**संदर्भ.सं.**: POSOCO/NLDC/Terms & Condition/ **दिनांक:** 28th Jan 2019

सेवा में,

सचिव,
केन्द्रीय विद्युत विनियामक आयोग,
तीसरा तथा चौथा तल,
चंद्रलोक भवन, 36 जनपथ,
नई दिल्ली-110001

**विषय: Regarding:** ***POSOCO comments on Draft Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2019***

**संदर्भ:** 1. Public Notice Ref no. No. L-1/236/2018/CERC dated 7th Jan 2019
2. Draft Notification on Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2019

महोदय,

The comments/suggestions by POSOCO on "Draft Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2019 for the tariff period from 1.4.2019 to 31.3.2024" are enclosed with this letter.

सधन्यवाद

भवदीय

देबाशिस
28/01/19
(देबाशिस दे)
मुख्य-महाप्रबंधक(रा.भा.प्रे.के.)

संलग्न: उपरोक्त अनुसार

**Power System Operation Corporation Limited**
**New Delhi**

**Date: 28th Jan 2019**

**Sub: Comments on behalf of Regional Load Despatch Centres (RLDCs)/National Load Despatch Centre (NLDC) on the draft CERC (Terms and Conditions of Tariff) Regulations, 2019**

Consultation Paper on Terms and Conditions of Tariff Regulations for the period from 1st April 2019 to 31st March 2024 was floated on 24th May 2018. POSOCO vide its communication dated 31st July 2018 had submitted its comments on the consultation paper. A copy of same is also available on the CERC website along with draft regulations. The draft regulation was notified on 14th Dec 2018. It appears that POSOCO's comments have not been considered in the draft Regulations. It is felt that regulations must complement reliability & security of the grid and therefore certain operational aspects which are important from reliability point of view also needs to be covered in the draft regulations. In this regard, following changes to the draft regulations are suggested:

## 1. Incentivising Flexibility of conventional coal and gas based generation

i. **Ramping support** from thermal generation would be an important attribute considering the large scale renewable integration and changing load shape. Although, the CEA (Technical Standards for Construction of Electrical plant and Electric lines) Regulations 2010 prescribe +/-3% per minute ramp rate for coal fired plants, the Indian Electricity Grid Code (IEGC) has provisions requiring only +/-1% per minute ramp rate only. The actual ramp rate provided by the thermal machines has been studied based on historical data available at RLDCs/NLDC and the report prepared in this regard is enclosed as **Annexe-1**. On an All India level, only around 35% of coal-fired generating units (438 Nos) have provided the ramp – Up/Down capability of at least 1%/Min.

**Therefore, suitable provisions regarding performance monitoring with regard to ramp rate may be included in the CERC (Terms and Conditions of Tariff), Regulations, 2019. In case of consistent non-compliance, provisions regarding penalty in terms of reduction in fixed cost charges may also be included.**

Suggested clause to be added in the tariff regulations under ***Section 30: Return on equity para 2(iv)*** is as follows:

*““the rate of return of a coal based generator shall be reduced by 1% for such period as may be decided by the Commission, if the generating station is found to be not providing ramp rate of 3% per minute in accordance with the CEA Technical Standards for Construction based on the report of RLDC.*

*Further, the rate of return shall be increased by 0.50% for the generating stations which display better ramp rate than CEA mandated standards. The daily ramp rates declared and used for scheduling each plant on daily basis by the RLDC would form the benchmark for deciding achievement with respect to ramp rates supplemented with random checks on actual ramp rate achieved by the plant.”*

**Similar provisions regarding ramping are also required to be included in the state grid codes and tariff regulations to achieve full benefits of ramping.**

ii. **Technical minimum** is another important aspect of flexibility. In the report **GREENING THE GRID: Pathways to Integrate 175 Gigawatts of Renewable Energy into India’s Electric Grid, Vol. I—National Study by** National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Power System Operation Corporation, and the United States Agency for International Development it is outlined:

***“6. Compensating Flexibility***

*Create a model tariff contract that can be used for contracts that are new and up for renewal based on economics of coal plants with lower plant load factors. For existing contracts, explore options used in other countries to renegotiate contracts. Develop a new tariff structure that moves away from focusing on energy delivery. Agreements can specify various performance criteria, such as ramping, specified start-up or shutdown times, minimum generation levels, along with notification times and performance objectives that achieve flexibility goals. The tariff structure should allow for full cost recovery, be applicable to both renegotiated contracts and new contracts, and be effective both during the transition to a high-RE future and after the high-RE future has been reached.”*

**In order to encourage generators to achieve technical minimum levels lower than the specified norms of 55%, following is proposed to be included in provision**

**Section 30: Return on equity para 2(v) :**

*"Any non pit head generator declaring technical minimum less than 55% will be provided incentive in terms of 0.10% increase in return on equity for every 1% reduction in technical minimum below 55%. The same would be computed based on the values declared on daily basis by the plant to the RLDCs/NLDC for scheduling purpose."*

**2. Linking fuel stock with availability**

Generators are allowed interest on working capital corresponding to different fuel stock circumstances. However, the availability calculations are based on day ahead availability which doesn't capture the on-site fuel stock position. It has been observed during real time operation that generators are declaring full availability for the day but not maintaining enough fuel stock as required under the regulations. This becomes evident during periods of continuous high demand where they are not able to generate on sustained basis up to the declared DC values. Instead, the generators revise the DC in such cases in accordance with the regulations. The same has been highlighted with examples in the 31st July 2018 communication by POSOCO.

The above gives a false sense of comfort on the generation availability front to the system operator and poses a threat to grid security. This comfort turns into a surprise when the plant actually starts getting scheduled but unable to sustain the high generation level for more than a day and reduces the declared availability.

**Normative Quarterly Plant Availability Factor (NQPAF) is being referred for norms of operation in the draft tariff regulations which is a welcome step**. Under quarterly calculation approach and with the same level of normative availability of 83-85%, the fuel adequacy should get captured most of the time. However, if the quarterly approach is revised to annual basis at the time of finalisation of tariff regulations then following provisions are suggested:

Suggested clause to be added in the tariff regulations under ***Section 53:*** **Declaration of Availability and Dispatch in case of thermal generating station**: is as follows:

*"The generating company shall declare day ahead availability or as well as weekly availability depending on the fuel stock position in addition to the day ahead availability any revision thereof in respect of generating station The weekly availability should factor the fuel stock as well as the anticipated daily fuel receipts as well as fuel consumption. A weightage of 20% will be given to this weekly availability figure and 80% for the day ahead availability in order to work out the plant availability for each fuel source which*

*may be differentiated in terms of their price and calorific value and the beneficiaries shall have an option to schedule the power based on their merit order dispatch."*

The availability of domestic gas for the gas power plants is limited and hence its utilization should be optimized considering the power system requirements. This aspect has also been brought out in renewable integration study under Greening the Grid program where it emerged that gas power plants shall be required to provide peaking support instead of flat generation round the clock in high renewable scenario. A study was also conducted by POSOCO on the request of Ministry of Power to look into the possibility of gas generation optimization.

Suggested clause to be added in the tariff regulations under ***Section 53:*** **Declaration of Availability and Dispatch in case of thermal generating station**:

*"Likewise gas generators should submit max DC for 3 hours for the entire plant and MWh capability separately on domestic gas, RLNG and liquid fuel for the next day for the entire plant. The monthly availability would be calculated based on the max DC given for 3 hours for the entire plant."*

**3. Norms of operation for thermal generating station :**

Section 59(A) for Norms of operation for thermal generating station provides for
"Normative Quarterly Plant Availability Factor (NQPAF)
(a) For all thermal generating stations, except those covered under clauses (b), (c), (d),& (e) - 83%
Provided that for the purpose of computation of Normative Quarterly Plant Availability Factor, annual scheduled plant maintenance shall not be considered."

In Control Period 2014-19, the recovery of fixed charges was linked to availability. 85% availability was specified with exceptions for some specific plants. There could be cases where a generator may achieve the target cumulative availability on annual basis even with lower availability declaration during the peak demand period and higher availability declaration during low demand period. Shifting of fixed cost recovery from annual cumulative availability basis to a lower periodicity, i.e. quarterly in the draft regulations is welcome step considering in this regard.

However, leaving out the annual scheduled plant maintenance for calculating Normative Quarterly Plant Availability Factor (NQPAF) is not desirable. In the explanatory memorandum, it is specifically mentioned that:

*“ For 29 NTPC Coal based plants (excluding Mauda STPS Stage I), the average availability factor works out to 91.63% and the median works out to 91.57% with standard deviation of 4.81% which means availability factor of the plant varies from 96.39% and 86.75%. In view of above, the Commission proposes to fix the Normative Annual Availability Factor of generating stations at 83% on quarterly basis*.”

From the draft regulation, it is not clear whether the time period of annual scheduled plant maintenance will be excluded from total time or outage will be deemed available. If the outage will be deemed available, then it will lead to substantial reduction in actual plant availability and owing to the revised target availability, plant will recover fixed costs.

**Accordingly, following is proposed:**

*“Normative Quarterly Plant Availability Factor (NQPAF)*

*(a) For all thermal generating stations, except those covered under clauses (b), (c), (d),& (e) - 83%*

~~*Provided that for the purpose of computation of Normative Quarterly Plant Availability Factor, annual scheduled plant maintenance shall not be considered,*~~

~~*”*~~

**4. Peak-Off peak declaration by RLDC:**

In the draft regulation, Chapter-11: COMPUTATION OF CAPACITY CHARGES AND ENERGY CHARGES, Section 51(3) mentions;

“*Normative Plant Availability Factor for “Peak” and “Off-Peak” periods shall be equivalent to the NQPAF specified in Regulation 59 (A) of these regulations. The number of hours of “Peak” and “Off-Peak” periods in a region shall be declared on monthly basis in advance, by the concerned RLDC and the Peak period in a day shall not be less than 4 hours.*“

In this regard, it is to be informed that different regions have different peak and off peak periods depending upon the seasonality. The daily load curve of different regions follows different peak timings. It is well understood that with interconnection of grids and a pan India electricity market, regional boundaries hardly matter. Declaring peak and off-peak periods region wise will not serve the purpose for their inception. To achieve maximum benefit of this philosophy, it is suggested that Peak and Off-Peak may be considered for All India Demand which will assist in unified load-generation balance as well as maintaining frequency within IEGC band.

**It is suggested that Section 51(3) may be modified accordingly as :**

“

***Normative Plant Availability Factor for “Peak” and “Off-Peak” periods shall be equivalent to the NQPAF specified in Regulation 59 (A) of these regulations. The number of hours of “Peak” and “Off-Peak” periods in the Indian Grid as well as the specific ‘peak hours’ shall be declared on monthly basis in advance, by the NLDC and the Peak period in a day shall not be less than 4 hours.***

5. **Penal provision on HVDC non-availability :**

   As per present tariff regulations, additional 12 hours outage shall be considered in addition to the actual outage for more than 2 tripping in a year. However no such provision is there for HVDC system. In current scenario, where HVDCs are providing bulk power transfer, greater availability of HVDCs need to be ensured in the interest of grid security.

   Hence, suggested clause may be modified in ***Norms of operation for transmission system Section 61.Normative Annual Transmission System Availability Factor (NATAF):***

   *“Provided also that for AC system as well as HVDC system , two trippings per year shall be allowed. After two trippings in a year, for every tripping, additional 12 hours outage shall be considered in addition to the actual outage hours:”*

6. **Penal provisions for LTA/MTOA curtailment due to outage**

   The present tariff regulations provides for following

   “in case of outage of a transmission element affecting evacuation of power from a generating station, outage hour shall be multiplied by a factor of 2”.

   **It is proposed to extend this clause to all cases of curtailment of Long Term Access (LTA)/Medium Term Open Access (MTOA) transactions considering the fact that in case of curtailment of Short Term Open Access (STOA) transactions, the customer is refunded the transmission charges for the period of curtailment. This must include HVDC installations also considering that the Transmission Planning Criteria already mentions the N-1 criteria for a single HVDC pole outage.**

   Suggested clause may be modified in ***Norms of operation for transmission system Section 61.Normative Annual Transmission System Availability Factor (NATAF):***

*"Provided also that in case of outage of a transmission element (AC or DC) affecting evacuation of power from a generating station or curtailment of Long Term Access (LTA)/Medium Term Open Access (MTOA) transactions, outage hours shall be multiplied by a factor of 2 including cases where HVDC system capability goes down due to any reason."*

**7. STATCOM availability**

In the draft regulations, STATCOM has been considered as separate element for the first time which means that the availability of each STATCOM will be used while calculating the transmission availability of the regional transmission system. As per 2nd All India Joint Standing Committee Meeting on Power System Planning held on 8th August 2013, thirteen no. of STATCOM were planned in the Indian power system. Presently eight no. of STATCOM have already been commissioned. In this regard, first time charging procedure for STATCOMs was issued by NLDC vide communication dated 19th April 2018. The same was furnished along with the POSOCO comments on consultation paper. In this communication NLDC has clearly brought out the list of telemetry points and data to be reported from site to RLDC/NLDC control room in reference to STATCOM operation. However, all telemetered data in this regard is yet to be provided in some cases.

STATCOM being a dynamic VAR compensation device, provides fast reactive support to the grid during transient as well steady state operation. STATCOM has an additional feature of power oscillation damping which need tuning of its settings. **In order to analyze the dynamic performance of STATCOM (STATCOM+ MSR /MSC) during day-to-day operation, installation of PMU for measuring the parameters of Coupling Transformer of the STATCOM is essential. In addition to PMUs, high resolution data of the period for faults where STATCOM should operate is also required to be provided by the transmission licensees**. In absence of dynamic response data, it will be difficult to analyse the performance or availability of STATCOM.

Suggested addition in ***Procedure for Calculation of Transmission System Availability Factor for a Month may be added in para (vi):***
*"In order to determine the STATCOM performance, transmission licensee shall be responsible for furnishing PMU output at RLDC/NLDC. To analyse the dynamic performance of STATCOM, transmission licensee shall report the high resolution data of the period for faults where STATCOM should activate or as and when requested for by the RLDCs/NLDC. Failure to furnish data related to dynamic compensation by STATCOM will render it unavailable for the period since last operation."*

In the calculation of availability of AC portion of Transmission System, STATCOM contribution appears missing. Suggested clause for TAFM modification is given below:

"

*% TAFPn for AC system*

$$= \frac{o \times AVo + p \times AVp + q \times AVq + r \times AVr + u \times AV_u}{o + p + q + r + u} \times 100$$

*U = Total number of STATCOMs*

*AVu = Availability of u number of STATCOMs*

## 8. Factoring series compensation in transmission availability

The draft tariff regulation has removed the Surge Impedance loading(SIL) based weightage for transmission line. In the absence of SIL reference, FACT based series compensation devices will not be in radar for availability. In order to factor them under the availability, **it is desired that Series/Shunt compensating devices may be defined as individual element with degree of compensation**. This clause may be added in ***Procedure for Calculation of Transmission System Availability Factor for a Month.***

## 9. Factoring HVDC Reduced capability in availability calculations

Unlike AC systems where the availability of any element is either 0 or 100%, HVDC systems have the facility to operate at any intermediate voltage up to the rated voltage and therefore the availability can vary between 0 to 100%. Mostly, the power transfer capability (MW) gets reduced as voltage reduces in most of the HVDCs. It is entirely possible that the system conditions may warrant operation well below the maximum rated level under steady state conditions. However, if any tripping takes place in the parallel AC system, the system operator could ask for ramping up HVDC power order any time. During such instances, there should be no constraint on account of reduced voltage mode of operation. This is the essence of 'availability'; an element which is considered 100% available should have the ability for operation at rated capacity whenever the system operator advises so in real time.

There is another related aspect of HVDC operation and that is the ability to utilize overload capability in case of tripping of any one of the poles; the other pole typically has a 133% overload capability for the first five (5) seconds and 110% capability for the next two (2) hours. These prove to be very useful during contingencies and when the system is heavily loaded. These features are however unavailable, if the HVDC operates at reduced voltage mode of operation. The above aspects had been explicitly captured in the CERC (Terms and Conditions of Tariff Regulations 2009) for the period 2009-14 but somehow not explicitly mentioned in the 2014-19 Tariff Regulations. This in no way changes the basic philosophy of HVDC operation outlined in the above paragraphs and the essence and spirit of 'availability' needs to be captured.

With the recent operationalization of Multi-terminal HVDC systems, it is important that availability of DC line for different sections and HVDC terminals at different stations be factored separately so that multi-terminal operation flexibility is captured in the availability calculations. **It is suggested that modified methodology for HVDC availability certification may be devised which is given below:**

***"FORMULAE FOR CALCULATION OF AVAILABILITY OF HVDC Link:***

*HVDC multi-pole links: Each pole of HVDC link along with associated equipment at both ends shall be considered as one element. For each pole of HVDC, rated capacity (in MW) shall be as approved in Tariff Petition of the corresponding element. Each master station of HVDC pole shall declare its maximum power transfer capability in day advance as is done for Inter-State Generating Station (ISGS). Following conditions may be referred while declaring maximum capability:*

1. *During Reduced Voltage operation (RVO), HVDC shall report its maximum power transfer capability to RLDC/NLDC. The Declared Capability of the HVDC will be revised by RLDC/NLDC in real time for the period of Reduced Voltage mode of operation. In the event of non-reporting of RVO capability by HVDC station, RLDC/NLDC will reduce the rated capability in proportion to DC voltage.*
2. *In case of non-availability of adequate filters at one or both end, HVDC will report the maximum power transfer capability to RLDC/NLDC. In case of non-reporting of reduced capability by HVDC station, RLDC/NLDC will revise the rated capability according to capability as per design for available filters.*
3. *In cases of one pole tripping during Bipole operation , after tripping of one pole, other pole fails to display overload capability, then rated capability of other pole may be revised to 90% of rated till bipole operation is restored.*
4. *In cases of multi terminal HVDC, during outage of one pole at any station, the revised capability shall be reported by HVDC station. A pair of rectifier-inverter will be considered as one element and outage of any one will make other unavailable for declared capability consideration."*

*Rated Capability (R ): Maximum Capability of HVDC pole as defined in Tariff petition order by CERC*

*Reduced Capability (X): Revised declared capability of HVDC due to reasons mentioned in S.No. 1to 4 above*

*T : Time period during which HVDC Pole operated on reduced capability*

*The period of non-availability of HVDC which will be considered while calculating Transmission Availability Factor for the month (TAFM) = T-(T*X/R)*

**Similarly, considering expected commissioning of Voltage Source Converter(VSC) based HVDC in control period 2019-24, a methodology to be adopted for VSC HVDC need to be suitably formulated.**

**10. Reasonable restoration time for construction related outages:**

In cases of construction related outages, there is no impact on the transmission licensee. This aspect needs to be further made more stringent to cover construction related outages. Many a times the line under outage on account of construction related works are restored late and since no outage is attributed to licensee, hence penalty increase by factor of 2 in case of backing down of generation and/or curtailment of LTA/MTOA also becomes immaterial.

Suggested clause may be added at para 5(i) in ***Procedure for Calculation of Transmission System Availability Factor for a Month:***

“5.*The transmission elements under outage due to following reasons shall be deemed to be available*:
*Shut down availed for maintenance or construction of elements of another transmission scheme. A reasonable restoration time for the element shall be considered by Member Secretary, RPC and any additional time taken by the transmission licensee for restoration of the element beyond the reasonable time shall be treated as outage time attributable to the transmission licensee. If the other transmission scheme belongs to the transmission licensee, the Member-Secretary, RPC may restrict the deemed availability period to that considered reasonable by him for the work involved.”*

**11. Disturbance Recorder/Station Event Logger furnishing:**

As per CEA Grid Standards "*All operational data, including disturbance recorder and event logger reports, for analysing the grid incidents and grid disturbance and any other data which in its view can be of help for analysing grid incident or grid disturbance shall be furnished by the Entities within twenty four hours to the Regional Load Despatch Centre and concerned Regional Power Committee.* Whether any tripping is attributable to licensee or not depends on event analysis outcome. Generally licensees include several tripping of lines due to over voltage or direct trip received from far end and by mentioning such reason, such type of outages get attributed to other agency. Further, spurious tripping can be identified only after confirming with Disturbance Recorder (DR)/Event Logger (EL). In this regard it is suggested that onus will lie on transmission licensee to submit all operational data regarding disturbance on time. In case DR/EL is not received in time, the outage must be attributed to the licensee for availability calculations.

Suggested clause may be added in para 6(ii) in ***Procedure for Calculation of Transmission System Availability Factor for a Month:***

"*Outage time of transmission elements for the following contingencies shall be excluded from the total time of the element under period of consideration:*

ii) *Outage caused by grid incident/disturbance not attributable to the transmission licensee, e.g. faults in substation or bays owned by other agency causing outage of the transmission licensee's elements, and tripping of lines, ICTs, HVDC, etc. due to grid disturbance. The onus will lie on transmission licensee to furnish all the station data related to disturbance(Disturbance Recorder Output, Station Event Logger etc.) to concerned RLDC, failing which ,outage will be attributed to transmission licensee. However, if the element is not restored on receipt of direction from RLDC while normalizing the system following grid incident/disturbance within reasonable time of one hour, the element will be considered not available for the period of outage for last seven days after issuance of RLDC‟s direction for restoration ."*

**12. Substation bays as an individual element:**

In the draft regulations, under Definitions section 'Element' is defined as an asset which has been distinctively defined under the scope of the transmission project in the Investment Approval such as transmission lines including line bays and line reactors, substations, bays, compensation device, Interconnecting Transformers; Moreover the Operation & Maintenance expenses norm for transmission system clearly defines that

"The total allowable operation and maintenance expenses for the transmission system shall be calculated by multiplying the number of sub-station bays, transformer capacity of the transformer (in MVA) and kMs of line length with the applicable norms for the operation and maintenance expenses per bay and per km respectively."

In general practice, the bays are not given any weightage in availability calculation of transmission system, the following sections will highlight the importance of incentivising the bay availability:

a. In case of one and a half circuit breaker scheme, the non-availability of tie bay may not affect the reliability under normal scenario but when there is outage of main bay due to any of the reasons the element which could have survived through tie bay, also trips in the incident. Thus reliability of the element is reduced under outage of tie bay.
b. In case when one or both the end bays are not owned by transmission owner, the suitable O & M measures are not taken by bay owners since they do not get any incentive out of it. The tripping of line on account of station bay issues is also not attributable to line owner, in such scenario, though the reliability of line is reduced but nobody takes a hit on availability.
c. In case where the transmission line terminates in station of state transmission utility or generating plant, the outage of line becomes difficult to be verified, since station owner is not affected by line availability and hence furnishing of DR/EL by them is up to their discretion.
d. With recent increase in Tariff Based Competitive Bidding (TBCB) based transmission system, incentivising bay availability will give a signal to owners of bay to follow best practices in station O & M which will enhance the reliability of the line.
e. With the bay availability based incentive, there will be a check on the busbar outages. In operation, it is observed that outage of busbar does not impact the availability.

Suggested addition in ***Procedure for Calculation of Transmission System Availability Factor for a Month may be added in para 1(viii):***

*"*Bay of an element: Each bay associated with an element shall be considered as separate element."

**13. Voltage Source Converter (VSC) based HVDC Operation:**

Considering expected commissioning of Voltage Source Converter (VSC) based HVDC in control period 2019-24, a methodology to be adopted for VSC HVDC availability need to be suitably formulated. Since VSCs are self-commutated, they do not necessarily require a strong AC bus for stable operation. The black start feature in VSC based HVDC can be used for system restoration. During islanded operation, the DC terminal independently controls both the AC voltage and the frequency of the islanded network to set reference points, i.e., it provides voltage and frequency control. System restoration can be performed in a careful and structured manner, with proper coordination.

VSC based HVDC are also capable to import/export reactive power to the AC systems at both ends of the transmission link. The reactive power can be controlled independently at each converter station. If no power flow is required or possible, each converter station is able to provide reactive power support to the local AC system.

These features can be used to the advantage of system reliability and VSC based HVDC need to have them in their design. Suggested clause to be added in the tariff regulations suitably is as follows:

"***in case of a new VSC based HVDC project, apart from the normal formula used for calculation of availability, the transmission licensee should facilitate testing of black start facility in either direction and/or any other tests twice every financial year as per the plan finalized by RLDCs/NLDC/SLDC. Failure to perform these tests should render a reduction of 0.5% Return on Equity (RoE) for the VSC based HVDC asset.”***

**14. Recording Operational Availability vs Certified Availability:**

It is observed in monthly certification that there remains considerable difference between operational availability and final availability as certified by RPCs. This difference arises due to outages deemed available under different circumstances. The RPCs can provide the breakup of certified availability in terms of operational availability and deemed availability under various heads. RLDCs also need this data to use as a reference in future availability verification and outage planning. Suggested clause in para 7 of ***Procedure for Calculation of Transmission System Availability Factor for a Month :***

***“Issue of availability certificate along with notional breakup by respective RPC – by 3rd of the next month and displayed on their website”***

**15. Definition of ‘force majeure’**

‘Force majeure’ is defined for the purpose of only construction risks. It needs to be extended to operation also so that there is focus on proper design, construction, operation and maintenance of assets so that the network is robust and resilient.

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**Annexure-I**

# Analysis of Ramping Capability of Coal-Fired Generation in India

## Volume-I

January 2019

**Power System Operation Corporation Limited**

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## List of Figures

## Acknowledgement

The authors would like to thank the management of POSOCO for motivating and guiding us in compilation of this report. The authors would also like to express gratitude towards Sh S K Soonee, Advisor, POSOCO, Sh K V S Baba, CMD POSOCO, Sh S R Narasimhan, Director (System Operation) and Sh A Gartia, Executive Director, SRLDC for constant support and guidance. The authors also acknowledge contribution of all others who have either directly or indirectly contributed towards the completion of this report.

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## Introduction

Electricity demand is constantly changing, making variability and uncertainty inherent characteristics of electric power system. As the penetration of variable renewable energy increases in the Indian grid, real time system operators are faced with a challenge of balancing variable renewable energy. A lot of focus, world-wide including in India, has been to harness the flexibility attributes in generation, transmission, distribution and electricity markets so as to incorporate more renewable energy and responsive demand.

One part of the solution is the flexible generation in which power plants can ramp up and down quickly and efficiently and run at low output levels (i.e., deep turn-downs). It has been observed that wind and solar generation can create the need for more flexibility as they lead to steeper ramps, deeper turn downs, and shorter peaks in system operations. It is recognized that rapid ramping and deep turn-downs constitute short term operational requirements and therefore, other factors also need to be considered.

In the report *GREENING THE GRID: Pathways to integrate 175 GW of Renewable Energy into India's Electric Grid, Vol I – National Study*, with 100 GW solar and 60 GW wind in 2022 scenario, the net load would be characterized by steeper ramps and lower minimum generation levels. The net load ramps observed in the study peak at 32 GW/hour. Hence, the generation that serves the net load, in aggregate, must be more flexible. Figure 1 below taken from the report shows the distribution of the hourly ramp of net load in 2022.

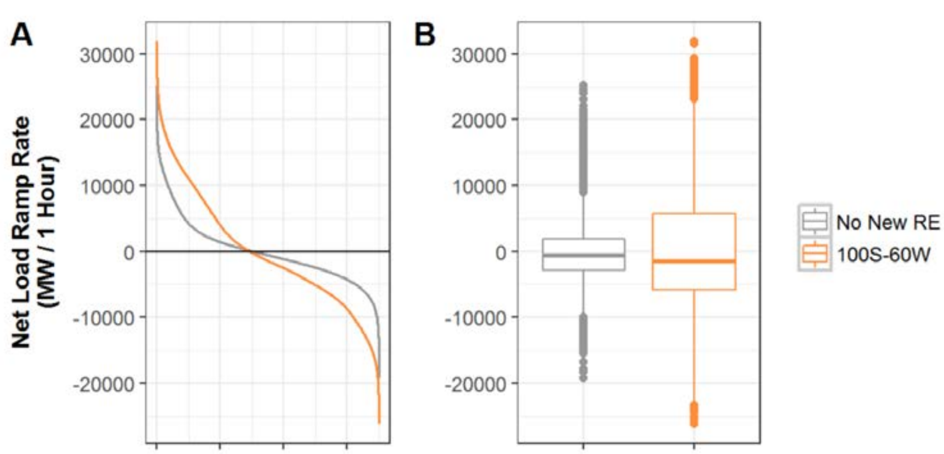



*Figure 1: Net load ramp rate per hour, arranged from highest to lowest for all periods of the year (A), and as a distribution (B), No New RE and 100 GW Solar & 60 GW Wind*

## Regulatory Provisions in Indian Context

There are various provisions in the Indian Electricity Grid Code (IEGC) and CEA Technical Standards pertaining to ramping requirements.as follows:

1. **CEA ( Technical Standard for Construction of Electrical Plant and Electrical Lines)**
    - **7 (4) -** The design shall cover adequate provision for quick start up and loading of the unit to full load at a fast rate. The unit shall have **minimum rate of loading or unloading of 3% per minute above the control load** (i.e. 50% MCR). For supercritical and ultra-super-critical units**, minimum rate of loading or unloading shall be 5% per minute above the control load (i.e. 50%** MCR).

2. **IEGC**
    - **5.2(i) -** The recommended rate for changing the governor setting i.e., supplementary control for increasing or decreasing the output(generation level) for all generating units, irrespective of their type and size, would be **one(1.0) per cent per minute or as per manufacturer's limits**.
    - **6.4.16 Demarcation of responsibilities: -** The ISGS shall make an advance declaration of ex-power plant MW and MWh capabilities foreseen for the next day, i.e., from 0000 hrs to 2400 hrs….**The generating stations shall also declare the possible ramping up / ramping down in a block.**
    - **6.5.14 Scheduling and Despatch procedure for long-term access, Medium – term and short-term open access -** While finalizing the above daily despatch schedules for the ISGS, RLDC shall ensure that the same are operationally reasonable, particularly in terms of ramping-up/ramping-down rates and the ratio between minimum and maximum generation levels. **A ramping rate of upto 200 MW per hour should generally be acceptable for an ISGS and for a regional entity (50 MW in NER), except for hydro-electric generating stations which may be able to ramp up/ramp down at a faster rate.**

3. **Standard Technical feature of BTG system for supercritical 660/800 MW Thermal units brought out by CEA in July 2013**

- **6.4.6 (i)Mode of steam generator operation and rate of loading -** The steam Generators shall be designed for minimum rate of loading/unloading mentioned below without compromising on design life of pressure parts
  1. Step Load Change : Minimum ± 10%
  2. **Ramp Rate: Minimum ± 3% per minute above 30% load**
- **12.1.4 (v) Operational Capabilities -** Fast Start – Up and Loading/Unloading Rate: The TG set shall be capable of being started from cold condition to full load operating conditions in as short time as possible. The TG set shall be designed for minimum rate of loading/unloading mentioned below without compromising on design life of the machine
  1. Step Load Change: Minimum ±10% to facilitate fast loading/unloading of unit
  2. **Ramp Rate: Minimum ±3% per minute above 30% load**

4. **Standard Technical specification for main Plant package of Sub-Critical Thermal project 2 x( 500MW or above) brought out by CEA in September 2008**
   - **2.1.14 Mode of Steam Generator Operation and Rate of Loading -** The steam generators shall be designed for minimum rate of loading/unloading mentioned below from 50% to 100% (TMCR) loads without compromising on design life of pressure parts
     1. Step Load Change: Minimum + 15%
     2. Ramp Rate :
        a. Minimum + 3% per minute under variable pressure operation
        b. Minimum + 5% per minute under constant pressure operation

## International Experience

Coal-fired plants are transitioning away from the base-load duties across the world. It is observed that internationally, coal-fired power plants are able to provide 2-5% per minute ramping capability. In the book *Modern Power Station Practice, Volume L: System Operation* (3rd Edition, 1992) based on operational experience of Central Electricity Generation Board (CEGB), UK, ramp rates for different classes of coal fired units are as reproduced below:

| Type of Plant | Block Load on Synchronization (MW) | Average pick-up and shutdown rates (MW/min) | Time to full load (min) | Minimum 'ON' Time (min) | Minimum 'OFF' Time (min) |
|---|---|---|---|---|---|
| 500/660 MW | 90 | 15 up/ 25 down | 35 | 120 | 240 |
| 200/300 MW | 45 | 5 up/ 10 down | 35 | 120 | 240 |
| 110/120 MW | 20 | 4 up/ 10 down | 25 | 60 | 240 |
| 60 MW | 2 | 3 up/ 5 down | 20 | 60 | 120 |

Considering the importance of ramping capability of conventional generation in integration of renewable generation, a number of studies have been conducted internationally on the subject. One such study *"A method and case study for estimating the ramping capability of a control area or balancing authority and implications for moderate or high wind penetration*" done by National Renewable Energy Laboratory (NREL), USA. In this study, hourly generation data for 3 control areas, CAISO, PJM and WAPA was obtained for one year. Ramping capability of any generator was determined by observing the maximum change in output between any 2 hours during the year. The observed maximum ramp rates were in the range of 1-1.2%/min. However, the ramp rate is significantly understated in this methodology, as the faster ramp rate of units that can attain full load in less than 1 hour doesn't get factored. Calculation of ramp rates in a more granular fashion would certainly improve the observed values.

In the Australian energy market, generators have to provide their ramp rates as part of their bid in the energy market. The minimum ramp rate should be 3 MW/min or 3%/min, whichever is lower. The minimum ramp requirement is calculated generating unit-wise and then aggregated.

## Data Analysis

The ramp-up and ramp-down rates as furnished by the RRAS Providers are given in figures 2 & 3 below:

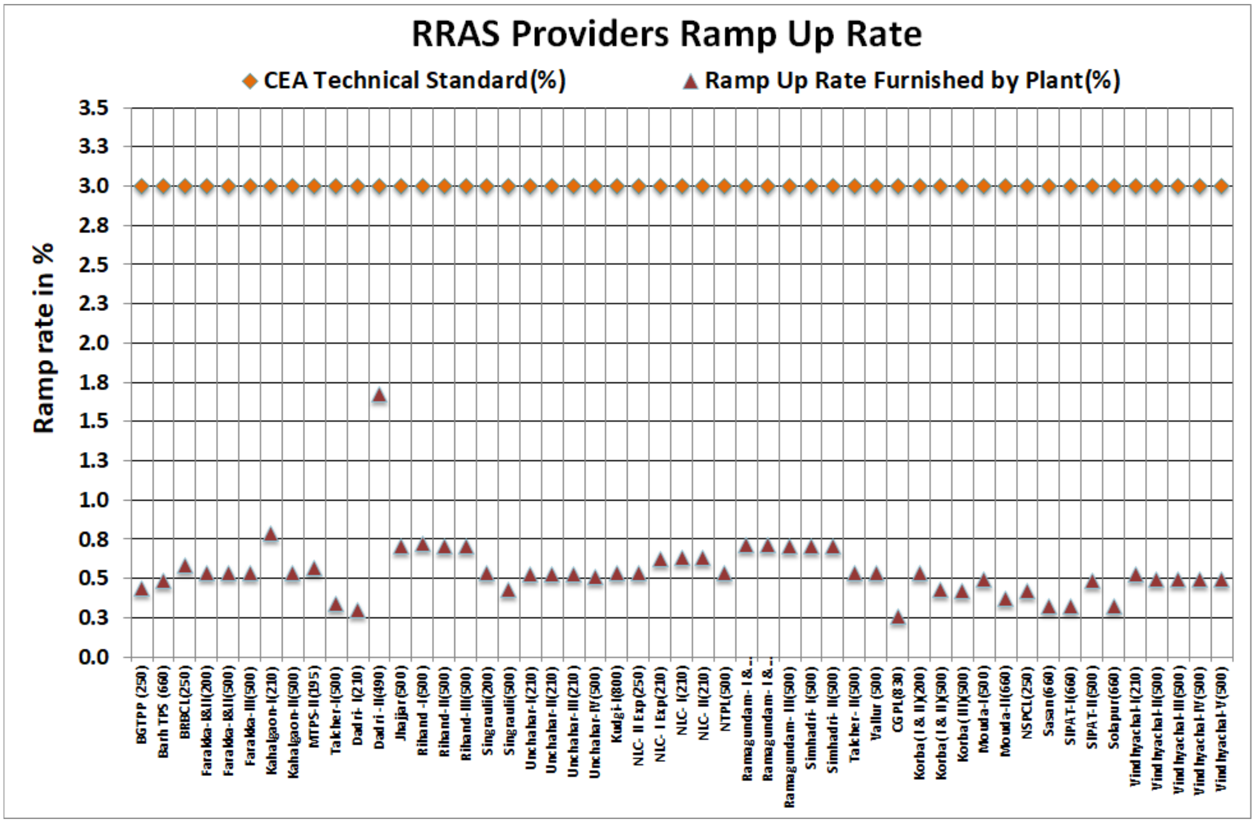



*Figure 2: Ramp-up rates furnished by RRAS providers for 16 Jan – 15 Feb 2019 (%/min)*

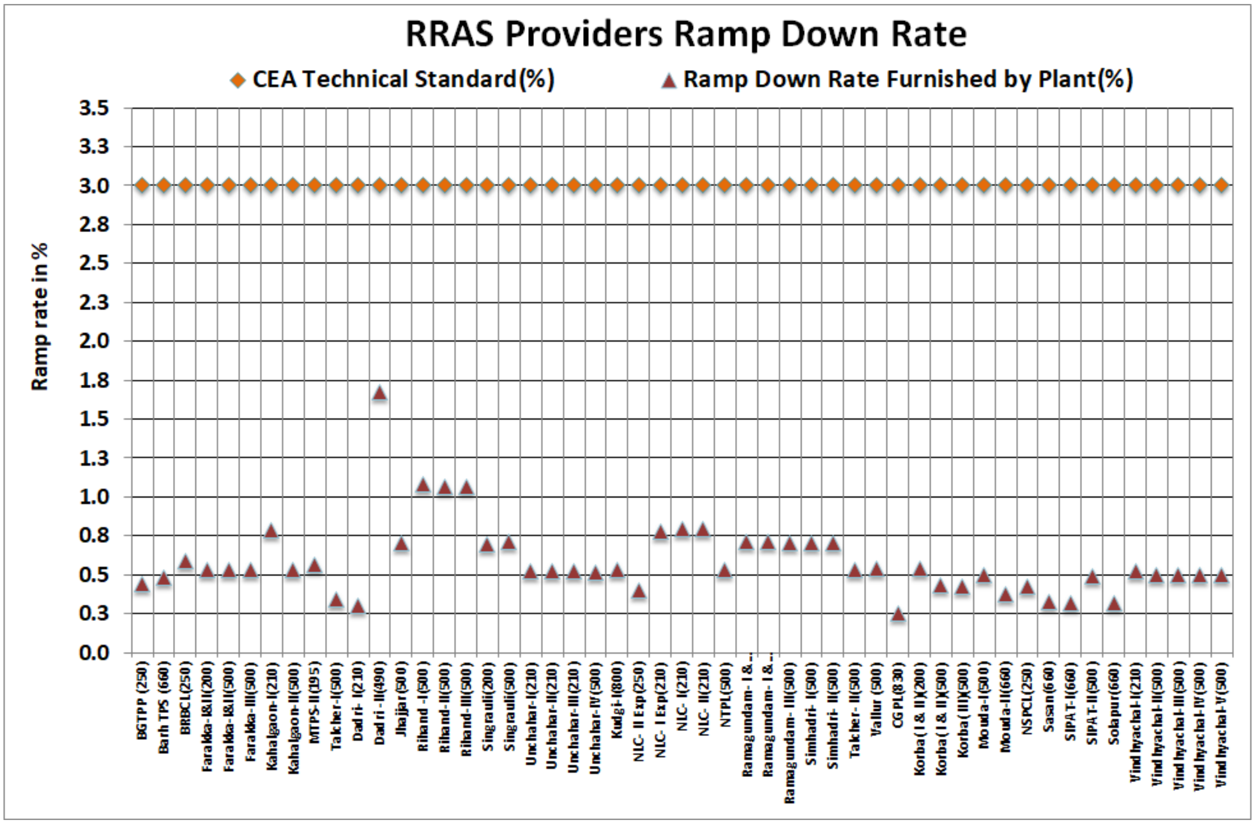



*Figure 3: Ramp-down rates furnished by RRAS providers for 16 Jan – 15 Feb 2019 (%/min)*

The ramp rates being adopted by the RRAS providers are quite less than those specified in the CEA Standards. With increasing penetration of renewables, ramping would be a critical requirement especially during peak hours and hence, higher ramp rates may be required. The flexibility metrics for thermal power stations should ideally cover technical minimum, ramp rates and number of start/stop operations. It would be appropriate if the ramp rates specified by CEA are also mentioned in the Grid Code and enforced.

## Analysis Method & Data sources

The 15 min average SCADA generation data of all the coal fired units is taken as the schedule of Generation is based on 15 Min block period. Thus only the 15-min ramping capability is identified. The dataset are extracted for seven years from FY 2011-12 to FY 2017-18, however the 2017-18 data is used to ascertain the ramping capability of 438 No's unit in the country accounting for 165 GW installed capacity for sizes above 200 MW. The 15 Min average generator data was analyzed for finding out the ramping capability for each generator. The change in the output between any two consecutive blocks is considered as ramp and performing the same quantum for at least few instances in a year is defined as the ramping capability of Unit. Upward and downward ramping have been determined separately and converted to MW/Min (%). The estimated figures are conservative, as the faster ramping Units which would have done fast ramping for first few minutes in a block and may have been averaged by the steady generation in rest of the block.

Analyzing load ramp helps to identify periods that may be operationally challenging and hence the generation ramping required to serve the load. The maximum Demand Ramp up/Block is 3750MW and downward ramp rate is 2500 MW. With further increase in demand and Renewable penetration, the requirement of Ramping is going to increase in future. An analysis is thus made on accessing the existing coal-fired generating stations ramping capability for accommodating the predictable nature of renewable generation variations into the grid.

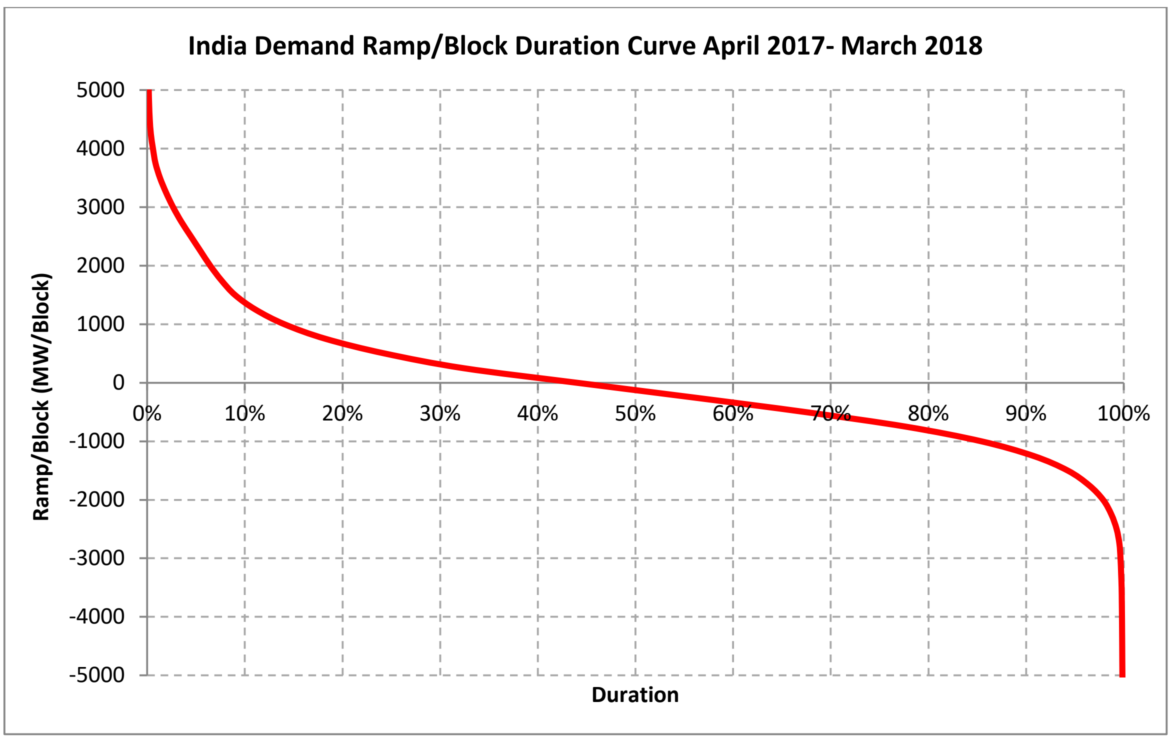



*Figure 4: Duration curve of All India Demand Ramp during 2017-18 (MW/block)*

## Results

Based on generation data of coal-based units, following analyses have been done – generation trend, duration curve, ramp trend, and ramp duration curve. Sample plots for one pithead and non-pithead machine in each region are enclosed in the annexure. Analysis for each thermal unit in the country would form Volume-II of this report.

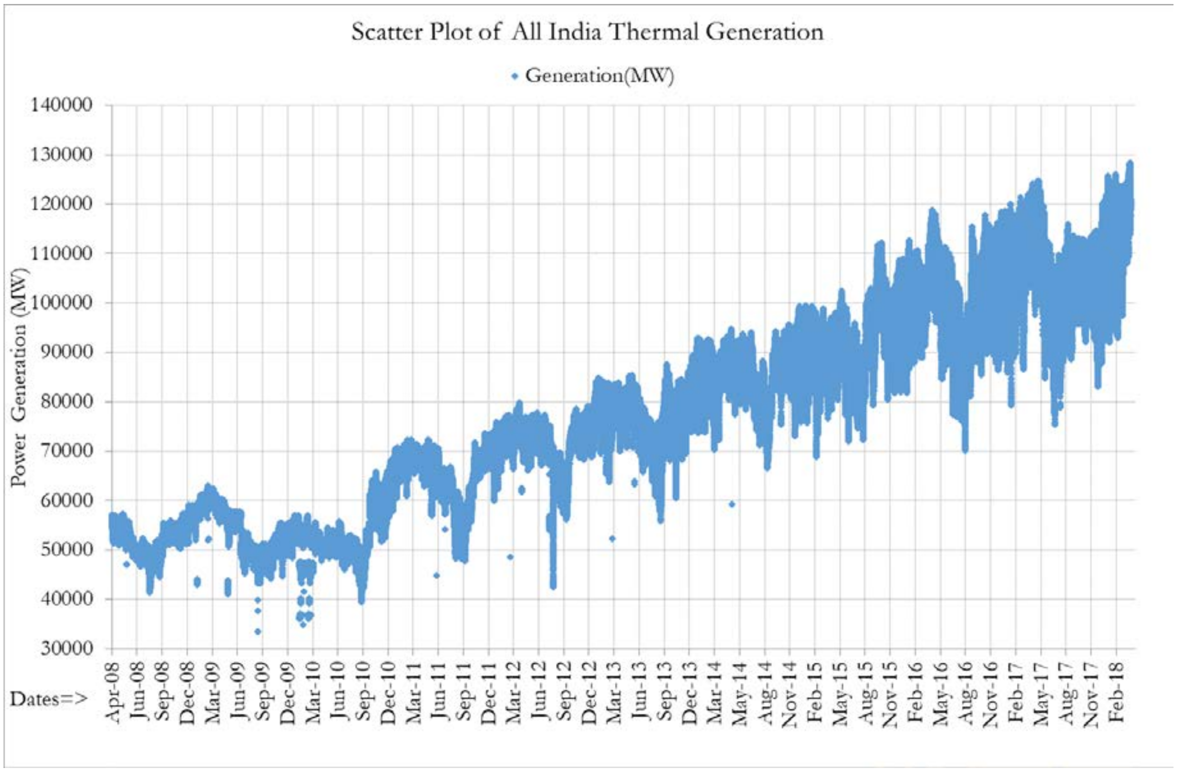
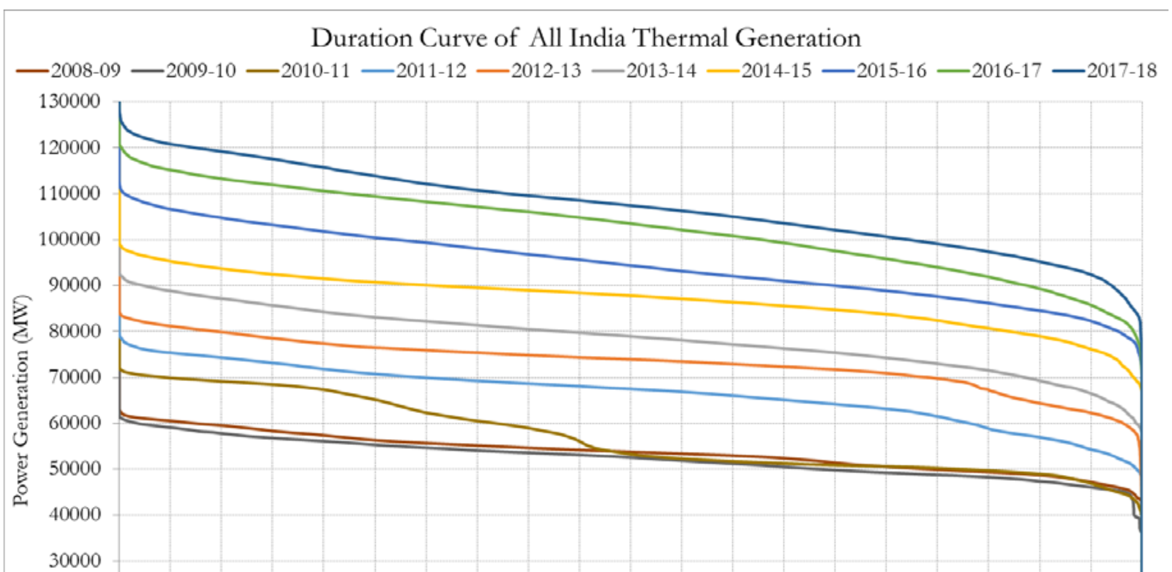



*Figure 5: Trend of All India Thermal Generation (MW) for 2008-09 to 2017-18*




| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | 2016-17 | 2017-18 |
|---|---|---|---|---|---|---|---|---|---|---|
| Average Gen (MW) | 53733 | 52396 | 57044 | 66494 | 73160 | 78470 | 86919 | 94508 | 102281 | 107079 |
| Maximum Gen (MW) | 63005 | 61677 | 72277 | 79813 | 84883 | 92882 | 99476 | 112720 | 121469 | 128396 |
| Minimum Gen (MW) | 45000 | 43600 | 43800 | 51000 | 58600 | 61200 | 70400 | 78000 | 80400 | 85200 |
| (Max - Min)/Max (%) | 29 | 29 | 39 | 36 | 31 | 34 | 29 | 31 | 34 | 34 |

*Figure 6: Duration curves for All India Thermal Generation for 2008-09 to 2017-18*

At All India level around 35% of coal-fired generating units (438 Nos) are having the Ramp – Up/Down capability of providing at least 1%/Min.

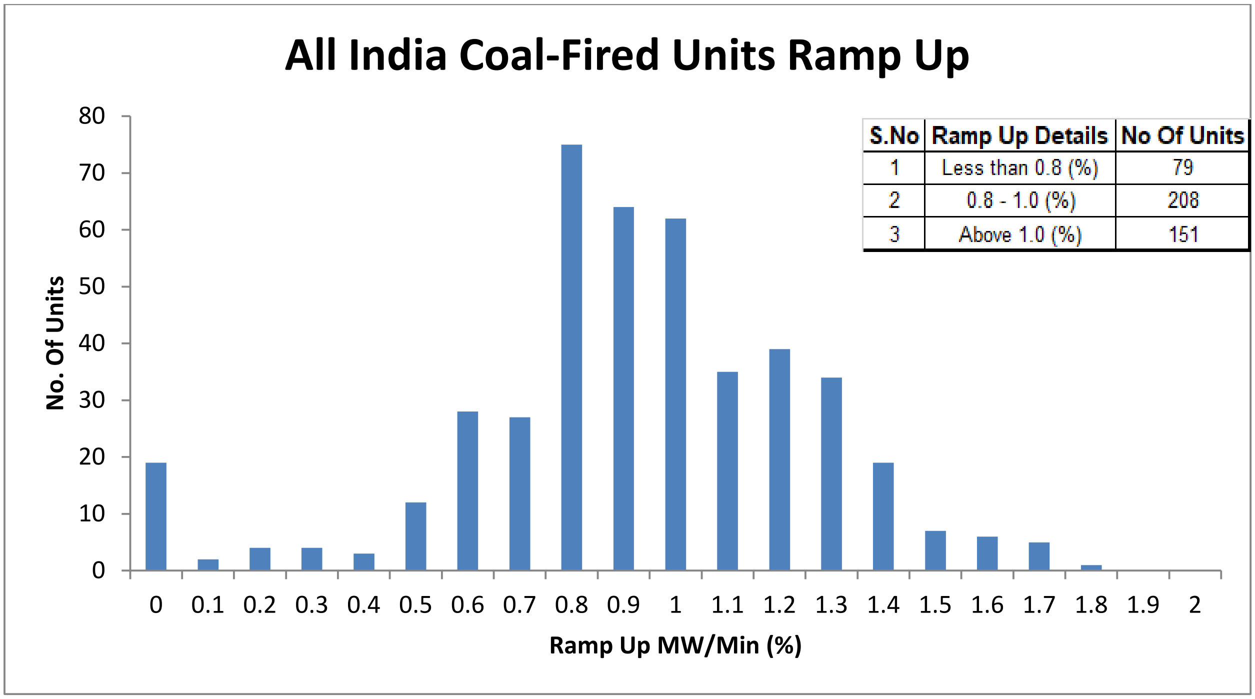



*Figure 7: All India Coal-fired Generating stations' Maximum Ramp UP Capability Distribution*

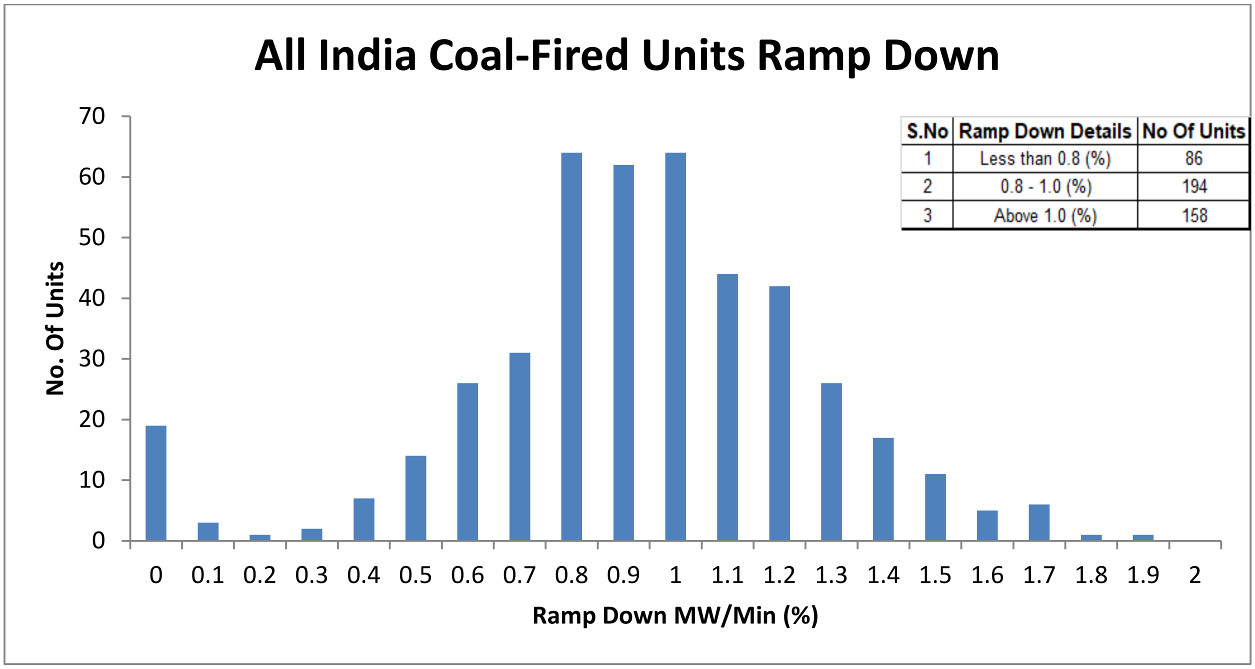



*Figure 8: All India Coal-fired Generating stations' Maximum Ramp down Capability Distribution*

At present the majority of the Coal-fired central generating stations are declaring a Ramp of 0.5 % - 0.7 % MW/Min, however as seen from SCADA data, units have done ramping greater than 1%/Min.

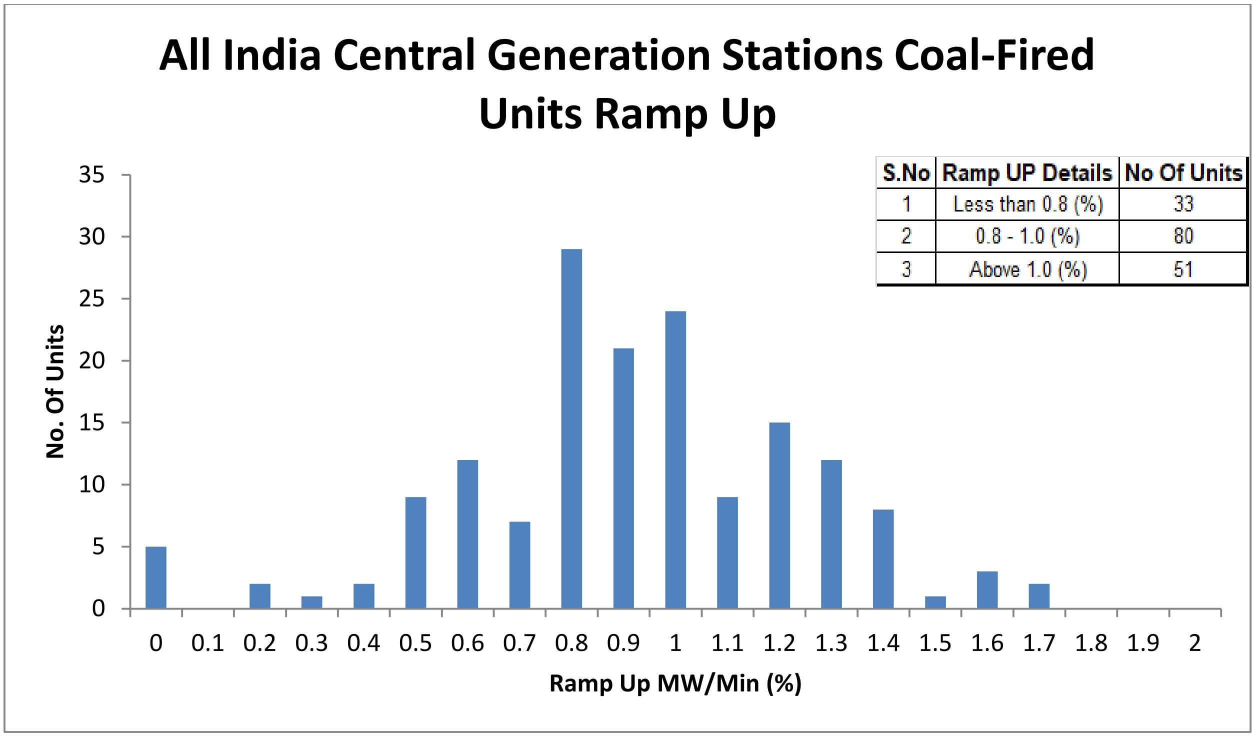



*Figure 9: All India Coal-fired Central Generating Stations' (CGS) Maximum Ramp UP Capability Distribution*

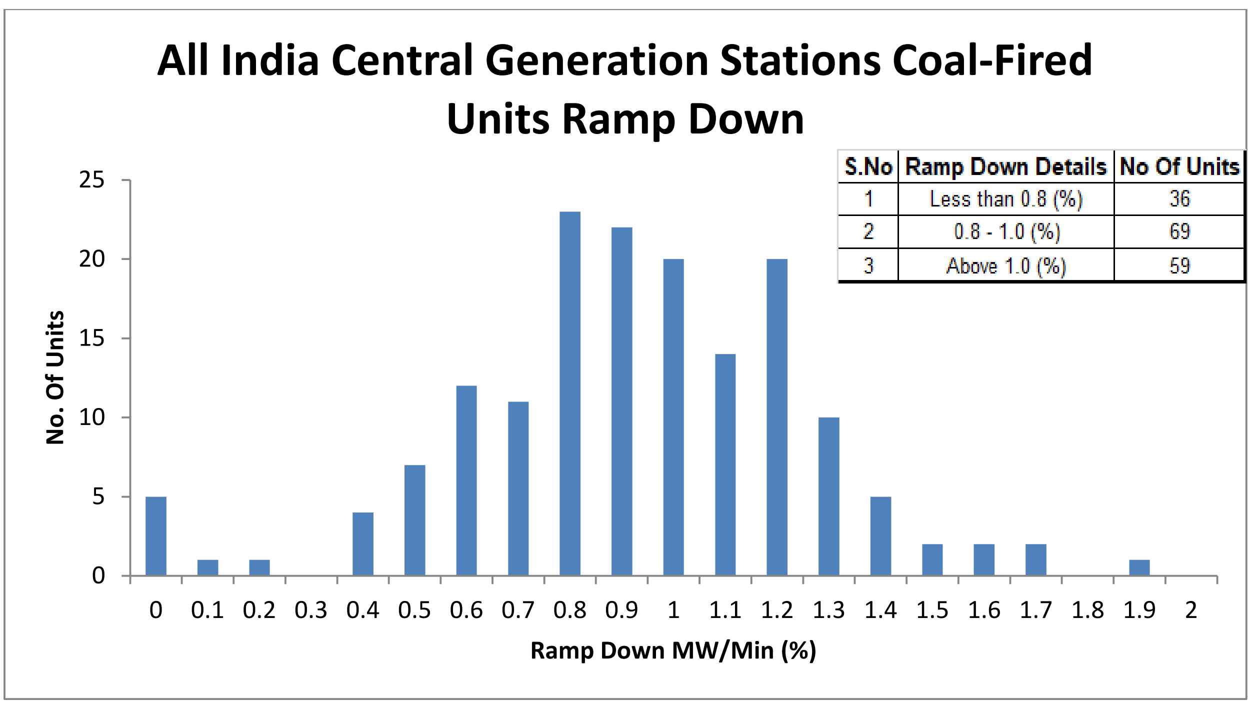



*Figure 10: All India Coal-fired Central Generating Stations' (CGS) Maximum Ramp down Capability Distribution*

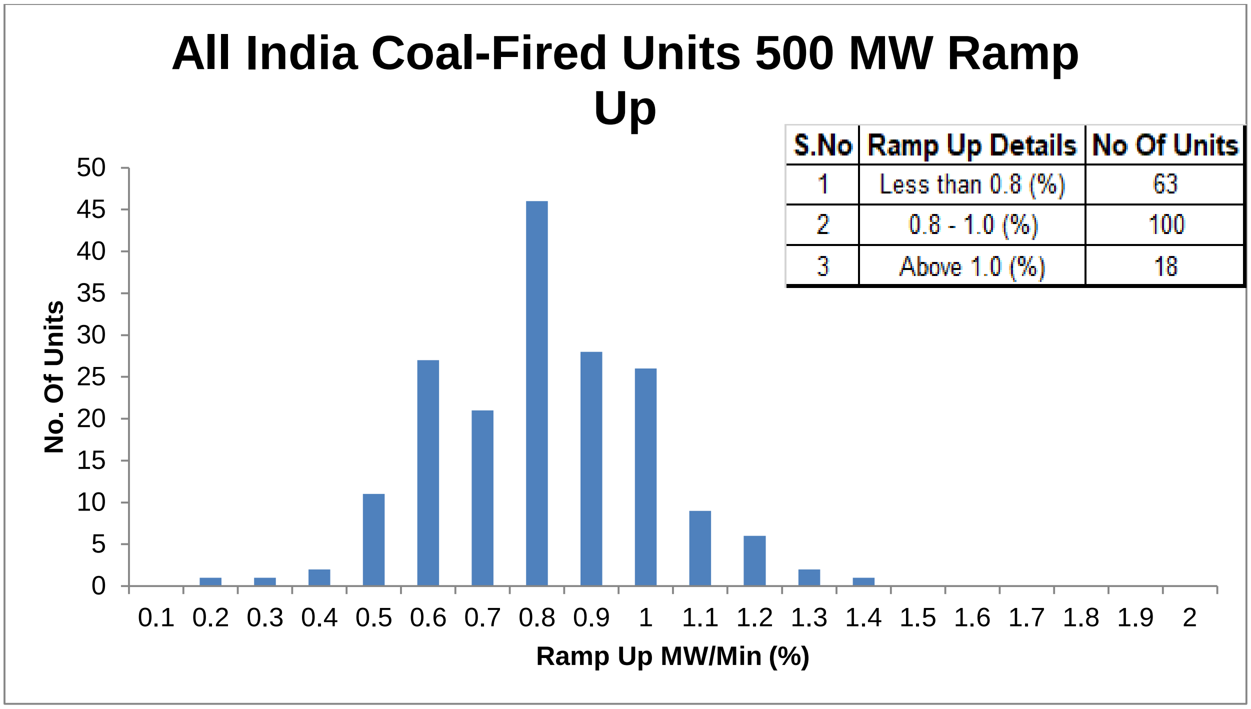



*Figure 11: All India Coal-fired Generating Units (Installed Capacity 500 MW and above) Maximum Ramp Up Capability Distribution*

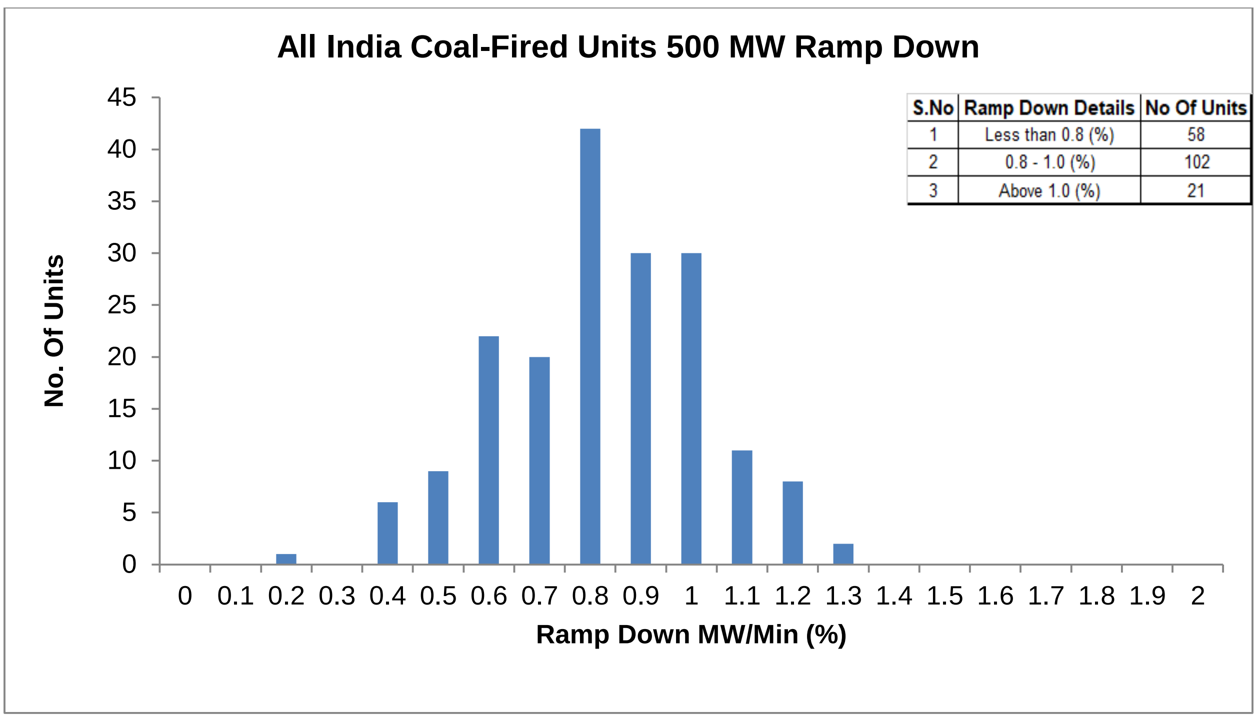



*Figure 12: All India Coal-fired Generating Units (Installed Capacity 500 MW and above) Maximum Ramp Down Capability Distribution*

## Way forward

Ramping support from thermal generation would be an important attribute considering the large scale renewable integration and changing load shape. Although, the CEA standards prescribe +/-3% per minute ramp rate, the IEGC has provisions requiring only +/-1% per minute ramp rate only. Even though, the generators are not able to provide +/- 1% ramp rate. As discussed in the report, higher ramping is only required for short durations, the concerns of thermal generators regarding stress on the machines is not justified.

Therefore, following is proposed:

1) Since non-pit head plants would be required to flex more in comparison to pit-head plants, it is proposed that IEGC may be amended to incorporate +/-3% ramp rate for non-pit head plants and +/-1% ramp rate for pit-head plants. Further, for gas based plants, ramp rate of +/- 6% may be specified in IEGC.
2) Suitable provisions regarding performance monitoring with regard to ramp rate may also be included in the CERC (Terms and Conditions of Tariff), Regulations. In case of consistent non-compliance, provisions regarding penalty in terms of reduction in fixed cost charges may also be included. Suggested clause to be added in the tariff regulations is as follows:

   *"the rate of return of a generator shall be reduced by 1% for such period as may be decided by the Commission, if the generating station is found to be not providing ramp rate in accordance with the IEGC based on the report of RLDC"*

3) Similar provisions regarding ramping are also required to be included in the state grid codes and tariff regulations to achieve full benefits of ramping. This may be discussed in the Forum of Regulators to arrive at common consensus.

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2. "Modern Power Station Practice, Volume L: System Operation" 3rd Edition, British Electricity International, 1992

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6. Minutes of Special Meeting on Ramp rates, technical minimum, startup from hot, warm and cold conditions, SRPC Bengaluru, January 2019 (http://www.srpc.kar.nic.in/website/2018/meetings/special/msplmrr21-01-19.pdf)

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11. Saif Rehman, NLDC
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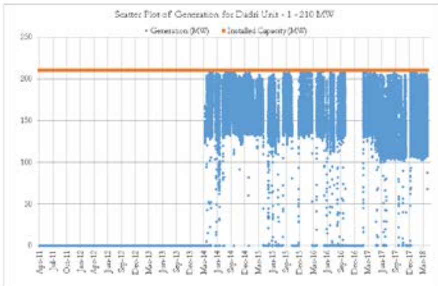
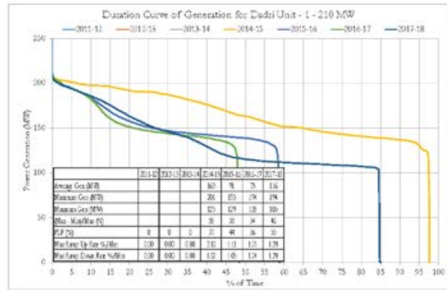
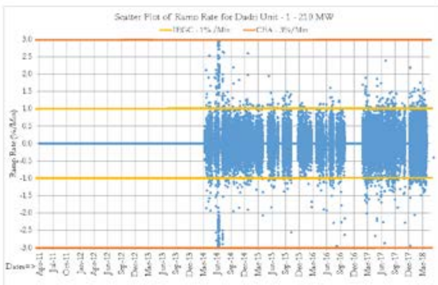
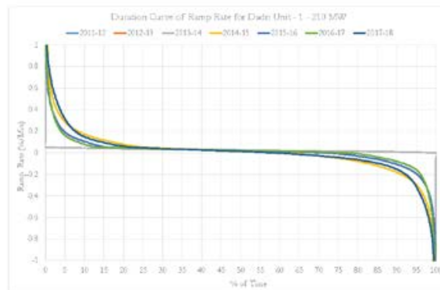
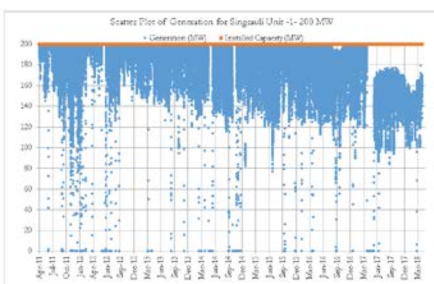
## Annexure-I

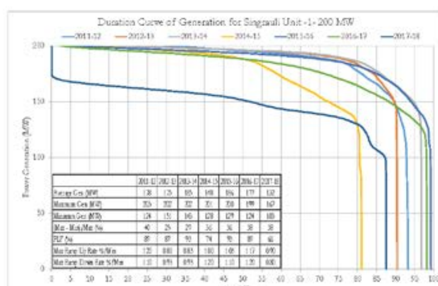

Scatter Plot of Generation for Dadri Unit - 1 - 210 MW
Generation (MW)
Installed Capacity (MW)

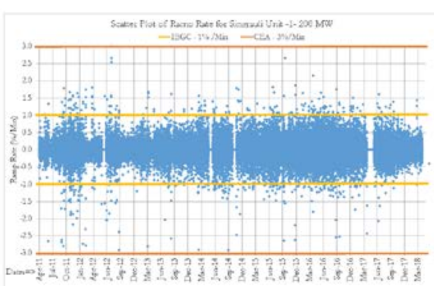

Duration Curve of Generation for Dadri Unit - 1 - 210 MW
% of Time

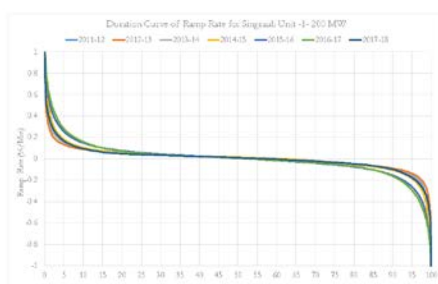

Scatter Plot of Ramp Rate for Dadri Unit - 1 - 210 MW
IEGC - 1% /Min
CEA - 3%/Min

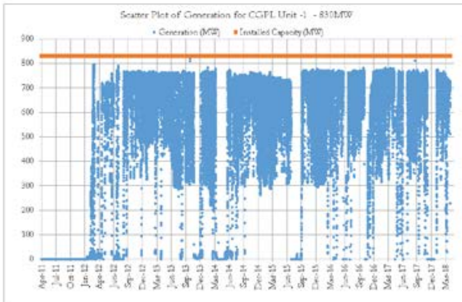

Duration Curve of Ramp Rate for Dadri Unit - 1 - 210 MW
% of Time

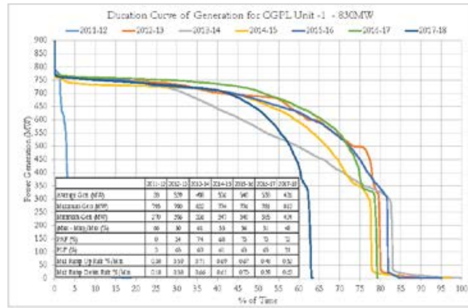

Scatter Plot of Generation for Singrauli Unit -1- 200 MW
Generation (MW)
Installed Capacity (MW)

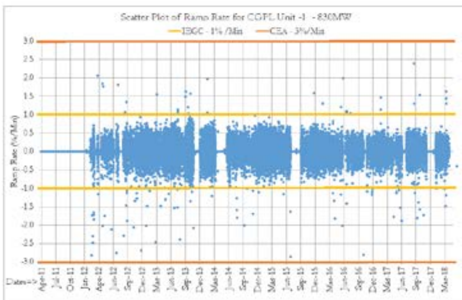

Duration Curve of Generation for Singrauli Unit -1- 200 MW
% of Time

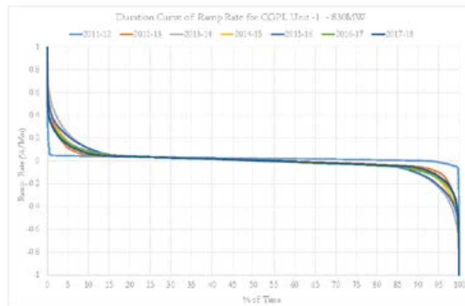

Scatter Plot of Ramp Rate for Singrauli Unit -1- 200 MW
IEGC - 1% /Min
CEA - 3%/Min

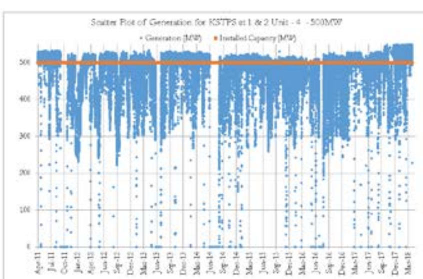

Duration Curve of Ramp Rate for Singrauli Unit -1- 200 MW
% of Time

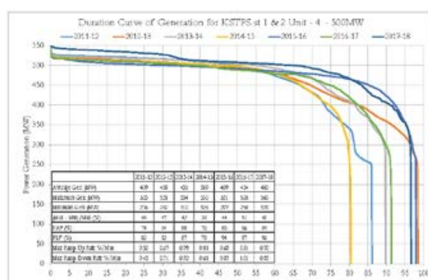

Scatter Plot of Generation for CGPL Unit -1 - 830MW
Generation (MW)
Installed Capacity (MW)

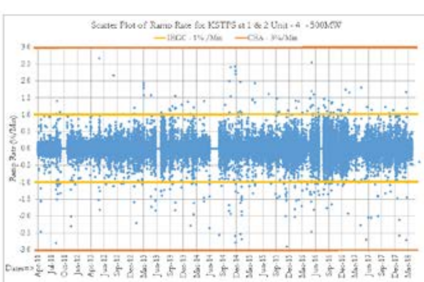

Duration Curve of Generation for CGPL Unit -1 - 830MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Power Generation (MW)
% of Time

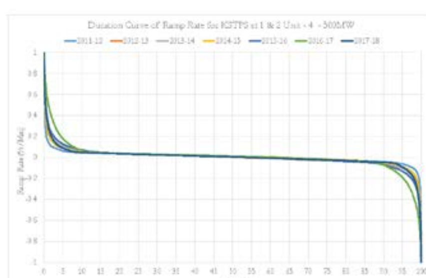

Scatter Plot of Ramp Rate for CGPL Unit -1 - 830MW
IEGC - 1% /Min
CEA - 3%/Min
Ramp Rate (%/Min)

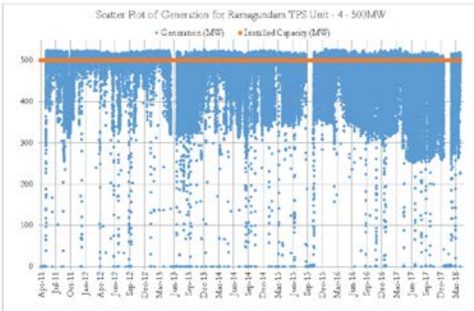

Duration Curve of Ramp Rate for CGPL Unit -1 - 830MW
% of Time


Scatter Plot of Generation for KSTPS st 1 & 2 Unit - 4 - 500MW
Generation (MW)
Installed Capacity (MW)

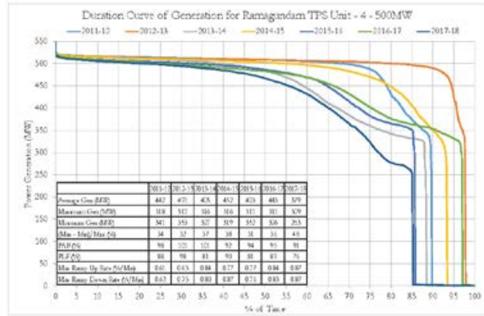

Duration Curve of Generation for KSTPS st 1 & 2 Unit - 4 - 500MW
% of Time


Scatter Plot of Ramp Rate for KSTPS st 1 & 2 Unit - 4 - 500MW
IEGC - 1% /Min
CEA - 3%/Min

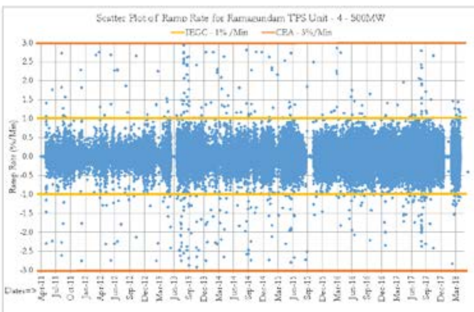

Duration Curve of Ramp Rate for KSTPS st 1 & 2 Unit - 4 - 500MW
% of Time



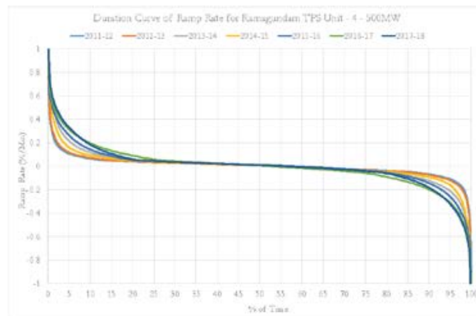
Scatter Plot of Generation for Ramagundam TPS Unit - 4 - 500MW
Generation (MW)
Installed Capacity (MW)

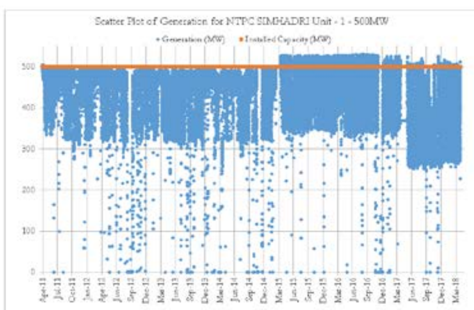
Duration Curve of Generation for Ramagundam TPS Unit - 4 - 500MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Power Generation (MW)
% of Time

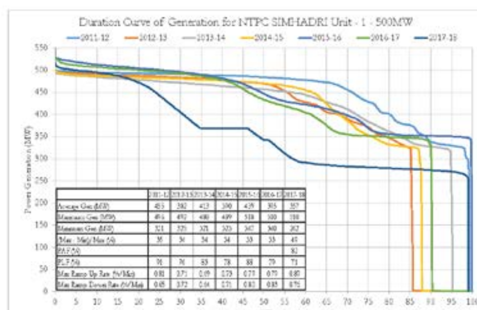
Scatter Plot of Ramp Rate for Ramagundam TPS Unit - 4 - 500MW
IEGC - 1% /Min
CEA - 3%/Min
Ramp Rate (%/Min)
Dates=>

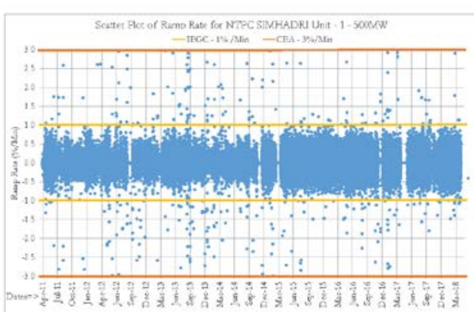
Duration Curve of Ramp Rate for Ramagundam TPS Unit - 4 - 500MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Ramp Rate (%/Min)
% of Time

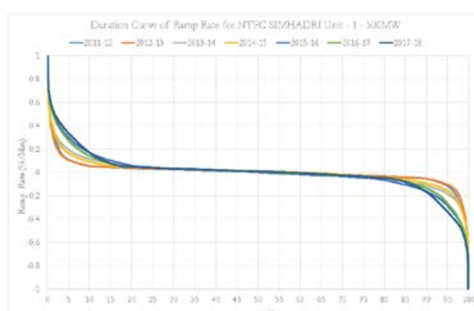
Scatter Plot of Generation for NTPC SIMHADRI Unit - 1 - 500MW
Generation (MW)
Installed Capacity (MW)

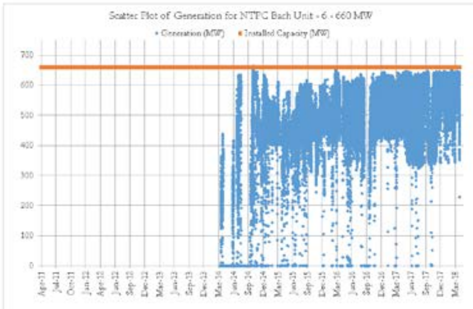
Duration Curve of Generation for NTPC SIMHADRI Unit - 1 - 500MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Power Generation (MW)
% of Time

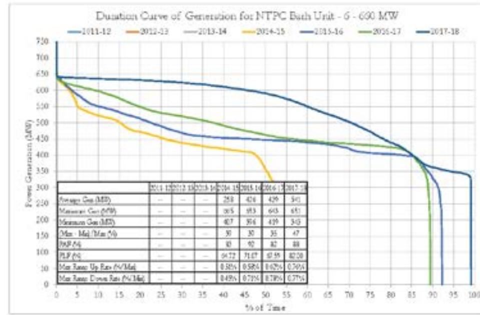



Scatter Plot of Ramp Rate for NTPC SIMHADRI Unit - 1 - 500MW
IEGC - 1% /Min
CEA - 3%/Min
Ramp Rate (%/Min)
Dates=>

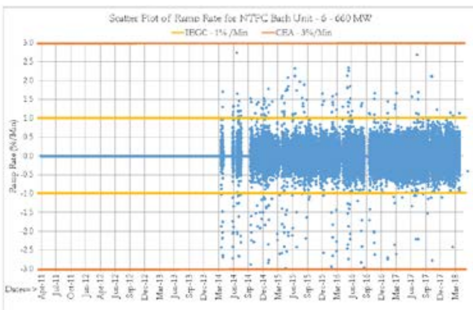



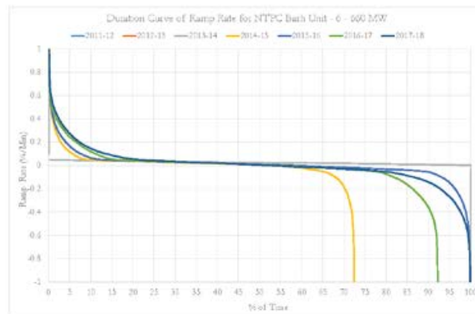
Duration Curve of Ramp Rate for NTPC SIMHADRI Unit - 1 - 500MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Ramp Rate (%/Min)
% of Time

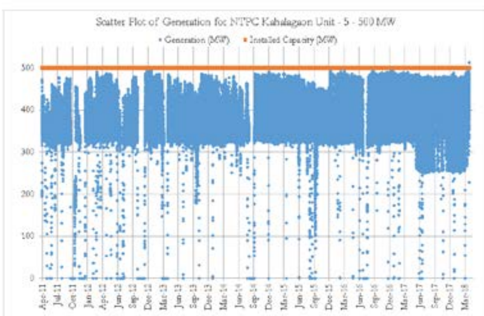

Scatter Plot of Generation for NTPC Barh Unit - 6 - 660 MW
Generation (MW)
Installed Capacity (MW)

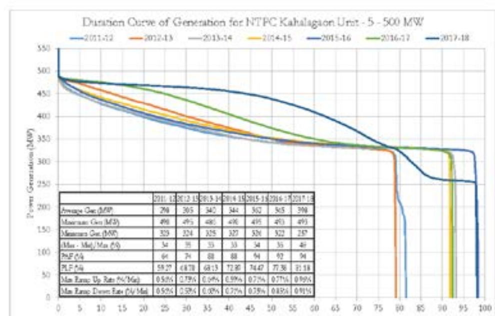

Duration Curve of Generation for NTPC Barh Unit - 6 - 660 MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Power Generation (MW)
% of Time

| | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | 2016-17 | 2017-18 |
|---|---|---|---|---|---|---|---|
| Average Gen (MW) | -- | -- | -- | 258 | 426 | 439 | 541 |
| Maximum Gen (MW) | -- | -- | -- | 605 | 653 | 643 | 651 |
| Minimum Gen (MW) | -- | -- | -- | 407 | 394 | 439 | 343 |
| (Max - Min)/Max (%) | -- | -- | -- | 30 | 30 | 35 | 47 |
| PAF (%) | -- | -- | -- | 80 | 92 | 82 | 88 |
| PLF (%) | -- | -- | -- | 64.72 | 71.67 | 67.55 | 82.08 |
| Max Ramp Up Rate (%/Min) | -- | -- | -- | 0.38% | 0.58% | 0.62% | 0.74% |
| Max Ramp Down Rate (%/Min) | -- | -- | -- | 0.49% | 0.71% | 0.78% | 0.77% |

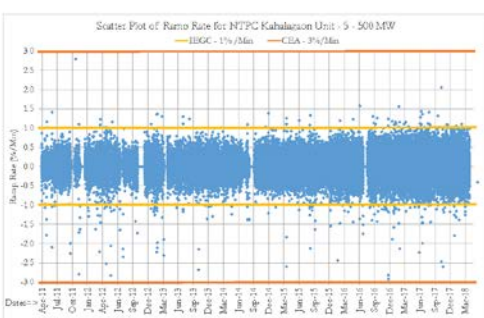

Scatter Plot of Ramp Rate for NTPC Barh Unit - 6 - 660 MW
IEGC - 1% /Min
CEA - 3%/Min
Ramp Rate (%/Min)

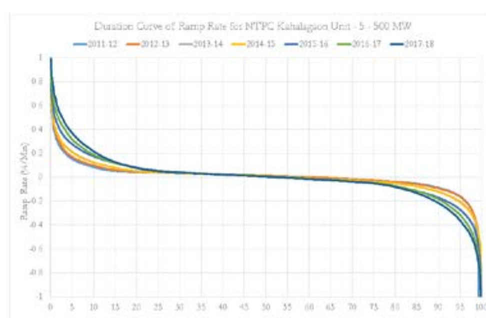

Duration Curve of Ramp Rate for NTPC Barh Unit - 6 - 660 MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Ramp Rate (%/Min)
% of Time

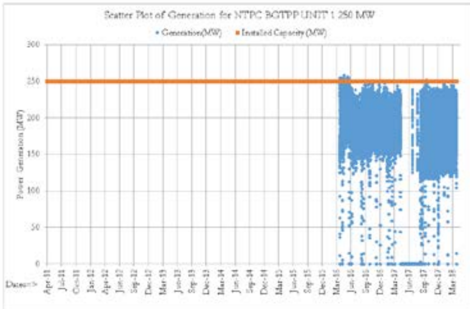

Scatter Plot of Generation for NTPC Kahalgaon Unit - 5 - 500 MW
Generation (MW)
Installed Capacity (MW)

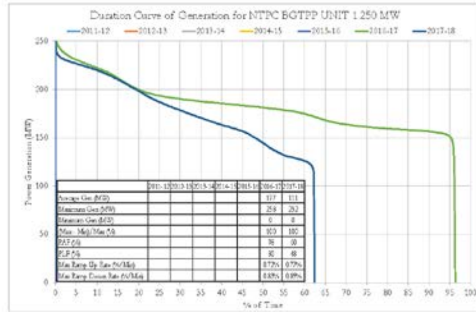

Duration Curve of Generation for NTPC Kahalgaon Unit - 5 - 500 MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Power Generation (MW)
% of Time

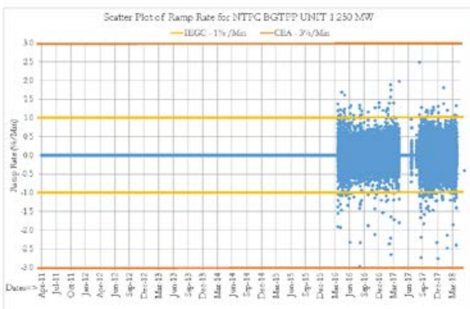
| | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | 2016-17 | 2017-18 |
|---|---|---|---|---|---|---|---|
| Average Gen (MW) | 298 | 305 | 340 | 344 | 362 | 365 | 398 |
| Maximum Gen (MW) | 498 | 495 | 480 | 496 | 495 | 493 | 493 |
| Minimum Gen (MW) | 329 | 324 | 325 | 327 | 326 | 322 | 257 |
| (Max - Min)/Max (%) | 34 | 35 | 33 | 33 | 34 | 35 | 48 |
| PAF (%) | 64 | 74 | 88 | 88 | 94 | 92 | 94 |
| PLF (%) | 59.27 | 68.78 | 68.13 | 72.80 | 74.47 | 77.36 | 81.18 |
| Max Ramp Up Rate (%/Min) | 0.56% | 0.75% | 0.69% | 0.99% | 0.75% | 0.77% | 0.96% |
| Max Ramp Down Rate (%/Min) | 0.52% | 0.58% | 0.60% | 0.77% | 0.75% | 0.85% | 0.91% |

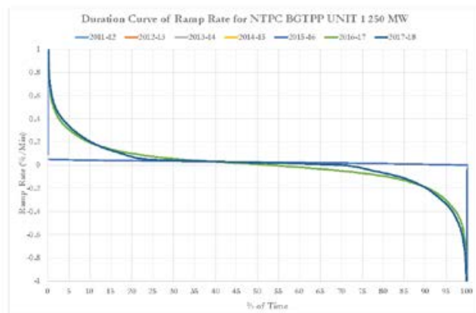

Scatter Plot of Ramp Rate for NTPC Kahalgaon Unit - 5 - 500 MW
IEGC - 1% /Min
CEA - 3%/Min
Ramp Rate (%/Min)


Duration Curve of Ramp Rate for NTPC Kahalgaon Unit - 5 - 500 MW
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Ramp Rate (%/Min)
% of Time


Scatter Plot of Generation for NTPC BGTPP UNIT 1 250 MW


Duration Curve of Generation for NTPC BGTPP UNIT 1 250 MW


Scatter Plot of Ramp Rate for NTPC BGTPP UNIT 1 250 MW


Duration Curve of Ramp Rate for NTPC BGTPP UNIT 1 250 MW