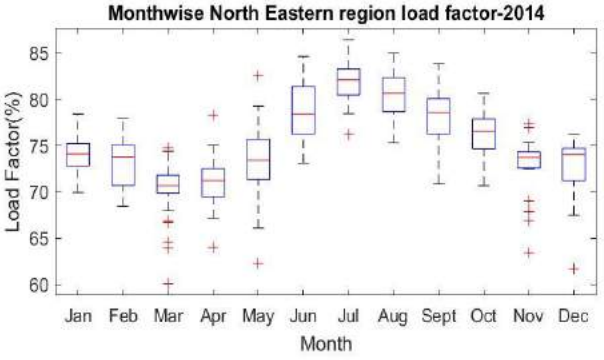


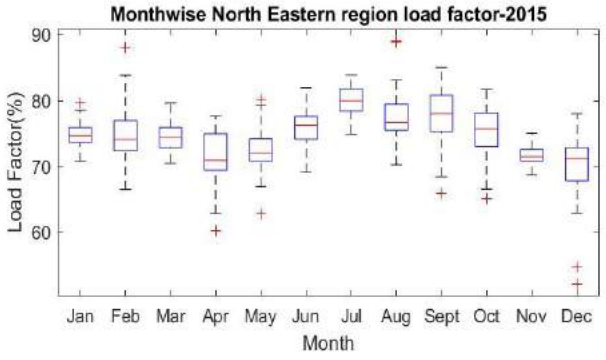


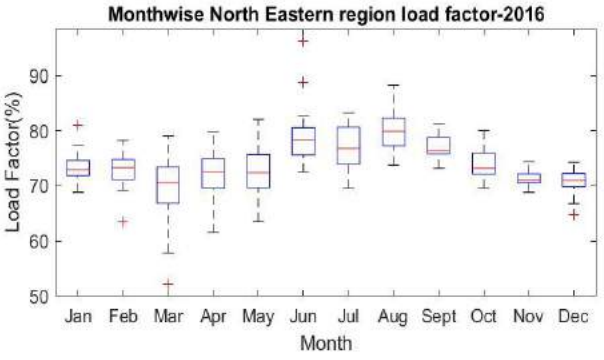












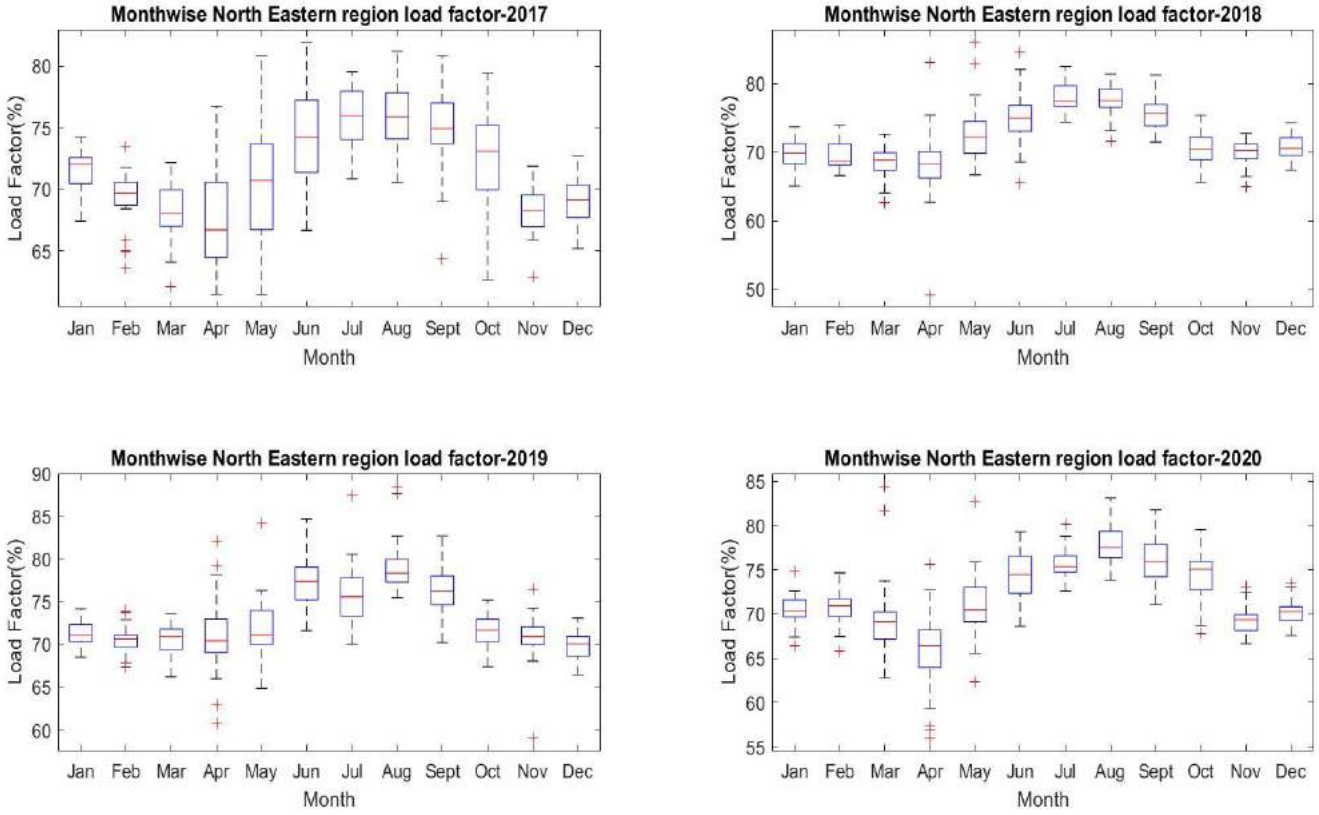


Figure 68:Monthly Variation of Load Factor over the years for NER

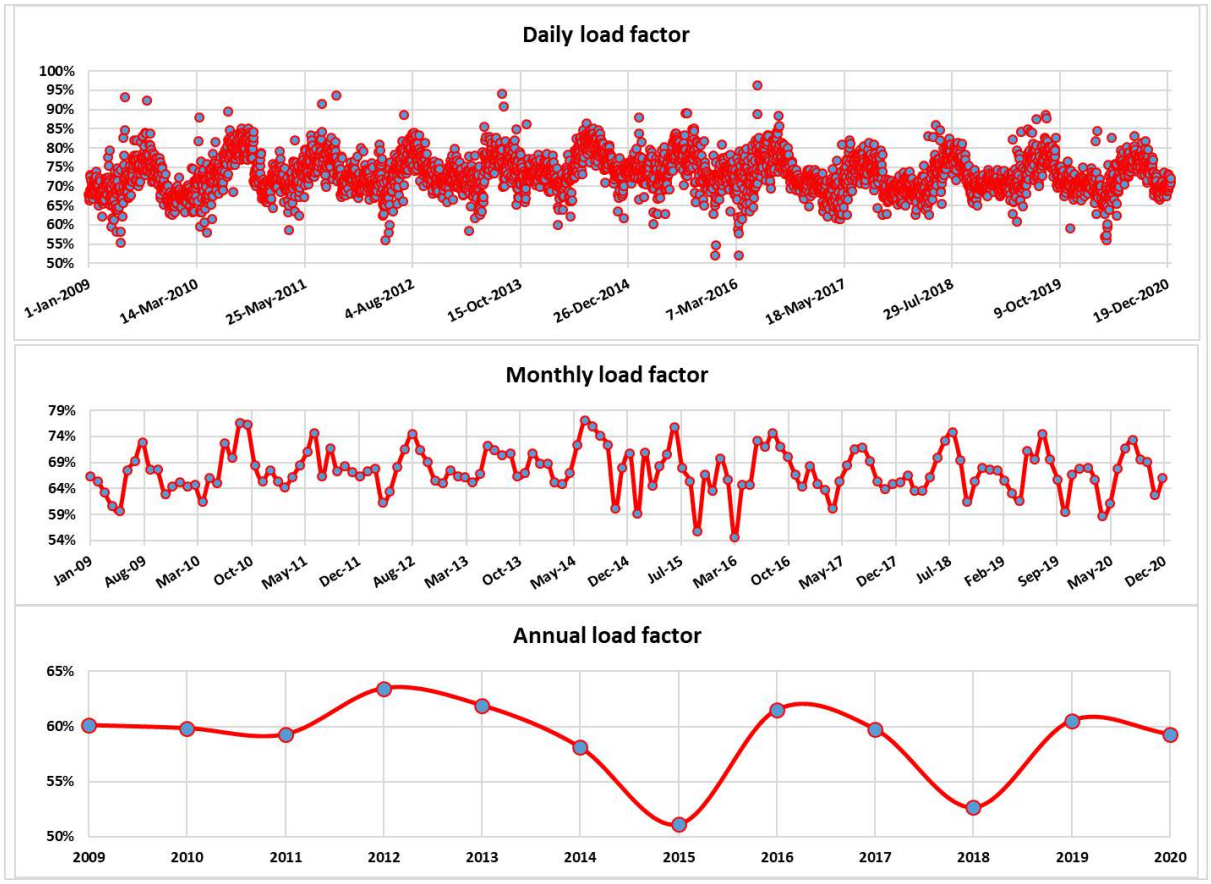
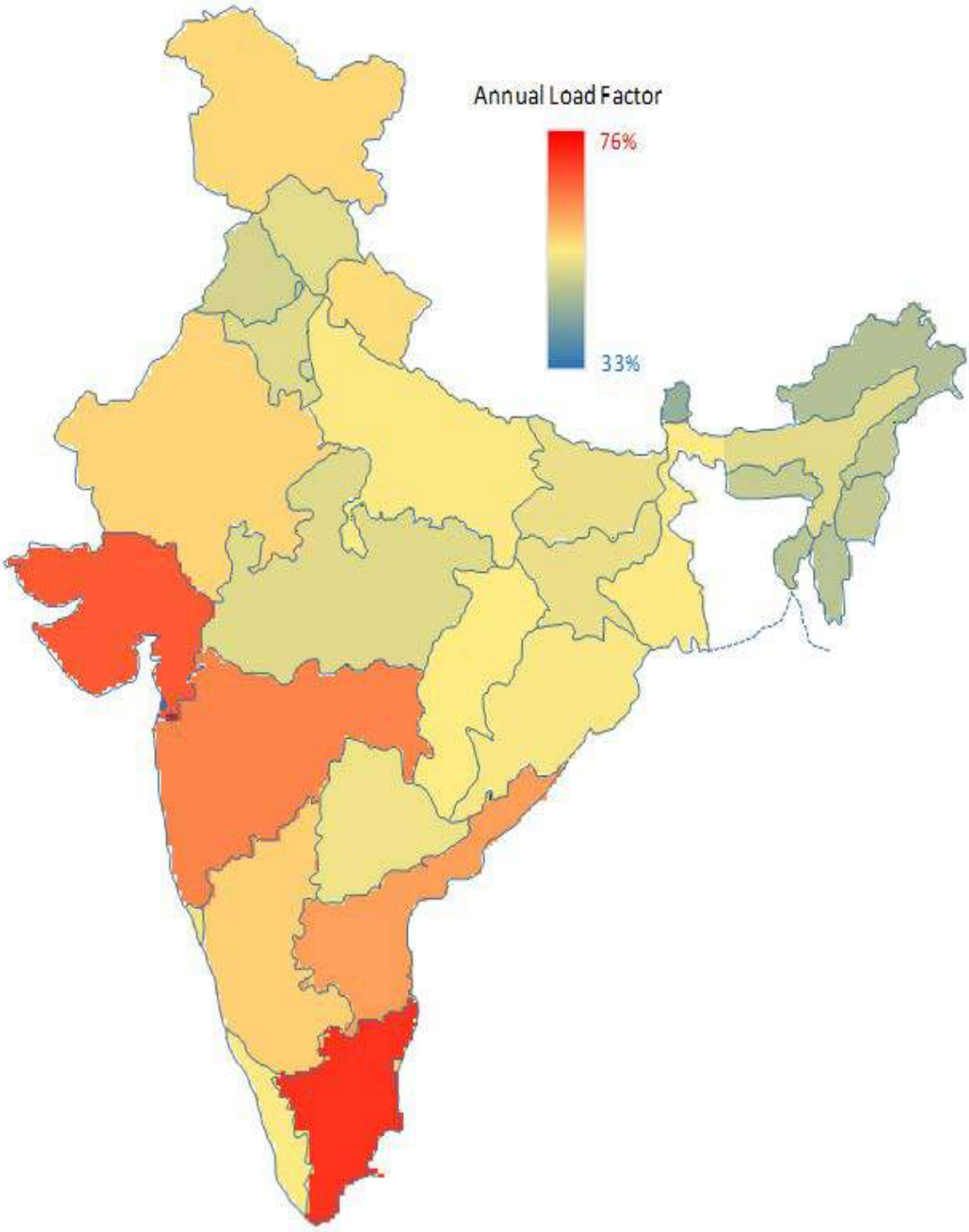


Figure 69:Variation of NER load factor



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