AN ANALYSIS OF MUMBAI POWER FAILURE ON 12/10/2020

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On Monday the 12th October, 2020, Train services came to a halt, homes, and businesses were without electricity as a grid failure resulted in massive power outages across Mumbai .

Local train commuters forced to walk on tracks

(Picture courtesy: mumbaimirror.indiatimes.com)

Our country had experienced a major power outage in 2012, affecting 360 million people all over India due to a grid failure. A fault at a power station of Tata Power led to disruption of power in many parts of Mumbai in 2014. Now after 6 years, Mumbai again witnessed a major power failure on 12th October 2020, leaving consumers in Mumbai and Mumbai Metropolitan Area (MMR area) without power in busy hours of Monday morning. It took upto 15 hours for restoration of power in major areas. Here is a flash report released by Power System Operation Corporation Limited (Western Region) following the power failure.

Power System Operation Corporation Limited
Western regional Load Dispatch Centre
FLASH REPORT

WRLDC/September//12.10.2020/

1. ***Event Summary:*** *As intimated by SLDC Kalwa at 09:58hrs, 400kV Kalwa-Padghe line-2 tripped on R-phase fault. At 10:00hrs 400kV Kalwa-Khargar line which was 900MW also got tripped due to conductor snap near Khargar. Subsequently, Khargar ICT-1 & ICT-2 also tripped at 10:05 hrs. due to this Kalwa and Khargar stations were dead. Expected Mumbai load loss was 2600MW.*

2. ***Date and Time****: 12.10.2020, at 10:05 Hrs.*

3. ***Elements affected****:*

Feeder/ICT/Bus/Unit	*Tripping time (hh:mm)*	*Restoration status*	*Remarks*
400kV Kalwa-Padghe line-1	*06:54*	*Revived at 10:41hrs*	*Emergency S/D availed by Maharasht ra at 06:54hrs*
400kV Kalwa-Padghe line-2	*09:58*	*Out of service. Conductor snap in R phase*	*Expected to revive by 15:00hrs*
400kV Kalwa-Khargar	*10:23*	*Out of service.Conductor snap near Khargar Tripped on R-Y phase fault.*	*Expected to revive by 20:00hrs*
Pune-Khargar	*10:05*	*Revived at 10:27hrs*	
Pune-Kalwa	*Out since 10.10.20*	*Out of service*	*Expected in next 4 days*
Kalwa ICT-1	*10:05*	*Restored*	
Kalwa ICT-2	*10:05*	*Restored*	
Kalwa ICT-3	*10:05*	*Restored*	
Kalwa ICT-4	*10:05*	*Restored*	
Khargar ICT-1	*10:05*	*Restored*	
Khargar ICT-2	*10:05*	*Restored*	
Khargar ICT-3	*10:05*	*Restored*	

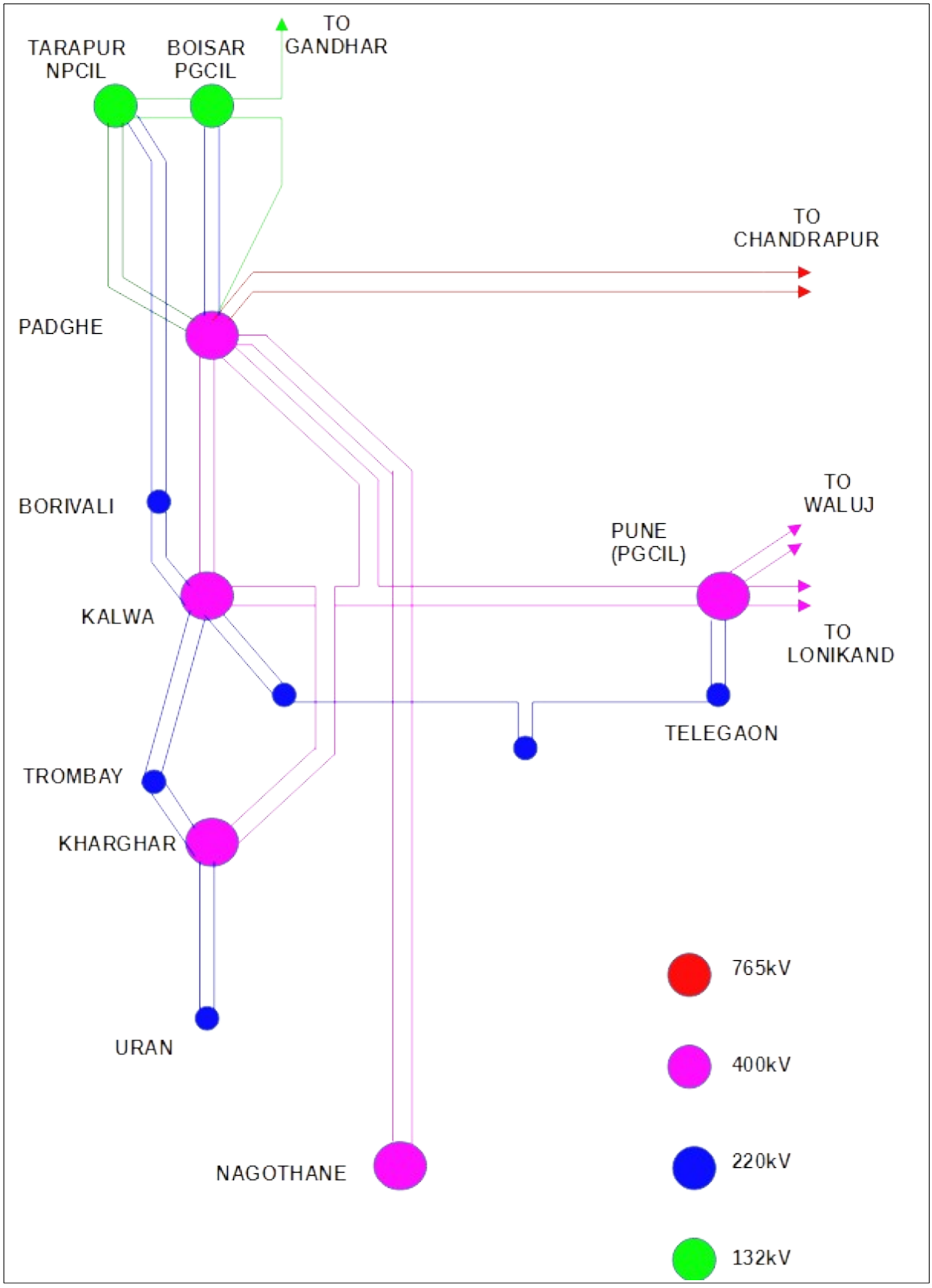
4. ***Generation loss:***
   Uran generation-220MW
   Trombay-450MW
   Dahanu generation-170MW
   TATA Hydro and Gas generation taken into service

5. ***Load Loss:*** *Total Mumbai load loss was 2600MW. Load is being restored. Present Mumbai load is 1354MW*

6. ***Further action required****: Maharashtra has been requested to provide the details of tripping at 220kV level along with restoration status.*

(Source: POSOCO Western region)

Let's have look at the Single Line Diagram of Mumbai area showing **only main EHV** lines and Sub Stations (Also please refer the Grid Map of Mumbai on Page 12)



(Source : InSDES compilation of Data available at Official website of M/s Mahatransco)

When we go to the details of this failure, it is seen that the events that led to such a crisis had started early in the same day morning when at 06:54 Hrs. Kalwa-Padghe # 1 tripped and emergency shut down was availed by Mahatransco keeping entire load on Kalwa-Padghe # 2. (400kV Pune-Kalwa line was out of service since 10/10/2020 and was expected to be resotred by 16/10/20 only.) Though the emergency shut down Kalwa – Padghe # 1 was availed up to 09:30 hrs, the feeder could not be taken back into service as planned and at 09:58hrs,
400kV Kalwa – Padghe # 2 (which was carrying total a load of 633MW) also tripped due to conductor snaping on R phase.

Meanwhile at 10:05 hrs Load on Pune-Kharghar rose to 900MW and sparking was observed on an Isolator at Kharghar end and was hand tripped.

Subsequently (exact time not available) hot spot was observed on a CT jumper of Kalwa-Khargar 400kV line and this was also hand tripped.

This led to no power supply to Mumbai as Tata Power and AEML lines tripped simultaneously.

Same time, at Trombay, Unit -5 (500MW), Unit 7A and 7B (170MW) , Uran unit 5 & 6 (108MW each) tripped at 10:05hrs

Here is what TATA POWER says about the event immediately after the event

"*At 10.10 am there was* ***simultaneous substation tripping in MSETCL's Kalwa, Kharghar causing a huge dip in frequency in the Mumbai transmission system*** *which led to tripping of Mumbai power supply. Restoration work is in progress to bring supply from the three Hydro units and Trombay units once the MSETCL transmission lines are connected,"*
"Based on the preliminary assessment of the situation, Tata Power would like to inform that today many parts of Mumbai experienced an unforeseen electricity failure starting at 10 am in the morning due to tripping of MSETCL's 400 KV transmission system at Kalwa which supplies to Mumbai and adjoining areas. MSETCLs 400kV Pune-Kalwa line was under forced shutdown since yesterday due to R-Y phase fault. It is understood that MSETCL had taken emergency shutdown for 400 KV Kalwa- Padghe line -1 at 6.54hrs today morning to attend fault and was expected to be revived by 09:30hr, but could not revive it. As understood, at 09:58hrs 400kV Kalwa-Padghe-2 carrying 633 MW tripped. The flow on Pune-Kharghar rose upto 900MW and tripped at 10:00 hrs resulting in load drop in Mumbai system. Mumbai's islanding system that saves the city from major power outages was separated, however, it could not hold as additional 900MW load dropped at 10:05hrs."

This indicates that the Islanding System of the major utility M/s TATAPOWER did not function effectively. According to TATAPOWER press release itself " Mumbai's islanding system

that saves the city from major power outages was separated, however, it could not hold as additional 900MW load dropped at 10:05hrs." which clearly points towards the fact that the existing settings of Islanding system needs updation / upgradation to take care of the present system demands and conditions.

Meanwhile, a Central team visited Mumbai on October 13 and completed their investigation by October 14. The Central team consisted of the chief engineer of the Central Electricity Authority of India along with representatives from the Power Grid Corporation of India, the Western Regional Load Dispatch Centre, Tata Power, AEML and MSETCL.

The Maharashtra Electricity Regulatory Commission (MERC), taking suo moto cognisance on the Mumbai power outage, has ordered an independent inquiry into the incident. The investigating committee has been directed to submit a report on the matter within three months prior to which an interim report is expected in a month.

MERC stated that the committee would include retired Indian Administrative Service (IAS) officer Dr Sudhir Kumar Goel as chairman, V Ramakrishnan, ex-member of the Central Electricity Authority and Dr Faruk Kazi, head of the electrical engineering department at the Veermara Jijabai Technical Institute. It has also directed the parties involved or the distribution companies to conduct and submit internal inquiries to the commission, and the committee constituted by it.

According to media reports, a committee appointed by the Central Electricity Authority (CEA) to probe the Mumbai power outage incident on October 12 started its investigation on 13th afternoon itself. The committee is investigating if there were lapses in the response to technical faults. It will also investigate why the islanding system that separates Mumbai in case of a state grid failure did not work owing to the sudden load.

According to Mumbai Newspapers, the State Energy Minister Sri Mr. Nitin Raut on 14th reiterated that the state can not rule out the possibility of sabotage that resulted in the massive power outage in Mumbai area. The minister also said that he has asked officials to submit a report on how many of the recommendations of the expert committee (which the state government had appointed to study a similar outage in Mumbai in November 2010) were implemented. That committee was headed by Indian Institute of Technology-Bombay (IIT-B) professor SA Khaparde and the committee had submitted its report in June 2011.

The important recommendations of the above expert committee submitted in June 2011 are quoted below for ready reference.

Recommendations on Protection and Islanding Schemes

<u>Protection Schemes</u>

◆ *The committee suggests that single phase auto-reclosure might be implemented immediately for all overhead lines in Mumbai system. In respect of such lines emanating from generating stations, the studies on the effect of such auto-reclosure on turbine-generator (TG) shaft being carried out by the Mumbai utilities might be completed at the earliest. (Notwithstanding the fact that many other generating stations in the country have kept this feature in service) For auto-reclosure on hybrid lines the committee strongly recommends a pilot project might be taken up by the utilities in Mumbai in collaboration with relay manufacturers.*

◆ *A separate pilot project on dynamic line rating needs to be taken up on very important corridor on experimental basis.*

◆ *Routine checks should be carried out at regular intervals to check configuration of relays. Reconfiguration of Alert and Trip mode of Relays on account of overload may be needed at some places.*

◆ *SPS providing automatic correction for network overloads or depletion needs to be commisioned by all utilities in Mumbai in a co-ordinated fashion. SLDC Kalwa to take the lead in this direction. Considering the state of Mumbai network, it is important that such SPS might be reliable through redundant measurements as well as duplication of equipment.*

<u>Islanding Schemes</u>

◆ ***UFR*** *and* ***df/dt*** *load shedding in Mumbai system can start at slightly higher frequency than the present level of 48.0 Hz.* ***(may consider 48.4 Hz.)****. In case of islanding in Mumbai system,* ***TPCL and R-Infra should try to stay together as far as possible, forming a bigger island.***

◆ *Primary response from Generating units and automatic under frequency based load shedding are crucial to the survival of any island formed. The Under frequency and over frequency settings of generators might be checked to ensure that a conservative setting leading to unit tripping does not jeopardize the island further. Rate of change of frequency based load shedding with the setting based on studies will be more suitable that flat frequency load shedding*

◆ *With expected Mumbai Demand touching 5000 MW and Generation Capacity of 2277 MW, existing islanding scheme will not work. The islanding schemes needs to be reviewed for possible load / generation balance and accordingly islands need to be formed by separating other network. Initially, if possible both TPCL and R-Infra can be islanded together but independent islands would be required to be formed so that they survive on their own available load generation balance.*

◆ *Situational awarness at control centres can be enhanced through availability of synchrophaser data. Locations from where such data needs to be made available can be worked out jointly by the utilities in Mumbai. In fact when the TPCL operator attempted closure of the 220kV Salsette bus coupler, immediately after tripping of the 220kV Trombay-Salsette circuit, one of the 220kV Buses at Salsette (connected to Trombay) underwent through three states viz. Connected to rest of the grids initially, part of Dahanu island for few seconds and then a black out. It would be extremely difficult for the operator to visualize this change in states in the absence of synchrophasor data. With the rise in fault level, more and more 220kV buses might need to be split in Mumbai system and availability of synchrophasor data would facilitate quick restoration of supplies through the bus couplers. To summarize, the committee recommends that option of installing PMU as a pilot project needs to be explored for this purpose.*

Now let's try to analyse what are all the possibilities that could have led to the crisis. First let us check what is the demand of Mumbai System during these days.

How much power does Mumbai and the Mumbai Metropolitan Region need per day?

During the monsoon season, at the peak hours, the average requirement is 2,700 to 3,300 MW in Mumbai and 3,800 to 4,011 MW in the MMR. Around 50% of power required by Mumbai is provided by MSETCL, while the remaining (around 1,877 MW) is provided by Tata Power and Adani.

Mumbai System Total Generation

Generating Stn	OLC(MW)
Tata Hydro	**447**
Tata Thermal	**930**
Rinfra Thermal	**500**
Mumbai System Total Avaiable Generation	**1877**

Source : Official website of M/s Mahatransco/STU Plan 2017-18_ 2022-23

Now let's have a look at the geographical area covered by M/s ADANI Power (Previously RInfra) and M/s TATA POWER, MSEDCL and BEST.

Source: Prayas (Energy Group). (2017, February). In the Name of Competition: The annals of 'cost-plus competition' in the electricity sector in Mumbai.

From above Map, it can be seen that multiple licensees are operating in same geographical area (may be intended to promote competetion and provide better power to consumers) and main city area is covered by two main private agencies and city outskirts only are covered by Mahavitharan and BEST – the two public sector utilities.

Tata Power has a capacity of 1,377 MW, which includes three hydro power units, two coal units and two gas units. Meanwhile, Adani (Previously RINFRA) has two units of 250 MW each at Dhanu. Tata Power's transmission network includes 1,188 ckt. km of Mumbai transmission network, connecting generating stations to 22 receiving stations; with around 9500

MVA transformation capacity. Adani Transmission has 539 ckt. Km of transmission network with 8 receiving stations with transformation capacity of 3215 MVA.

The Western Regional Load Despatch Centre of POSOCO updated the grid events on 14.10.2020 as given below. The report specifically states that " Adani system got islanded and survived with a total load of 400MW (feeding through Dahanu Unit-1 and Unit2).

Power System Operation Corporation Limited

Western Regional Load Despatch Centre

GRID EVENTS FOR COMPUTATION OF FREQUENCY RESPONSE CHARACTERSTICS

Last updated on: 14.10.2020

DATE	*ANTECEDENT TIME (A)*	*POST EVENT TIME (B)*	*Delta f (in Hz)*	*Delta P (in MW)*	*Event Description*
12.10.20	*10:05:00*	*10:06:00*	*0.11*	*1540*	*On 12th of October 2020, As reported, At 09:58hrs, 400kV Kalwa-Padghe line-2 tripped on R-ph fault.* *At 10:05hrs, 400kV Pune-Khargar line emergency hand tripped (due to heavy sparking on isolator)* *400 KV Kalwa – Kharghar line also hand tripped due to CT jumper hot spot leading to Mumbai system blackout .* *Trombay Unit5(500MW), Trombay Unit-7(A) & 7(B), Uran-5(108MW) and Uran6(108MW) Uran(A0) tripped at 10:05hrs during Mumbai blackout.* *Adani system got islanded and survived with a total load of 400MW (feeding through Dahanu Unit-1 and Unit2).* *It is reported that loads at Bhiwandi area feeding from Padghe also tripped.* *Total load loss was observed to be 2600MW (2200MW of Mumbai, 400MW of Khargar, Navi Mumbai, Bhiwandi and Thane). Total Generation loss was around 840MW at TATA) and 220MW at Uran.* *FRC has been calculated for load relief of 1540 MW.*

(Source: POSOCO Western region)

In many events of Western Regional Power Grid disturbances, Mumbai was not affected just because of the unique ‘ Islanding System’ set up by TATA POWER which ensures uninterrupted supply of Power to Mumbai city. During Western Regional Grid failure, this islanding system automatically isolates the Mumbai system from rest of the grid and their generating units continue to operate and powers all essential services

In 2012, During a major grid disturbance in Eastern Grid, on 30 th and 31st of July, the city of Kolkata could survive owing to the islanding system properly executed in the city Power network and islanding of Badarpur Thermal Power Station helped in the restoration activities after grid failure.

What is Islanding System?

Islanding is a unique way of preventing large grid disturbances from spreading into the rest of the network and causing a severe system failure. The initial disturbances may be caused by a loss of a major transmission element or loss of major generation element in the system.

The methods used for Islanding can broadly be classified into (i) Passive methods and (ii) Active methods.

i) Passive methods monitor the transient events in the grid such as Rate of Change of Frequency, Under / Over frequency and Under / Over Voltage etc. Passive methods are convenient since they do not create any power quality issues in the system.

The Rate of Change of Frequency (ROCOF) will be very high when a distributed generator is islanded. The ROCOF relay monitors the voltage wave form and will operate when the ROCOF is higher than the set value for a set duration.

The Under Frequency condition will occur when load exceeds generation due to some reasons like loss of bulk generation unit. Over frequency condition may occur when generation is surplus due to some reason like loss of some major transmission line or so.

Under / Over voltage: an unbalance between reactive power production and consumption occurs after the loss of grid. This unbalance leads to change in voltage level which can be measured locally.

ii) Active Method probe the grid by sending signals of some sort from the inverter or the grid distribution point to measure system source impedance etc; and isolate the system from the rest depending up on the settings.

An efficient Islanding system not only islands the required portion of the network from the faulty portion but will ensure that the islanded portion survives successfully also. For this methods like automatic Load shedding (of loads with relatively less priority) will have to be employed. Making more generation available to the islanded system to avoid load shedding also can be employed to reduce the failure time.

Inference

When MSETCL could not complete the work on 400kV Kalwa-Padghe # 1 by 09:30 as planned, the load on Kalwa-Padghe # 2 should have been closely watched and steps to limit load to a safe value should have been initiated from 09:30 itself. (May be that the operators in those area conversent with such critical conditions might have taken the situation lightly)

If load reduction was initiated from 09:30 itself, perhaps sparking on Isolator of 400 KV Kalwa – Kharghar line would not have happened or atleast severity be reduced and operator could have initiated load reduction instead of hand tripping the main line. We understand that all main stations are SCADA connected and operators can switch off any remote line from the control centers.

Similarly in the case of 400 KV Kalwa – Kharghar line which was hand tripped for a hot spot on CT jumper connection, If load reduction was enforced after 09:30, or atleast when hot spot was observed, hand tripping could have been delayed and cascading might not have happened. Kalwa being a SLDC will be having adequate powers to take proper decision.

Having taken to a cascade trippng, if the islanding system was efficient especially that of TATAPOWER, the islanded area should have survived successfully. Then they could have taken more hydel generation in to service without much delay and down time could have been reduced to less than half an hour. Media reports say that TATAPOWER took hours to take hydel stations into service and TATAPOWER tries to transfer the blame to non availability of MSETCL lines.

As pointed out by the Energy Minister of the state, an analysis of the status of implementation of recommendations of the expert committee constituted in 2010 will help to find the short comings and avoid such situations in future.

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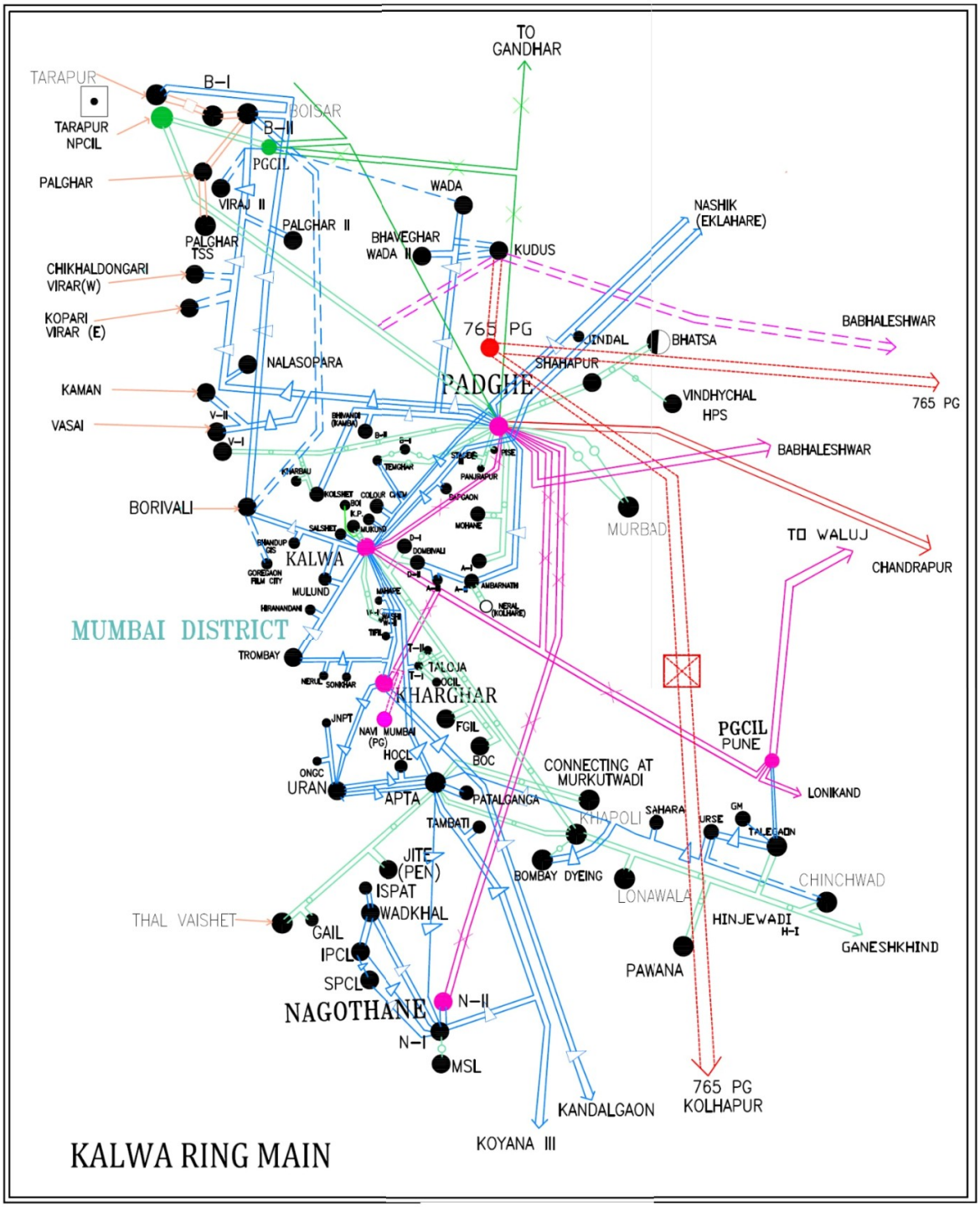

REFERENCE

GENERATING STATION	EXISTING STATION	UNDER CONSTRUCTION STATION	PROPOSED STATION	TRANSMISSION LINES	EXISTING	PROGRAMME FOR 2017-18 TO 2021-22
HYDRO				66KV SINGLE CIRCUIT		
STEAM				100KV SINGLE CIRCUIT		
NUCLIEAR				110KV SINGLE CIRCUIT		
GAS TURBINE				132KV SINGLE CIRCUIT		
SUB-STATION 66KV AND ABOVE				220KV SINGLE CIRCUIT		
SWITCHING SUB-STATION				400KV SINGLE CIRCUIT		SANCTIONED / UNDER CONSTRUCTION
SOLAR PV POWER PROJECTS / WIND POWER PROJECTS	MSETCL 765KV LINE			HVDC		UNDER CONSTRUCTION
				765KV		PGCIL LINES

(Source : InSDES compilation of Data available at Official website of M/s Mahatransco)

References

1. *Official website of Hon. Maharashtra State Electricity Regulatory Commission*
2. *Official website of M/s Mahatransco*
3. *Official website of M/s POSOCO Western Region*
4. *Official website of M/s Prayas (Energy group)(2017, February). In the Name of Competition: The annals of 'cost-plus competition' in the electricity sector in Mumbai.*
5. *Various Indian Newspapers: Mumbaimirror/Indiatimes.com, The Hindu, Economic times Hindustan Times, Business Standard etc.*
6. *IEEE Publication on Controlled Islanding Scheme for Power System Protection: Guidelines and Approach Case Study: Proposed Bhopal Islanding Scheme*