महापारेषण

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(CIN NO U40109MH2005SGC153646)

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MSETCL/CO/STU/Sys/SGC/[illegible] 5170 **Date:** 8 AUG 2024

NOTICE

Inviting Comments / Suggestions on the Draft "Integrated Resource Plan" prepared by IIT-Bombay in consultation with STU & SLDC for Five Years (FY 2023-24 to FY 2027-28)

Hon'ble MERC has issued, the MERC (State Grid Code) Regulations, 2020, notified on dated 02.09.2020. The Regulation No. 11 (ii) of the said Regulations is reproduced below:

Based on the generation resource plans of distribution licensees, STU in consultation with SLDC shall develop Integrated Resource Plan for next five years for the state.

Based on the above directives, IIT-Bombay in consultation with STU and SLDC has formulated draft **Integrated Resource Plan** in accordance with the said Regulations and is hereby published on dated 8 August, 2024 on MSETCL's Website (STU section): www.mahatransco.in, for seeking comments / suggestions, if any, from various Stake holders. In view of above, it is requested to offer valuable comments/suggestions if any on the said Draft Integrated Resource Plan for next five Years in the Maharashtra State. After receipt of the comments / suggestions from various stake holders, the same shall be scrutinized and draft shall be finalized.

The details for submission of comments / suggestions are as follows:

Last date of submission	:	**23 August, 2024 by 18.00 Hrs.**
Mode of submission	:	**Soft copy in '.xls' form in the attached format along with 'PDF' copy through e-Mail. No hard copy is required.**
E-Mail Id	:	sesys@mahatransco.in

Inviting Comments / Suggestions on the Draft Integrated Resource Plan" prepared by IIT-Bombay in consultation with STU & SLDC for Five Years (FY 2023-24 to FY 2027-28)

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Please make a note that any submission after the mentioned date & time and comments/ submission on any other e-mail-ids' of MSETCL shall not be considered.

Encl: 1) Draft Integrated Resource Plan
2) Format for Comments

Place : Prakashganga, BKC,
Bandra (E), Mumbai: - 400051.

Date : 8 August, 2024

Yours faithfully,

(P.S. Sharma)
Chief Engineer
(State Transmission Utility)

Inviting Comments / Suggestions on the Draft Integrated Resource Plan" prepared by IIT-Bombay in consultation with STU & SLDC for Five Years (FY 2023-24 to FY 2027-28)

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Format for submission of Comments/Suggestions

Name of Stake holder:			
Sr. No	**Draft IRP Section**	**Comments of the Stakeholder**	**Suggestion of the Stakeholder**

Note: *Suggestions on any additional points which are not covered in the Draft Integrated Resource Plan shall be added separately as "Additional".*

Above format is to be submitted in "excel" form through e-mail for ease of consolidation of comments of all the Stakeholders.

Maharashtra State Integrated Resource Planning for Five Years (2023-2028)

Technical Report

by

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March 2024

Contents

Abbreviation

RES	Renewable Energy Resources
EVs	Electric Vehicles
IRP	Integrated Resource Planning
RA	Resource Adequacy
UC	Unit Commitment
FOR	Forced Outage Rate
CUF	Capacity Utilization Factor
LOLH	Loss of Load Hours
LOLP	Loss of Load Probability
ENS	Energy Not Served
NENS	Normalized Energy Not Served
PRM	Planning Reserve Margin
RA	Resource Adequacy
VaR	Value at Risk
CVaR	Conditional Value at Risk
NEP	National Electricity Plan
ERCOT	Electric Reliability Council of Texas

1 Abstract

As per CEA guidelines, utilities are required to conduct a five-year resource adequacy assessment study on a one-year rolling basis. This study was initiated by MSETCL for FY 23-24 to FY 27-28. It is a first-of-its-kind exercise. This report details data collection, methodology and salient findings for the five years. The thresholds for LOLP and NENS given by CEA are one day in ten years and 0.05%, respectively. The last two years of the planning horizon show higher values of Loss of Load Probability (LOLP) but Normalized Energy Not Served (NENS) is found to be well within bounds. We suggest planning Battery Energy Storage Systems and capacity additions in subsequent years as remedial measures.

2 Introduction

Ensuring uninterrupted power supply to the end consumers is one of the main requirements of a power system network. This requirement is termed as resource adequacy and the process to plan this much ahead of the actual timeline is resource adequacy assessment. The resource adequacy assessment is carried out at different timescales and it is an integral part of the power system planning. The resource adequacy assessment, hitherto, has been carried out considering only demand uncertainty and forced outage of the system components. However, the increasing penetration of mainly Renewable Energy Resources (RES) on the supply side and Electric Vehicles (EVs), demand response, peer-to-peer trading, and demand side management has complicated the assessment. There are several factors accounting for uncertainty on the supply side, demand side as well as market interactions. Once the resource adequacy is ascertained electric transportation network adequacy should also be ascertained.

The recent guidelines by the Central Electricity Authority mandate the utility to determine the resource adequacy for the next five years and then revise it yearly Central Electricity Authority, 2023. The metrics to be used for the RA framework are Loss of Load Probability (LOLP), Normalized Energy Not Served (NENS), and Planning Reserve Margin (PRM).

3 Methodology

This section presents the methodology used for the Maharashtra State resource adequacy assessment for the next five years (FY 23-24 to FY 27-28). The study was initiated in FY 23-24.

Inputs to the resource adequacy assessment model include demand, RES data, generation resources data, market data, and energy storage data. The demand data includes the historical demand profile and demand projections for the planning horizon. The generation data include information for existing and planned capacities for renewable and conventional generation, historical RE generation profile unit-wise, historical forced outage data, MoD rate for state/IPP generators, historical hydro scheduling profile, and future commissioning and decommissioning plans. Finally, the storage data include the existing and planned storage such as Pumped Hydro, and Battery ESS. At present, energy storage is minuscule and there are no energy storage expansion plans.

The historical normalized demand and solar and wind generation profiles are used to create a representative day (59 days per year in this study). The reasoning behind 59 representative days is given in Section 2.1. Then net demand scenarios are generated for a futuristic demand projection trend. [1] Generator availability is calculated by drawing a random number from the uniform distribution of the historical forced outages. Then, all the inputs are given to the Resource Adequacy block which checks the adequacy and RPO target satisfaction. This is done by solving the Unit Commitment problem for several Monte Carlo runs. If the existing installed capacities are adequate then we calculate the planning reserve margin.

If the resources are not adequate then report the gap in RPO targets, report LOLP and EENS, and suggest additional resource requirements, market procurement requirements and storage sizing. Histograms of LOLP and EENS are used to estimate the Value at Risk (VaR) and Conditional Value at Risk (CVaR) [2] of LOLP and EENS is reported for different confidence levels.

A summary of the resource adequacy methodology is shown in Figure 1. The figure shows the key components of the resource adequacy assessment which are explained in this section:

1. Clustering for selection of representative days
2. MC-based probabilistic Unit Commitment
3. Estimation of reliability metrics such as LOLP, NENS.

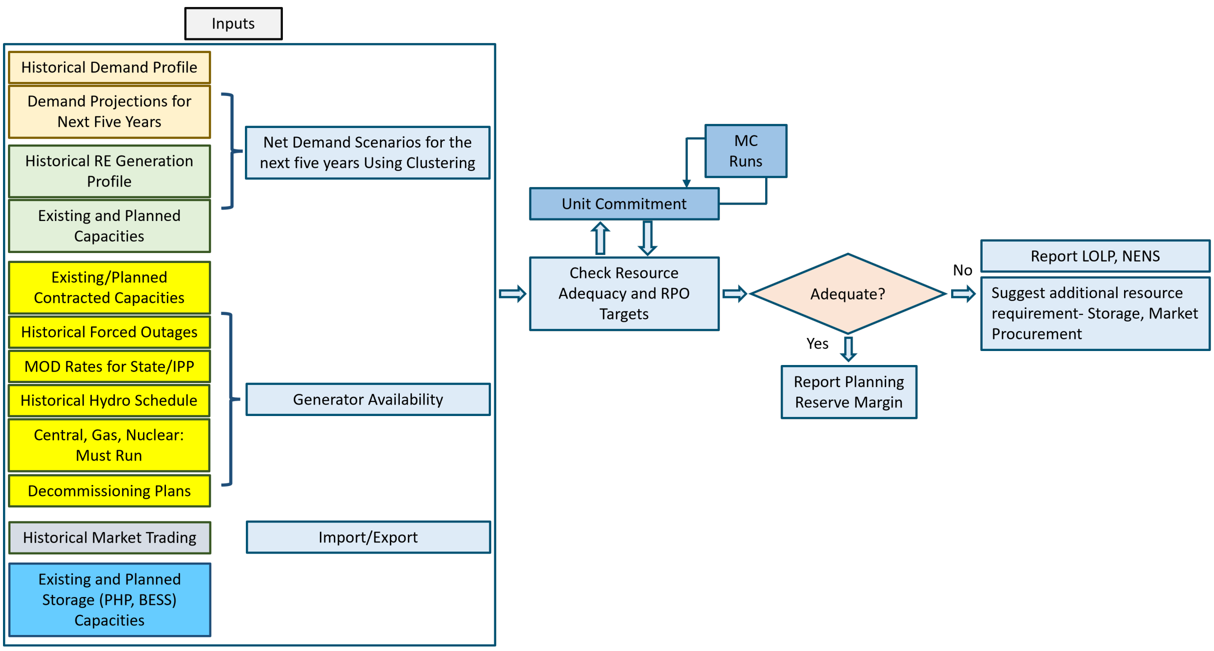


Figure 1: Methodology for the Integrated Resource Planning Study

[1] Percentage trend values obtained from MSEDCL are 6.5, 4.5, 4.3, 4.1, 3.8 for FY 23-24 to FY 27-28 respectively.

[2] For a distribution of cost function, VaR represents the minimum worst case cost with a certain confidence level. While CVaR determined the expectation of the worst-case costs beyond VaR for that particular confidence level.

3.1 Clustering of demand, solar and wind generation profiles of FY 22-23

Clustering is an unsupervised machine-learning technique widely used for reducing the size of the power system planning problems. There are several clustering approaches such as K-means, K-medoids, DB-scan, hierarchical clustering, etc. K-means clustering is the most widely used clustering approach, followed by the K-medoid approach. Using one over the other can be the user's choice. However, it is important to note that clusters or the representative days obtained from the K-means clustering do not represent the real profile of any of the days in the historical data, as a cluster is the mean of all the days in that particular cluster. On the other hand, the K-medoid cluster is the median of all the days in a particular cluster, and thus it represents the actual day in the historical data which is likely to materialize in the future years with a high confidence level. There can be significant differences in the load or generation profiles of the K-means and K-medoid clusters for the same dataset as shown in the Figure 2. It can be observed from the figure that for a typical DISCOM with a peak demand of around 26 GW the two approaches can result in a difference of up to 1 GW for some time blocks in the representative days for the two techniques. Such a difference can drastically alter the outcome of the RA study. It is more apt to consider the median representative day from the historical data to preserve the actual variation in the dataset. Thus, in the present study K-medoid clustering has been used.

Clustering can be performed for historical demand, solar and wind generation separately. However, separate clustering will result in incoherent clusters (representative days) for demand, solar and wind generation. Thus, clustering is performed on combined normalized data where demand, solar and wind generation data are stacked for each day. Month-wise clustering is done to ensure that each month is represented adequately in the final clusters as shown in Figure 3a. The first step is to find three clusters for the month under consideration. Then, the days corresponding to the maximum demand and minimum solar generation are separated and the probabilities of the three clusters are readjusted. If in some month, the day corresponding to the maximum demand coincides with the day corresponding to the minimum solar generation then four clusters are contained for that particular month. In this study, the month of February has four clusters due to this coincidence. Thus, 59 representative days for each year are obtained with their respective probability of occurrence.

3.2 Probabilistic Unit Commitment for FY 23-24 to FY 27-28

The input to this block is historical forced outage data or availability factor. The outage data is used to estimate the forced outage rates of the generators. Then generator availability is ascertained by random sampling from a uniform distribution of forced outage rate. Finally, N runs[3] of Monte Carlo are performed for Unit Commitment considering the generator availability. The entire process is summarized in Figure 3b.

[3] In this study N was taken to be 101.

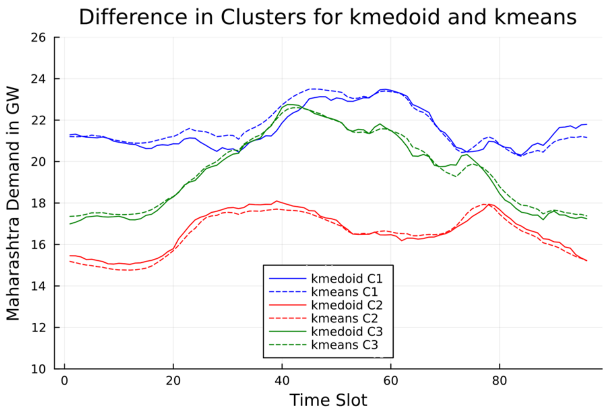
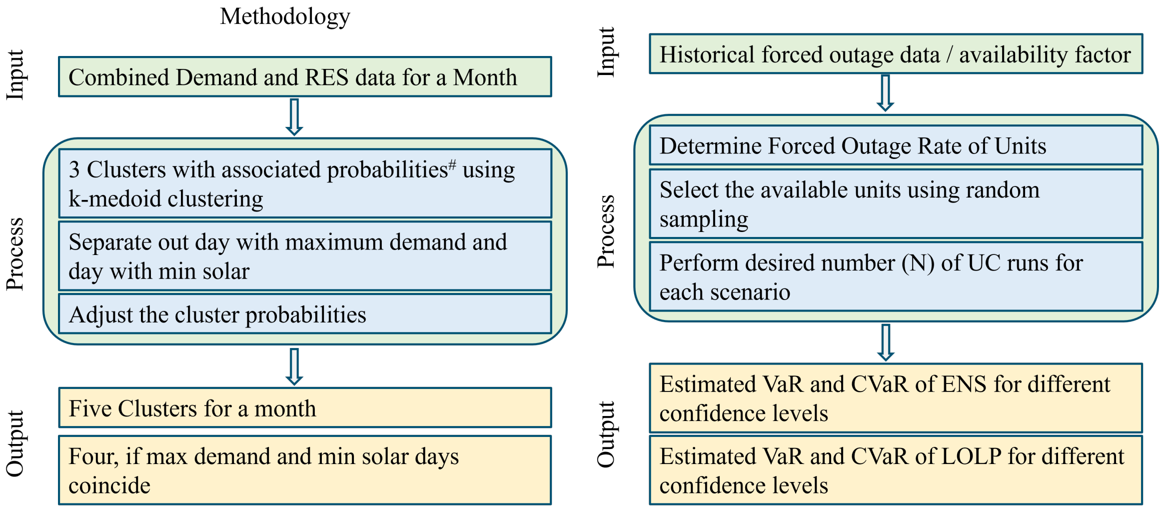


Figure 2: Difference between the representative days for the two clustering approaches-Kmeans and Kmedoids.



(a) Clustering (b) Unit Commitment

Figure 3: Flow charts for K-medoid Clustering for determining representative days Figure 3a, flow chart for MC Simulations for determining the resource adequacy metrics Figure 3b.

3.2.1 Optimization Problem Formulation

The objective function of the program is the net cost of dispatch over the day which is composed of 96 time blocks. This cost has to be minimized. The objective function is linear and the MOD rate for each generator is provided by MSETCL. There are must-run generators for which the rate is taken to be zero. Solar and wind generation are also must-run and their contribution is subtracted from the utility total load value and this adjusted load is the net load used by the program. Solar and wind generation is time-dependent and this feature is already captured by the clustering process. For this purpose, clustering has used normalized values so that it can be scaled for projection years. There can be situations that demand load curtailment or must-run technical minimum may be more than the net load. To handle these scenarios, the penalty function is used in the objective function with residuals to model load curtailment and excess generation. When a feasible solution exists without any load or generation curtailment residuals will be zero.

Nuclear and other renewable generations such as biomass, municipal solid waste, and small hydro plants are considered must-run plants. there are only two nuclear plants at Tarapur and Kakrapar and their FOR is very low, around 0.02%. For municipal solid waste, the capacity factor depends upon the month and this has been captured.

The constraints correspond to minimum and maximum limits for each generator, net power balance equation. In addition, there is a time coupling between the 96 time blocks due to ramping limits on thermal, hydro generation, etc. Ramping costs are taken to be zero. This is based upon the availability of data and for projection exercise related to resource adequacy it is not a constraining factor. Modelling of hydro generation, being reservoir-based, for Koyna and others is based on the energy discharge profiles from the previous year. This limits the net energy that can be used in a day and power limits for the generators are also used. For Koyna, the net minimum generation is considered 40 MW as per the historical profile but individual units can go to zero. For Small hydro plants, their profile was not available, capacity factor of 0.3 was used. Similarly, for biomass , bagasse cogeneration and municipal solid waste, the capacity factor was taken as 0.3, 0.3, and 0.5, respectively.

Markets are not modelled as they should be kept out of resource adequacy exercise. Their inclusion dilutes the goal of the project because it assumes that other players in the country have taken due care of their resource adequacy to make available enough capacity in the market. Such assumptions, in the present regulatory framework, are unrealistic.

3.3 Estimates of Reliability Metrics - LOLP, NENS, VaR, and CVaR

The most commonly used reliability metrics are LOLH, LOLP and NENS. LOLH indicates the duration (in hrs per day) for which load exceeds the generation. LOLP[4] is probability that the load exceeds the generation. The standard for LOLP adopted by regulatory authorities around the globe is one day in 10 years Ascend Analytics, 2023, Central Electricity Authority, 2023. This implies that the load will exceed the generation with a probability of 0.0274%. NENS is the energy not served normalized with respect to the annual demand (MWh).

Resource adequacy assessment is driven by decisions to secure the system against the risk posed by low probability high impact scenarios. Thus, measures such as VaR and CVaR are used to quantify the risk of worst-case scenarios. VaR and CVaR risk measure have been widely used in financial studies. For a distribution of cost function, VaR represents the *minimum worst case cost* with a certain confidence level. While CVaR determines the expectation of the worst-case costs beyond VaR for that particular confidence level. Figure 4 shows VaR and CVaR for a confidence level of 90 percent.

Thus, VaR of LOLH means minimum loss of load hours that will not be exceeded for a given confidence level and CVaR will provide the mean of loss of load hours above VaR.

4 IRP Study Data

[4] $LOLP = \dfrac{\sum_{i=1}^{S}\left(365\pi_s \sum_{j=1}^{N} LOLH_{ij}\right)}{365 \times N \times 24}$ p.u.

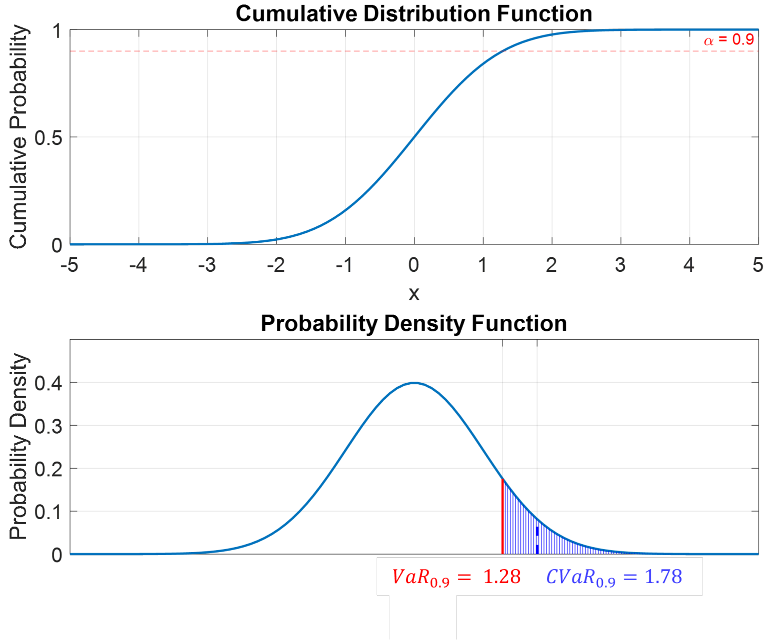


Figure 4: VaR and CVaR for cost function.

4.1 Data Collection

The Data[5] provided by STU, DISCOMs, SLDC, and MSETCL have been used to carry out this study. The data is provided in the Appendix.

The data include -

1. Demand Side Data of MSEDCL
   (a) DISCOM's load profile for FY 22-23
   (b) Load Growth projection for next five years (FY 23-24 to FY 27-28)
   (c) RPO Targets
2. Generation Side Data from STU and MSEDCL
   (a) RE generation profile for FY 22-23
   (b) Generation Installed capacity- commissioned and planned year-wise
   (c) Generation decommissioning plans
   (d) Historical hydro generation profile (obtained for Koyna Dam)
   (e) Historical forced outage data for generators
   (f) MOD rate for generators.
   (g) Generator Technical Data - minimum and maximum generation limits, and ramp up and ramp down limits.

[5] Data will be included in the Appendix in the final report

Wherever data was not available necessary assumptions have been made based on different government resources such as CEA reports, MSEDCL annual report, and data available on their websites.

4.2 Data Exclusions

The data from Tata Power, Adani Power, Railways, and other minuscule (GEPL, KRCIPPL, and NUPLLP) have not been considered. From the above list data from Tata Power and Railways is not available. It is not expected to affect the results as MSEDCL remains the prominent and predominant DISCOM in Maharashtra.

4.3 Considerations for FOR and CUF

The following assumptions have been made while carrying out the study.

1. conventional generator forced outage rates (FOR)-
   (a) MSPGCL generators- FOR provided by MSETCL
   (b) Central Sector/IPP - FOR obtained from historical forced outage data provided by MSETCL
   (c) For remaining generators- the median FOR was assigned as obtained from the historical data
   (d) New upcoming units- FOR same as that of existing units.

   .
2. Hydro Power Plants forced outage rate
   (a) Koyna - FOR determined from the historical outage data
   (b) Other MSPGCL hydro plants - as per the FOR data given by the MSETCL
3. Capacity Utilization Factor (CUF)
   (a) Biomass - CUF is considered as 0.30
   (b) Bagasse cogenration - CUF is obtained from the Centre For Science and Energy, 2007 (which is close to 0.5)
   (c) MSW - CUF is considered as 0.30
   (d) SHP - CUF is considered as 0.30
   (e) Koyna - modelled using historical generation profile
   (f) Other intra state hydro plants- by scaling the historical generation profile of the Koyna plant.
   (g) Inter state hydro CUF is taken as 0.4 with respect to their design MU.

4.4 Installed Capacity

The break of the installed capacity - existing and planned - is shown in Table 1. It is seen that thermal is the predominant component and right now RES (solar and wind) are not that significant. Even among wind and solar, solar is more dominant than wind. There is no storage in the system but no renewable drought is foreseen because conventional generation is predominant. As RES penetration increases, renewable drought could happen and would require energy storage for mitigation.

The last two columns of the table report net peak demand and net excess generation. The net peak demand is demand adjusted by solar and wind. It needs to be met from other generations which include hydro, thermal, nuclear, biomass, Municipal Solid Waste and bagasse cogeneration, etc. It is seen that for each year the net excess keeps reducing and it has a significantly low value in FY 27-28. As will be seen later, when FOR is considered along with low capacity factors for biomass, MSW and SHP and bagasse cogeneration, that it has a detrimental effect on LOLP and LOLH which increase beyond the prescribed threshold.

Table 1: Breakup of Installed Capacity (MW) for the period FY 22-23 to FY 27-28. The capacities correspond to March 31 of the financial year.

Year	Solar	Wind	Other Capacity	Total Capacity	Net Peak Demand	Net Excess Capacity
FY 22-23	4154.5	2805	28188.50	35148.00	22297.70	5890.80
FY 23-24	6054.5	2905	28673.60	37633.10	23544.40	5129.24
FY 24-25	11054.5	3405	30023.30	44482.80	24530.70	5492.59
FY 25-26	13554.5	3905	30123.30	47582.80	25523.90	4599.45
FY 26-27	14554.5	3905	30390.30	48849.80	26607.30	3782.98
FY 27-28	15554.5	3905	30504.30	49963.80	27657.50	2846.83

5 Results

5.1 Representative Days for the base year FY 22-23

The k-medoid clustering was performed on the combined normalized demand, solar and wind generation profile for the base year FY 22-23. The same representative days (clusters) have been used for the entire planning horizon with their respective probabilities. The representative days are shown in the Table 7. For each month the representative days are presented. The number of days in each cluster is shown within brackets. The red coloured cell represents the day with maximum demand and green coloured cell represents the day with minimum solar generation in the respective month.

Table 2: Month-wise K-medoid Clusters for FY 22-23

Month	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
April	3(10)	6(11)	7(1)	21(1)	29(7)
May	2(1)	6(10)	20(1)	28(8)	30(11)
June	8(1)	10(11)	15(8)	26(9)	27(1)
July	4(1)	11(7)	19(10)	22(12)	23(1)
August	3(11)	13(9)	15(1)	19(9)	29(1)
September	3(1)	12(1)	22(12)	25(5)	27(11)
October	4(1)	6(1)	16(4)	17(13)	22(12)
November	4(9)	9(11)	14(8)	25(1)	26(1))
December	6(12)	12(1)	15(7)	27(1)	29(10)
January	7(10)	13(9)	14(1)	25(10)	31(1)
February	9(8)	14(13)	15(6)	18(1)	-
March	1(9)	4(1)	10(10)	11(1)	27(10)

5.2 LOLP, LOLH and NENS for FY 23-24 to FY 27-28

Table 3: Reliability metrics for the period FY 23-24 to FY 27-28 for 90% confidence level

Metric	FY 23-24	FY 24-25	FY 25-26	FY 26-27	FY 27-28
LOLP (%)[1]	**0.5639**	**0.1467**	**0.3174**	**1.4108**	**3.9394**
LOLP(days in 10 years)[1]	20.58	5.35	11.59	51.59	143.77
NENS (%)[2]	0.0296	0.0066	0.0129	**0.0629**	**0.1873**
VaR LOLH (hrs/day)	0	0	0	0	1
CVaR LOLH (hrs/day)	0.1353	0.0352	0.0762	0.3386	9.3746
VaR NENS (%)	0	0	0	0	0.0001
CVaR NENS (%)	0.0008	0.0002	0.0004	0.0017	0.0051

[1] CEA standard as per NEP for LOLP is 1 day in 10 years which is equivalent to 0.0274%.
[2] CEA standard as per NEP for NENS is 0.05%.

Table 4: Reliability metrics for the FY 27-28 for extreme scenario for different confidence level

	Confidence Level				
Metrics	**0.90**	**0.95**	**0.99**	**0.999**	**0.9999**
VaR LOLH (hrs/day)	1	9	16.75	24	24
CVaR LOLH (hrs/day)	9.37	14.53	18.74	24	24
VaR ENS (GWh)	0.2220	6.2935	26.4183	48.8080	63.8194
VaR NENS (%)	0.0001	0.0031	0.0129	0.0238	0.0312
CVaR ENS (GWh)	10.4856	18.4610	35.7333	56.5095	63.8194
CVaR NENS (%)	0.0051	0.0090	0.0175	0.0276	0.0312

Table 5: NENS for the period FY 23-24 to FY 27-28 for extreme scenario (with 99.99 per cent confidence level)

Metric	**FY 23-24**	**FY 24-25**	**FY 25-26**	**FY 26-27**	**FY 27-28**
LOLH (hrs per day)	24.00	17.75	22.75	24.00	24.00
ENS (GWh)	43.84	25.30	27.45	46.83	63.82
NENS (%)	0.0252	0.0139	0.0144	0.0237	0.0312

6 Conclusion

The energy resource adequacy assessment study was carried out for Maharashtra state for the period FY 23-24 to FY 27-28. The base year for data collection was FY 22-23 and data was provided by MSETCL. Percentage load growth values obtained from MSEDCL are 6.5, 4.5, 4.3, 4.1, and 3.8 for FY 23-24 to FY 27-28 respectively. Peak demand for FY 22-23 was 23.65 GW and annual energy demand was 156.84 TWh. Peak demands for the subsequent five financial years are 26.08 GW, 27.26 GW, 28.44 GW, 29.61 GW, and 30.75 GW, respectively. Fifty-nine representative days for a year were obtained for each year. The representative days also include the extreme scenarios of days maximum demand and days minimum solar generation. The probabilistic unit commitment was used to estimate the LOLP and NENS.

The salient observations are as follows:

1. VaR LOLH is zero at 95% confidence level for the first four simulation years (FY 23-24 to FY 26-27). This means that 95% of the time there are no violations. For FY 27-28, VaR LOLH is zero upto 85% confidence level.

2. For the period FY 23-24 to FY 25-26, NENS is well within the stipulated limit, which is 0.05%. However, for the FY 26-27, NENS is 0.0629% and for FY 27-28, it increases to 0.1873%.

3. All across the five simulation years, the LOLP is beyond the stipulated limit of 0.0274%. LOLP will reduce if market interactions are considered in the simulation.

4. Higher values of NENS as well as LOLP for the last two simulation years, indicate requirement for planning capacity addition.

6.1 Importance of the results at the extremities

On March 4, 2024, The Electric Reliability Council of Texas (ERCOT), USA reported net load ramps and high RTM prices. The net load peak was 46.2 GW (65% of January 2024 record of 70.7 GW). Many generators were under planned outage after the end of the winter embargo. Wind generation was well below its thirty-day rolling average (with 4-5 GW wind availability). The capacity available for economic dispatch fell to just 842 MW at 6:25 PM. BESS responded with a max net output of 1 GW at 6:35 PM and 550 MW of ERCOT Contingency Reserve Services were also deployed to meet the short-term scarcity. Further details can be found in Appendix I.

In India, such scenarios have been reported post-summer when thermal generation is scheduled for maintenance. If the rains are delayed irrigation load picks up and this stresses resource availability. One of the primary reasons for the July 30, 2012, ER-NR blackout was such load growth in North Indian states.

In our study following extreme case came out. The duration of load exceeding the generation, LOLH, for extreme scenario is as high as 17.75 hours per day in FY 24-25, 22.75 hours per day in FY 25-26, 24 hours per day in FY 26-27, and 24 hours per day in FY 27-28. The ENS for extreme scenario is as high as 25.30 GWh for FY 24-25, 27.45 GWh for FY 25-26, 46.83 GWh for FY 26-27, and 63.82 GWh for FY 27-28. This happened as many generators simultaneously went out of service. On the lines of ERCOT, Contingency Reserve Services and energy storage solutions could be considered by the state.

6.2 Energy Storage Consideration

One concern that we have is that no battery energy storage has been planned by the state. The cost of the BESS has been falling down and recently, in the GUVNL tender, a rate of Rs 3.25/KWh has been awarded. If such a storage buffer is built by the state then unit commitment would report much lower values of LOLP and extreme generator outages can be handled with ease. It helps in demand side management, RES volatility, in addition to reliability benefits in IRP. Hence, we strongly encourage the state to work towards integrating storage. We at IIT Bombay would be happy to associate with any such exercise.

6.3 Suggestion towards automation for subsequent IRP studies

IRP study will be a regular exercise for MSETCL. This exercise was the first instance of IRP and had to be done from scratch. Data collection took a lot of time in this exercise. Now, that we have the data, a repository can be made for the collected data. PowerAnser Labs, IIT Bombay has a solution BRIQ which can be used to create a data repository so that such an exercise can be carried out within one month time with new updates in the data. We can customize this repository for the IRP exercise which has to be done on a rolling basis every year. With this automation, the evaluation time would be reduced to around one month and the data quality will also improve significantly. The capabilities of this tool are summarized in Appendix II.

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Appendix I

ERCOT: Why Prices Hiked on March 4, 2024?

High RTM Prices and Net Load Ramps March 4

✓ ***Net Load peak of 46.2 GW*** (65% of 2024 January's record of 70.7 GW)
✓ End of the winter embargo for planned generation outages
✓ Thermal capacity outages (increased from 11.7 GW on Feb 29 to 22.4 GW on March 4)
✓ ***Wind generation was well below its 30-day rolling average (4-5 GW wind availability)***

capacity available to the **economic dispatch** fell to just 842 MW at 6:25pm - and System Lambda reached $885/MWh in the following SCED intervals.

❖ ***BESS responded with a max net output*** of 1,041 MW during the 6:35pm SCED interval.

❖ Deployment of ***550 MW of ECRS*** (ERCOT Contingency Reserve Services) to help meet the short-term scarcity.

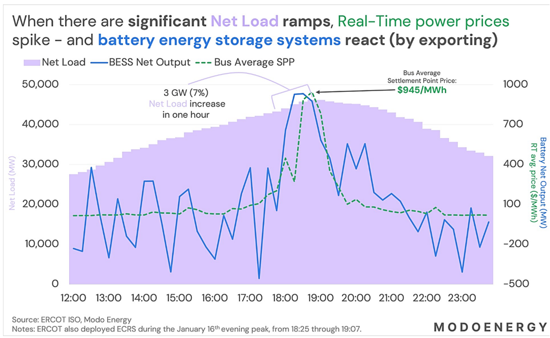

Fig. Net load ramps, BESS net output and RTP average price on March 4, 2024 for ERCOT.

Figure 5: Extreme Scenario Case Study: Net load ramp and high market price in ERCOT on March 4, 2024.

Appendix II

Network Editor

We at PowerAnser Labs, IIT Bombay have facilitated transmission cost allocation for NLDC, through webNetUse, since the regulation was introduced. One of the components of this software is network editor. The software has recently gone through major up-gradation. Post upgrade, following are salient features of network editor.

1. Browser based application: Client can access the application from any computer, provided server is accessible from the machine. There is no separate client application installation. One has to only enter a valid URL to access the application. Further, multiple users can access the same network dataset and hence, there is no need for each user to maintain a local copy.

2. Allows incremental network update: Network elements can be incrementally added, updated or deleted to update the network dataset. Hence, whenever there is a change in the physical network, only network elements, which have been added, updated and deleted in current cycle, will have to be accounted for.

3. History Tracking: With checkpoints, network history can be easily maintained. One can access network at an earlier date by using these checkpoints. Hence, the software maintains single dataset, which grows with time.

4. Different scenarios at a checkpoint: Multiple scenarios can be created at a checkpoint for different studies.

5. Support for export to PSS/E raw format

While the network editor has been developed as a webNetUse module, it can also be independently used. We would like to suggest MSETCL to use this tool to maintain its network repository. We would like to highlight that for this study, data collection required enormous effort and time. With this tool in place, retrieving the required data will be a few clicks away, provided the repository is kept up to date.

Appendix III: Commissioned and Future Installed Capacity Technology Wise (in MW)

	Existing[1]	Future Capacity				
Type of RE	**FY 22-23**	**FY 23-24**	**FY 24-25**	**FY 25-26**	**FY 26-27**	**FY 27-28**
Wind	2805[2]	2805	3305	3805	3805	3805
Solar	4154.5[2]	5854.5	10824.5	13354.5	14354.5	15354.5
Wind-solar	-	300[3]	300	300	300	300
Wind+Solar	**6959.5**	**8959.5**	**14459.5**	**17459.5**	**18459.5**	**19459.5**
Bagasse	2474.3	2644.6[4]	3394.3[5]	3394.3	3394.3	3394.3
Biomass	37[6]	37	37	37	37	37
MSW	4	17.18[7]	17.18	17.18	17.18	17.18
Small Hydro	310.68	317.3[8]	317.3	317.3	317.3	317.3
Other RE	**2825.98**	**3016.12**	**3765.82**	**3765.82**	**3765.82**	**3765.82**
Thermal	21625	21625	22225	22225	22225	22339
Nuclear	852	964	964	964	964	964
Conventional	**22477**	**22589**	**23189**	**23189**	**23189**	**23303**
Hydro	2885.5	3068.5	3068.5	3168.5	3435.5	3435.5
Total NSW[9]	**28188.47**	**28673.62**	**30023.32**	**30123.32**	**30390.32**	**30504.32**
Total [10]	**35147.97**	**37633.11**	**44482.81**	**47582.81**	**48849.81**	**49963.81**

[1] Already commissioned generation capacity till FY 22-23 as per MSEDCL, 2023a
[2] MSEDCL, 2023a
[3] MSEDCL, 2023f
[4] Out of 170.3 MW capacity to be added in FY 23-24, Daund Sugar (64 MW), Baramati Agro (28.40 MW), and Shri Subhash Sugar (14.90 MW) were added on Oct 20, Nov 1, and Nov 2, 2023, respectively MSEDCL, 2023b. The remaining capacity of 63 MW is assumed to added by the March 2024.
[5] A total capacity of 749.7 MW of Bagasse co generation is planned to be added in FY 24-25. A capacity addition of 32 plants of 20 MW each and one plant of 7.7 MW is distributed across the year.
[6] MSEDCL, 2023c
[7] MSEDCL, 2023d
[8] Mukhane HEP (1.45 MW) and Jambhre HEP (2 MW) where commissioned on July 12 and July 19, 2023, respectively. The remaining 3.2 MW capacity is assumed to be commissioned by the end of FY 23-24 MSEDCL, 2023e.
[9] Total NSW = Other RE + conventional + Hydro
[10] Total = Solar + Wind + Other RE + conventional + Hydro

Table 6: MSEDCL Existing Conventional Generation PPA (in MW)

Name of the Station	Installed Capacity	Contracted Capacity
Bhusawal Unit 03	210	210
Bhusawal Unit 04 & 05	1000	1000
Khaperkheda Unit 01 to 04	840	840
Khaperkheda Unit 05	500	500
Nashik TPS	630	630
Chandrapur Unit 03 to 07	1920	1920
Paras Unit 03 and 04	500	500
Parli Unit 06 and 07	500	500
Koradi Unit 06	210	210
GTPS Uran	672	672
Parli Unit 08	250	250
Chandrapur Unit 08,09	1000	1000
Koradi Unit 08,09,10	1980	1980
MSPGCL Total		**10212**
KSTPS I &II	2100	652
KSTPS III	500	127
VSTP I	1260	446
VSTP II	1000	347
VSTP III	1000	286
VSTP IV	1000	308
VSTP V	500	168
Kawas	645	201
Gandhar	648	197
KhSTPS-II	1500	148
SIPAT TPS II	1000	284
SIPAT TPS I	1980	585
Mauda I	1000	398
Mauda II	1320	550
NTPC Solapur	1320	666
Lara	1600	291
Gadarwara	1600	111
Khargone	1320	100
NTPC Total		**5448**
JSW U-1	300	300
CGPL	760	760
APML (125+1320+1200+440)	3085	3085
GMR	200	200
RPL (450 + 750)	1200	1200
SWPGL	240	240
IEPL	180	180
IPP Total		**5965**

Name of the Station	Installed Capacity	Contracted Capacity
TAPP 1&2	320	160
TAPP 3&4	1080	434
KAPS 1&2	440	149
KAPS 3&4 Unit-3	700	112
NPCIL Total		852
Total existing conventional		**22477**

[1] MAHASLDC, 2024

Table 7: Conventional Planned Capacity Addition (in MW)

Name of the Station	Installed Capacity	Contracted Capacity	Expected COD
Bhusawal Unit 6[1]	600	600	Feb 2024
Lara Stage-II, Unit 1&2 (2 X 800 MW)[1]	1600	291	Jan 28, Jul 28[2]
Sipat Project, Stage – III[3]	800	228	FY 28-29
MBPL[3]	1600	480	Dec 2028
KAPS Unit-4	700	224	Feb 20, 2024[5]
Total Planned Conventional[4]		**1822**	

[1] CEA, 2023
[2] COD of Unit 1 and Unit 2 are Jan 2028 and July 2028, respectively. CEA, 2023
[3] Expected COD of these stations are outisde the planning horizon FY 23-24 to FY 27-28 NTPC, 2023, PIB, 2023
[4] 969.5 MW of planned conventional capacity is only available in the planning horizon. Out of this, 824 MW is available from March 2024 and 145.5 MW is available from Jan 2028.
[5] KAPS Unit 3 was laready in operation at the end of FY 22-23.