

# Impact of Very Severe Cyclone “Nisarga” on Mumbai Tata Power System Operation

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**Abstract**—Nisarga was the strongest tropical cyclone to strike the Indian state Maharashtra in the month of June 2020. It was also the first cyclonic impact to Mumbai, since Cyclone Phyan in year 2009. As a result of depression in the Arabian sea, cyclone originated and moving towards north on 2<sup>nd</sup> June-2020, the India Meteorological Department (IMD) upgraded their system to track the movement of cyclonic storm and assigning the name *Nisarga*. Pre-preparedness by all utility and load dispatchers prevented for severe loss to the electrical system. This paper includes impact of Nisarga Cyclone on power system operations across all facets in Mumbai at Maharashtra i.e. generation, transmission, distribution system.

**Keywords** – India Meteorological Department (IMD), Western Region Load Dispatch Center (WRLDC), Maharashtra state Load Dispatch Center (MSLDC), Emergency Restoration System (ERS), Very Severe Cyclonic Storm (VSCS)

## 1. INTRODUCTION

Impact of ‘Cyclone Nisarga’ that is hit on seacoast located at Alibaug in Maharashtra’s Raigad district on Wednesday afternoon with wind speed of up to 120 kmph on 3rd June 2020, on power system operation. Power system operation is very sensitive to slight changes in weather conditions (temperature, rainfall etc.) that has been impact across all facets i.e. generation, transmission, distribution, and power system restoration. Also, with modern power systems being interconnected with tie lines and disturbances caused by such a severe climatic change could be catastrophic for entire regional grid, the nature of power system being such that it leaves very slightly margin for reactive control due to high disturbance. Indian Meteorological Department (IMD) published a yellow warning for a cyclonic storm over east central Arabian sea at 1440 hrs. on 01st June’ 2020 that is likely to cross north Maharashtra and South Gujarat coast between Harihareshwar (Raigad, MH) and Daman during afternoon of 03rd June’ 2020. As per the IMD, there were heavy to very heavy rains forecasted for remote places over South Konkan, Goa, Daman & Diu, Dadra Nagar Haveli, South Gujarat and North Madhya Maharashtra on 03<sup>rd</sup> and 04<sup>th</sup> June’ 2020.

The forecasted track is as under:

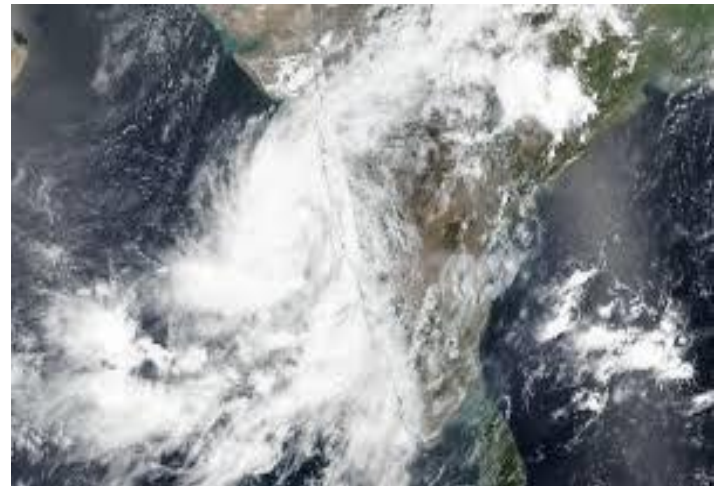


Fig 1: Shows the satellite image of Nisarga the super-cyclone

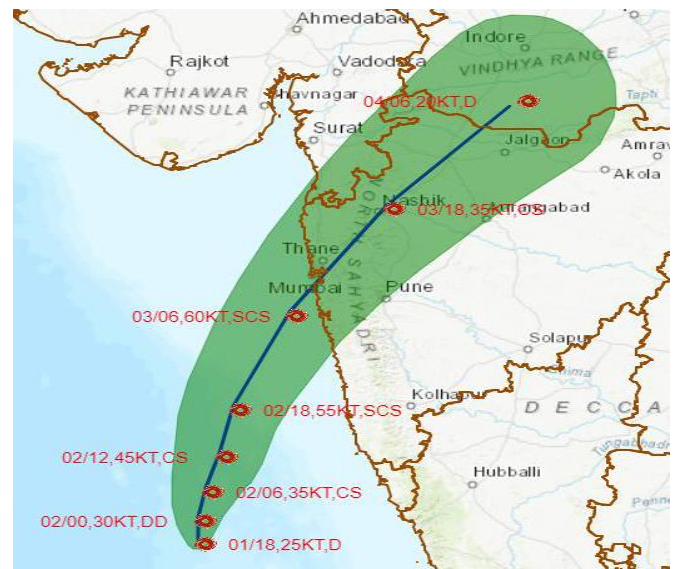


Fig 2: gives the track of the same over the period based on meteorological data.

From the above diagram, it is observed that the geographic location of various districts such as Ratnagiri, Sindhudurg, Raigad, Thane, Mumbai, Palghar, Pune, Ahmednagar, Aurangabad, Nashik, Malegaon, Dhule, Nandurbar and Jalgaon are within the “Cone of Uncertainty”.

## 2. THE OVERALL SYSTEM CONFIGURATION OF MUMBAI TRANSMISSION NETWORK

The Mumbai Power System is interconnected with Maharashtra State grid at three locations (Trombay, Kalwa Borivli, Boisar). The State grid is further interconnected with

Gujarat and Madhya Pradesh State grids through 400 kV and 220 kV interstate tie lines.

The Tata Power Company forms an important component of the Maharashtra State grid. The present installed capacity of Tata is 1377 MW and Adani 500 MW in Mumbai. Tata power generating and receiving stations are strongly interconnected through 220 kV & 110 kV overhead and underground transmission lines and 33/22/6.6 KV distribution network.

Tata Transmission & Distribution network	
220 KV lines	32
110 KV lines	51
Transmission R/S No	27
Distribution Sub Station	34
Consumer Sub Station	943

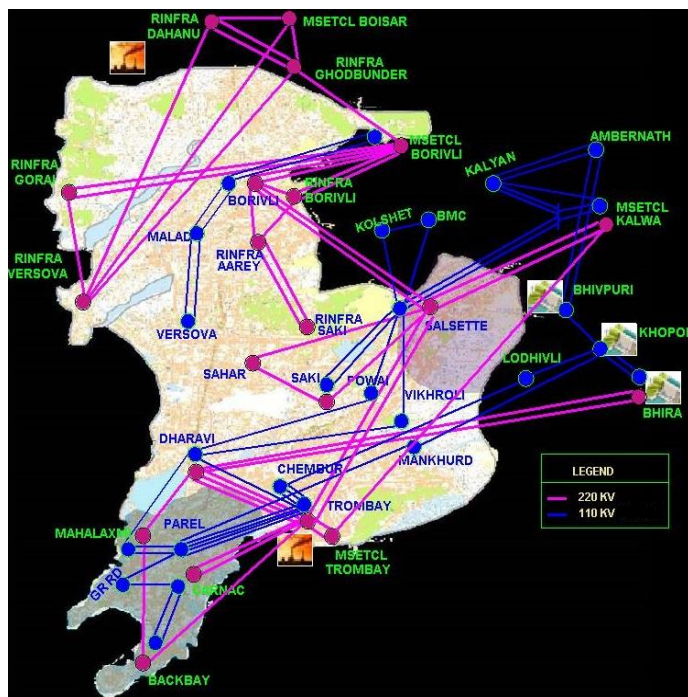


Fig 3: Mumbai Tata Power Transmission Layout with Tie line connection

The distribution node at PSCC is responsible for handling the TPC-D load of direct consumers at 33, 22 and 11 KV levels. Distribution node has total 6 zones:

- 1) North suburbs (North)
- 2) West (Central)
- 3) Metro (South-Central)
- 4) Urban(South)
- 5) East
- 6) City



Fig 4: Mumbai Tata Power Distribution Layout

### 3. DIRECTIVE'S PREVENTIVE MEASURE TAKEN BY WRLDC/MSLDC BEFORE LANDFALL OF CYCLONE

#### For All Users:

- Cyclone is likely to have impact on transmission distribution infrastructure and may result in tripping/break-down of the same. Substation & Line O&M personnel and Protection Engineers to remain alert in Sub-Stations and Power Stations to analyse the cause of tripping. Healthy elements of the network shall be quickly taken into service in consultation with SLDC to ensure system integrity.
- Planned shut-downs in North Maharashtra and MMR region shall be avoided on 3rd and 4th June' 2020.
- System restoration procedure/program shall be kept readily accessible at Power Stations & Sub-Stations.
- SCADA/IT/Communications teams at MSLDC / MSETCL /TPC/AEML shall remain alert to quickly restore voice and data communication from substation/power station to MSLDC/RLDC.

#### For Transmission Licensees:

- High voltage is likely to be experienced consequent to demand crash. All switchable shunt reactors shall be taken in service to control voltage. Shunt capacitor banks in sub-transmission system shall be taken out of service to control high voltage.
- In case of high voltage (>410 kV), bus reactors shall be taken in service in consultation with MSLDC. If required, EHV lines shall be manually opened for Voltage regulations in consultation with MSLDC. SLDC Maharashtra shall inform all the switching actions to WRLDC during cyclonic storm.
- Lightly loaded and redundant EHV lines could be taken out of service for voltage control wherever feasible. Switchable lines reactors wherever available shall be utilized for voltage control.

- Single phase auto reclosure in all EHV lines above 220 kV shall be kept enabled to avoid line outage on transient faults.
- Sub-stations and lines feeding traction supply shall be closely monitored. In case of interruption, restoration shall be done on priority.
- Transmission lines connected to Nuclear power stations of Tarapur shall be monitored closely and in case of tripping, best efforts shall be done to extend the supply within 30 minutes to avoid poisoning of nuclear units.
- Healthiness of islanding schemes Mumbai System & Urban shall be ensured. Load identified for island vis-à-vis generation in the identified island shall be monitored in real time to enhance probability of survival of the island. Adequacy of internal generation in Mumbai Island shall be ensured.
- All line and Generation unit outage plan were deferred during period
- Healthiness of UFR (Under frequency Relay) and df/dt load shedding scheme shall be ensured by respective Transmission licensee.
- Emergency restoration system shall be kept ready by transmission utilities for deployment in cyclone prone areas.
- Loading of transmission lines and ICTs, in cyclone affected areas shall be closely monitored and suitable measures shall be taken to ensure adequate margins to handle contingencies.

#### For Generation Companies:

- Fast ramping gas and hydro units shall be deployed to manage loss of generation due to tripping of thermal stations or loss of RE generation. Unit commitment for 2nd, 3rd and 4th June' 2020 shall be reviewed in the light of weather forecast updates.
- Generating units on bar shall absorb reactive power within its capability curve during high voltage (>410 kV)
- Synchronous condenser facility available at Koyna shall be deployed for voltage control as and when required on instructions of MSLDC
- Adequate fuel stock for Diesel Generator set shall be ensured at generating stations having black start capabilities. Healthiness of the black start DG facility shall be ensured.

#### For Distribution Licensees:

- Demand in Maharashtra is likely to reduce because of cyclone. Load Management Cell, MSEDCL, PSCC Tata Power & BCC Transmission, AEML in coordination with MSLDC shall monitor the demand & drawl pattern and take adequate measures to maintain load generation balance and shall be in communication with MSLDC/RLDC in case of any contingency.
- Distribution utilities shall explore facets in Real-time market to maintain interchange as close to schedule as possible to control deviations from schedule.
- High voltage is likely to be experienced consequent to demand crash. All switchable shunt reactors shall be taken

in service to control voltage. Shunt capacitor banks in distribution system shall be taken out of service to control high voltage.

- Load identified for island vis-à-vis generation in the identified island shall be monitored in real time to enhance probability of survival of the island.
- Suitable advisory to ensure adequacy of back-up power supply in the areas under predicted cyclone path shall be issued to establishments serving critical essential load such as hospitals, district headquarters, communication, etc.

#### For RE Generators/QCAs:

- Wind and Solar PV generating stations shall provide reactive support to control voltage at the respective pooling stations within their capability.
- RE developers shall be alerting to ensure availability of telemetry to MSLDC.
- RE generation shall be curtailed on instructions of MSLDC in case of threat to grid security due to high frequency consequent to large load throw off.
- Schedules shall be carefully submitted by all the QCAs considering impact of Cyclone. All the revisions shall be utilized judiciously for most accurate forecasts, as under reduced demand conditions and abnormal weather conditions, RE generation plays critical role in Grid management.

#### **4. CONTINGENCY PLAN TAKEN BY TATA POWER BEFORE LANDFALL OF CYCLONE AT MUMBAI**

- The demand was expected to reduce drastically prevailing cyclone conditions hence close monitoring of demand and drawl pattern was required for maintaining generation – load balance
- Thermal generation may be dropped on instruction by WRLDC / SLDC below technical minimum for frequency control
- All Thermal power stations shall units were kept on FGMO / RGMO with droop setting between 3-5%.
- Operational staff at Hydro stations shall be on alert for quick generation variation and supply was restoration after any tripping
- Healthiness of DG sets to be ensured at Hydro stations for black start readiness.
- Due to inclement weather conditions, all the operational staff at Receiving stations was on alert for quick response followed by any tripping for supply restoration.
- High voltage was likely to be experienced after change in weather conditions and demand crash and preventive measures such as cutting out of capacitor banks / change in tap of Transformers (OLTC) was kept active.
- Guidelines issue to all consumer for Cut-OFF capacitor at their end and TATA Power Mumbai manage voltage profile and reactive power as per line loading and system condition.
- Extra manpower was deployed at all stations as part of crisis management.
- No outages of power system element were planned for 3<sup>rd</sup> and 4<sup>th</sup> June 2020 for system security





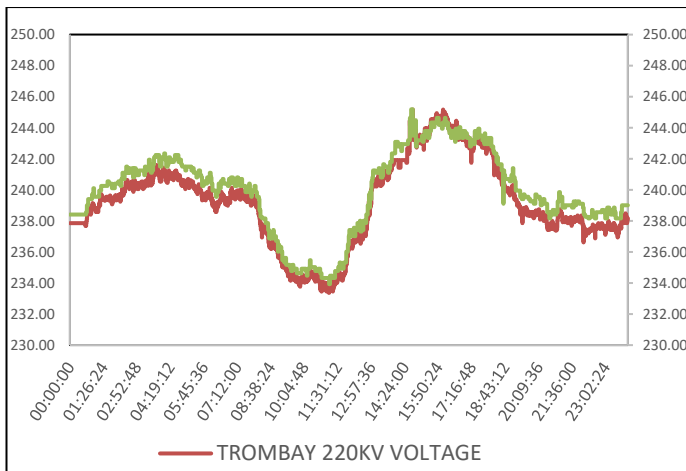


Fig 8: Mumbai Tata Power Voltage variation

The power demand in Maharashtra was likely to reduce due to the cyclone. Load Management Cell, the Maharashtra State Electricity Distribution Company Limited (MSEDCL), PSCC Tata Power & BCC Transmission, should monitor the demand and drawl pattern during the cyclone. Distribution licensees should explore the real-time market to maintain interchange as close to schedule as possible to control deviations from schedule. Suitable advisory to ensure the adequacy of back-up power supply in the areas under predicted cyclone path will be issued to establishments serving critical load such as hospitals and district headquarters, among others.

#### 6. IMPACT ASSESSMENT AND RESTORATION:

There were total 11 numbers of 110 KV and 2 numbers of 220 KV line tripping between 1017 & 1554 hrs. on account of inclement weather / gusty wind due to Nisarga cyclone. MSETCL stations supplying Mumbai network such as Trombay, Kalwa, Borivli and Boisar also reported tripping of 400/220 KV incoming lines in their network. System experienced high voltages across the stations due to drastic load drop. There was no major shutdown involved to any consumer in Mumbai served by TPC T&D network. Mumbai load remained lower by about 500 MW compared to 02.06.2020 .Below Graph is for Mumbai Power Variation

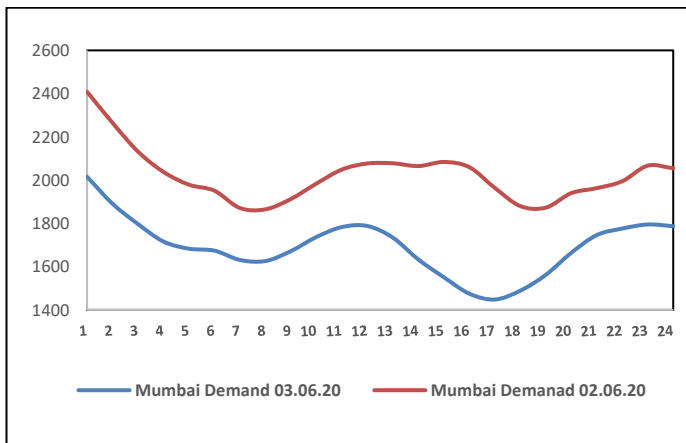


Fig 9: Mumbai Tata Power Demand variation

Below graph shown that State load remained lower by about 9800 MW compared to 02.06. 2020. Similar Wind generation variation from 1000 to 2500 MW. This have impacted on heavy under draw and high voltage in the system

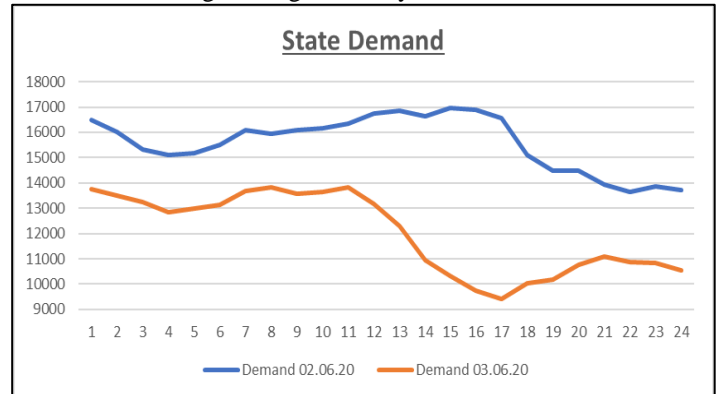


Fig 10: Maharashtra State total Demand Variation

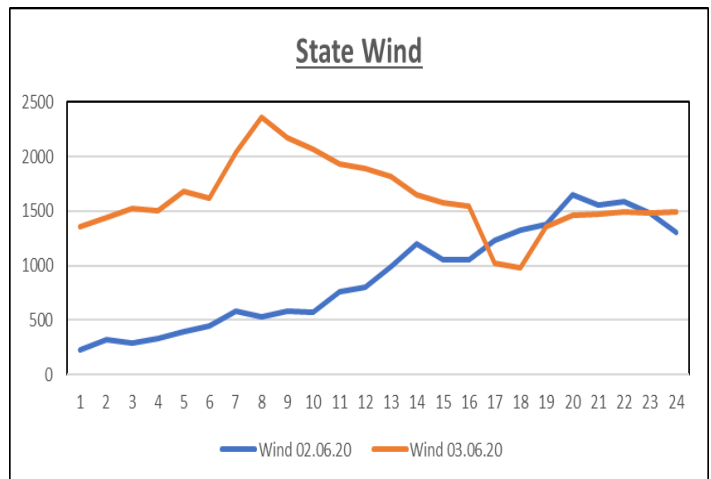


Fig 11: Maharashtra State Wind Variation

220 KV and 110 KV line tripping due to inclement weather/gusty wind on account of cyclone "Nisarga":

- At 1017 Hrs. 110KV Khopoli-Davdi line tripped and auto close faulty. The line taken in service at 1946 hrs. after inspection.
- At 1120 Hrs. 110KV Dharavi-Powai line tripped. The line was taken in service at 1128 Hrs.
- At 1235 Hrs. 220KV Bhira-Karanjade-7 line tripped. The line was taken in service at 1255 hrs.
- At 1242 Hrs. 110KV Bhira-Khopoli-2 line tripped. The line was taken in service at 1255 Hrs.
- At 1320 Hrs. 110 Dharavi-Kurla-1 line tripped at 1320 Hrs. The line was taken in service at 1705 Hrs.
- At 1352 Hrs. 220KV Bhira-Karanjade-7 line tripped again.
- At 1352 Hrs. 110KV Bhira-Khopoli-2 line tripped again.
- At 1436 Hrs. 110KV Trombay-Chembur-3 line tripped. The line taken in service at 1455 Hrs.
- At 1436 Hrs. 110KV PRL-MKD-CM line tripped at Parel end only, same was taken in service at 1443 hrs.
- At 1437 Hrs. 220KV Bhira-Karanjade-7-line test charged faulty. Hence the line was taken in service at 0532 hrs. on 4th June after inspection.

- At 1438 Hrs. 220KV Bhira-Karanjade-8 line tripped. The line was test charged at 2038 hrs. & taken in service at 2050 hrs. (Delayed due to Islanding).
- At 1450 Hrs. 110KV Bhivpuri-Neral line tripped. The line taken in service at 1505 Hrs.
- At 1524 Hrs. 110KV Bhira-Davdi line tripped. The line taken in service at 2139 Hrs.
- At 1528 Hrs. 110KV Bhokarpada-Karanjade line tripped. The line taken in service at 1531 Hrs.
- At 1532 Hrs. 110KV Bhokarpada- Karanjade line tripped again. The line taken in service at 0139 hrs on 4th June after removing tree branches at loc 183.
- At 1550 Hrs. 110KV Khopoli-Karanjade line tripped. The line taken in service at 0345 hrs. on 4th June after tree trimming.
- At 1554 Hrs. 110KV Kalwa-Kalyan-Salsette-2 line tripped. The line taken in service at 1616 hrs.

#### **Bhira Islanding - In above continuous tripping's:**

300 MW Bhira generating station went on house load when 220 KV Bhira - Karanjade -8 tripped at 1438 hrs. (All other 110 & 220 KV lines emanating from Bhira was already tripped). 220KV Bhira-Karanjade-8 line charged at 2038 hrs and was taken in service at 2050 Hrs at Bhira, thereby Bhira station was synchronised with grid and generation was picked-up accordingly. However, there was no shutdown involved to any consumer in Mumbai served by TPC T&D network.

#### **7. KEY LEARNING:**

In the pre, during, and post CYCLONE, it has been possible to face such calamities with strategic plan in anticipation of the happenings, correct and quick decisive action to face the deviation and situation, and early restorative action. The same was in fact achieved through, namely,

- Shutdown / backing down of critical Generating Units and Transmission Lines
- Maintenance of communication links.
- Deployment of ERS Towers / additional equipment for quick restoration
- Deployment of Emergency Response Teams from Power Utilities at all critical sub-stations and Control Centres.
- Curtailment of Market Trades during extreme contingencies.
- Documentation of previous experiences Incident so that every time preparation has not to be done from scratch.

#### **8. Conclusions**

In India through previous experiences we have developed an efficient method of monitoring adverse climatic conditions and natural disasters. Power sector has no different when it comes to mitigating a disaster. This is a multiparty and multiagency setup under adverse conditions and must work in coordination across all levels with high prioritizing on system security over anything else. Experiences gained and skills developed while facing such cyclone as a system operator were refined by the challenges faced by Nisarga. Planning for Power system while

keeping in mind such a natural disaster might be uneconomical and unpragmatic, but faculties must be developed for mitigating any such challenge without suffering a heavy loss and then timely recuperation of any such losses. Calamities such as Nisarga bring out the fragility of an aged system which otherwise seems robust. Hardening the grid to withstand all extreme weather is prohibitively costly. Thus, such events advocate for Grid resiliency, i.e. minimizing impact and quick restoration. This approach would require combination of traditional tactics (such as trimming trees near distribution poles and sub-stations) and new technologies such as Emergency Restoration system (ERS), energy storage and micro grids to maintain continuous supply to essential utilities.

#### **9 ACKNOWLEDGEMENTS**

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