Interim Report on Partial Grid Disturbance in Mumbai System

by

IIT Bombay and SLDC Kalwa

January 2011

Foreword

Based on scrutiny of data received from various utilities, discussions in the group meetings and system studies conducted at IIT Bombay, the committee has finalized the interim report.

The complexity of protection policies followed by different transmission companies' viz. MSETCL, TPCL (T) & R Infra (T) requires more time for standardization. Also, in-depth study of islanding and associated load trimming schemes is required. Further, the study on N-1 compliance of upcoming schemes on Mumbai system in medium-term is required.

Hon' Commission is requested to grant additional three months period for submission of final report, from the date of submission of interim report.

The study results and recommendations of the committee are presented in the succeeding chapters.

Shri A.H. Kulkarni Regulatory Expert, MERC, Mumbai. (MEMBER)	Shri S.R. Narasimhan D.G.M (OS), WRLDC, POSOCO, Mumbai. (MEMBER)	Shri S.G. Kelkar C.E., SLDC, Airoli, Navi Mumbai. (MEMBER- SECRETARY)

Prof. (Dr.) S.A. Khaparde
IIT Bombay.
(CHAIRMAN)

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PREFACE

Partial Grid Disturbance in Mumbai system took place on 18th Nov-2010 at 17:40 hrs and 21st Nov-2010 at 17:05 hrs. In this matter, The Hon'able Commission issued Notices dated November 19, 2010 and November 22, 2010 to SLDC, Kalwa, the concerned Licensees and to other Users of intra-State Transmission System regarding suo-motu hearing to be held in the matter on 25th November 2010. The Hon'able Commission issued the order vide Case No. 84 of 2010 dated 1st December 01, 2010.

The Commission directed to review of protection setting at all inter-connection points between two transmission licensees and also between Transmission- Distribution Inter-connection boundary points. The Commission directed that a Committee headed by Professor (Dr) S. A. Khaparde, IIT Bombay consisting of representatives from SLDC, WRLDC, STU, TPC, R-Infra and Commission's Officer be constituted for review of existing protection schemes , under frequency relay settings, Islanding scheme, Studies on compliance of (N-1) criteria and investigate the prime reasons for aforesaid two system disturbances. The Committee also directed to suggest remedial measures so that such occurrences can be avoided in future.

The Chief Engineer (MSLDC), Kalwa was directed to act as Member Secretary to the Committee & take all initiatives for holding the Committee meetings.

On 4th December 2010, The chairman of the committee, Prof. (Dr.) S. A. Khaparde, IIT Bombay sent the Terms of Reference (ToR) to MERC for finalization of working groups.

After consultation with Hon'able Member (Technical), MERC, following apex committee is formed as below.

Apex Committee:

Sr. No	*Name*	*Designation*
1	Dr. S.A. Khaparde	Professor, IIT, Bombay
2	Shri S.G. Kelkar	Chief Engineer, MSLDC, Kalwa
3	Shri S.R. Narasimhan	D.G.M (OS), WRLDC, Mumbai
4	Shri A.H. Kulkarni	Regulatory Expert, MERC

Nominations for working group were requested from IIT Bombay, MERC, WRLDC, MSETCL [MSLDC, STU, Trans (O&M)], TPCL, R-Infra on 8th Dec2010 vide letter No CELDK /Tech-SO/ 2108. After receiving the nominations, the following working groups were formed as below.

Working Committee Group-1: Protection System and Islanding Scheme Review

Sr. No	*Name*	*Designation*
1	Shri A.M. Kulkarni	Professor, IIT, Bombay
2	Shri D.J.Kolhe	DyEE, MSLDC, Kalwa
3	Shri S.S. Rajurkar	S.E. (Trans O&M), MSETCL, C.O., Mumbai
4	Shri M.B. Kini	DGM, Testing, TPCL
5	Shri R.H. Satpute	Dy.E.E, TCC, MSETCL, Vashi.
6	Shri Avinash Waghambare	AVP, Reliance Infra. Ltd.
7	Shri C.S. Bobade	Chief Manager, WRLDC, POSOCO, Mumbai

Working Committee Group-2: System Study Review

Sr. No	*Name*	*Designation*
1	Shri Chandresh V Dobaria	IIT, Bombay
2	Shri Bhaskar Kulkarni	Regulatory Officer, MERC
3	Shri K.D.Daware	DyEE, MSLDC, Kalwa
4	Shri N.R.Sonkavday	S.E. (STU), MSETCL, C.O., Mumbai.
5	Shri V.R.Shrikhande	DGM, LCC, TPCL
6	Shri Vikas Sonar	AVP, Reliance Infra. Ltd.
7	Smt. Pushpa S.	Manager, WRLDC, POSOCO, Mumbai

List of Group Meetings

Sr. No.	Date	Place	Description
1	13-12-2010	WRLDC, Andheri	This was the first group meeting of the investigation committee. The committee decided three separate groups, 1) Apex body, 2) Protection and Islanding study, and 3) Contingency study, and assigned duties to members.
2	20-12-2010	IIT Bombay, Powai	**Group-1 meeting:** Discussed event and sequence of occurrences. Utilities submitted related documents to the committee
3	23-12-2010	IIT Bombay, Powai	**Group-2 meeting:** Discuss and finalized criteria of N-1 study for Maharashtra system
4	03-01-2011	SLDC, Kalwa	**Group-2 meeting**: Base case results are presented and Scenarios for further studies are finalized
5	04-01-2011	IIT Bombay, Powai	**Group-1&2 meeting:** Finding and suggestion on existing protection/islanding schemes are presented and discussed
6	10-01-2011	IIT Bombay, Powai	**Group-2 meeting:** Discussed N-1 contingency study results
7	13-01-2011	IIT Bombay, Powai	**Group1 meeting:** Suggestions and comments of group-1 discussed
8	15-01-2011	IIT Bombay, Powai	**Apex body meeting:** To finalize interim report

1. Partial Grid Disturbance in Mumbai System

Brief discussion of the grid disturbance in the Mumbai system is as follow,

Partial Grid Disturbance in Mumbai system on 18th November 2010

a) Maharashtra System Conditions

(Prior to Disturbance)

- State Catered Demand : **13007** MW
- State Generation : **9583** MW
- Central Sector (Receipt) : **3424** MW
- System Frequency : **49.76** Hz
- *Mumbai System*

Mumbai Catered Demand	:	**2599** MW
TPC Hydro	:	**186** MW
TPC Thermal	:	**1257** MW
R-Infra Thermal	:	**498** MW
Exchange with MSETCL	:	**658** MW

- *Transmission Equipments Out:*

1) *220 kV Salsette {TPC-T} Bus- Coupler : status OPEN*

   Bus-Coupler is normally kept open in order to control loading on 220 KV Kalwa-Salsett D/C

2) *220 kV Borivali {MSETCL}- Borivali {TPC} : status OPEN*

   Flow on this line normally remains above 300 MW and during Mumbai peak 380 MW. Major source to Borivali is from Kalwa S/s During forced outage of ICT-1 at Kalwa line kept off from 19th Oct.

3) *220 kV Kalwa - Borivali {MSETCL}: status OPEN*

   - planned outage for numerical relay commissioning.

b) Sequence of Events of disturbance in Mumbai sub urban system

Sr No	*Time*	*Sequence Events*
1	**17:39:17**	At **17:39:17:852 Hrs** 220 kV Trombay-Salsette ckt-1 carrying 170 MW, tripped on phase to phase fault caused due to kite string in span 70-71 at Tagorenagar, Vikroli.
2	**17:44:43**	At **17:44:43:868 Hrs** 220 kV Trombay-Salsette ckt-2 carrying 290 MW, tripped at 220 kV Salsette end. Earlier both the lines where carrying 170 MW each.
3		Prior to tripping, at 220 kV Salsette, Bus coupler was off.
4		R-Infra system remain connected to Borivali(Tata) and further to Borivali(MSETCL) on 100 kV BO-BO Lines.
5	**17:44:44**	Borivali(T) started drawing from Borivali(M) on 100 kV Borivali, due to network configuration. 220/100kV, 2X125 MVA ICT's at MSETCL Borivali, which were carrying 180 MW (Pre fault loading) tripped on over load.
6		Due to tripping of Borivali ICT, Borivali(T) load shifted on Reliance network.
7		This has resulted in reversal of power flow from 190 MW, from Borivali(T) to RInfra Aarey to 274 MW export from RInfra Aarey to Borivali(T).
8		Reliance network was carrying about 950 MW with a Dahanu generation of 498 MW. Reliance system remained connected to Boiser(M) system.
9	**17:45:19**	Drawal from Boisar(M) increased and 220 kV Boisar-Versova carrying 319 MW and 220 kV Boisar-Dahanu carrying 229 MW consequently tripped on over- load.
10	**17:45:19**	Load of @ 950 MW remained connected to Reliance network having source of 498 MW, which resulted in dipping of frequency at **17:45:19:563Hrs**, Automatic load shedding of @ 400 MW was initiated at 48.00 Hz.

Sr No	Time	Sequence Events
11	**17:45:20**	Due to further frequency dipping to 47.6 Hz, islanding scheme at Aarey operated resulting in tripping of both TPC lines at Aarey at **17:45:20:252 Hrs** which was feeding to Borivali(T) S/s**.**
12		Due to load throw off on account of loadshedding on U/f and disconnection of TPCL lines at Aarey, frequency shotup to 51.75 Hz of islanded system.
13	**17:45:37**	During these frequency oscillations, the GT-1 at Dahanu TPS tripped on overspeed at **17:45:37 Hrs.**
14	**17:45:39**	Dahanu unit 2 remained in service with the island load of @ 370 MW. Thereby tripping on under frequency at **17:45:39 Hrs**.
15		Thus Total AC failure in R Infra network was of 770 MW.
16	**17:46:21**	220 kV Bus coupler at 220 kV Salsette was closed at **17:46:21:564 Hrs** and supply to Borivali(T) restored.
17		Total restoration at 19:04 hrs 664MW load was restored in Rel Infra system (400 MW from TPCL and 264 MW from Boisar)
18		Unit-2 synchronized at 2014 hrs and Unit-1 synchronized at 21:18 hrs.

*Time details are taken from SCADA system at SLDC, Kalwa, TPCL, Trombay, R-Infra, Aarey.
* All the control centers in Mumbai region viz., SLDC, Kalwa, TPCL, Trombay, and R-Infra, Aarey are time synchronized using GPS.

c) System Restoration

1] 220 KV Trombay-Salsette-II taken in service at 17:48 hrs

2] 220 KV Borivali (T)-Aarey (R)-I at 17:55 hrs (Aarey sub-station restored)

3] 220 KV Boisar (MSETCL)- Dahanu(R) at 18:03 hrs (aux supply toDTPS)

4] 220 KV Trombay-Salsette-I at 18:12 hrs

5] 220 KV Boisar (MSETCL)-Versova (R) at 18:15 hrs

6] 220/100 KV Borivali(M) 125 MVA ICT-I at 18:06 hrs

7] 220/100 KV Borivali(M) 125 MVA ICT-II at 18:10 hrs

8] At 19:04 hrs 664 MW load was restored in R-infra system. (400 MW from TPCL and 264 MW from Boiser).

9] DTPS U-2 syn.at 20:14 hrs. & DTPS U-1 syn.at 21:18 hrs.

Partial Grid Disturbance in Mumbai system on 21st November 2010

a) Maharashtra System Conditions *(Prior to Disturbance)*

- State Catered Demand : **11706** MW
- State Generation : **9114** MW
- Central Sector (Receipt) : **2592** MW
- System Frequency : **50.14** Hz
- *Mumbai System*

  Mumbai Demand : **1792** MW

  TPC Hydro : **0** MW

  TPC Thermal : **936** MW

  R-Infra Thermal : **496** MW

  Exchange with MSETCL : **360** MW

b) Following lines tripped

- 220 KV Trombay-Dharavi-V & 220 KV Trombay-Salsett-II tripped on fault at 1705 Hrs.
- 220 KV Trombay-Dharavi VI tripped at 1710 Hrs. This has resulted in failure of 220 KV supply to Dharavi and tripping of other 110 KV lines on over load, causing shut down to Dharavi substation.
- Bhira plant not working due to work in tailrace by irrigation department.
- No source to Dharavi on 220 KV Bhira-Dharavi D/C
- 220 KV Dharavi – Backbay supply failed at Backbay.

c) Area affected

Load at Dharavi	– 299 MW
Load fed from Dharavi at Vikhroli	-- 67 MW
Load fed from Dharavi at Mahalaxmi	-- 30 MW
Load fed from Dharavi at Backbay	-- 29 MW
Total Load affected	-- 425 MW

- Supply affected in full or partial in the part of

Marin Drive, Mantralaya, Backbay, Nariman point, Cuff-Parade, Colaba, Lower Parel Mahalaxmi, Chinchpokali, Bombay central Lalbag, Dadar, Mahim, Matunga, Sion, Dharavi, Bandra, Kurla, Ghatkopar, Vikroli, Chunabhatti, Mankhurd, Chembur.

d) System Restoration

- 17:14 Hrs supply extended to Mahalaxmi from 110 KV Parel and about 30-35 MW load restored
- 17:23 110 KV Trombay-Dharavi – II taken in service
- 17:27 220 KV Trombay-Dharavi – VI taken in service
- 17:28 110 KV Dharavi-Vikroli taken in service
- 17:30 Hrs supply extended to Backbay from 220/110 KV Carnac S/s about 35 MW load restored including Mantralaya
- 17:32 Railway feeders at Dharavi & Vikroli charged Central Railway section from Chinchpokali to Mulund and Western Railway section from Dadar to Vileparle affected during 17:10 to 17:32 Hrs for about 22 min.
- 17:52 Hrs 220 KV Trombay-Dharavi – V taken in service
- 18:01 Entire load at Dharavi & Vikhroli restored
- 18:02 220 KV Trombay-Salsette taken in service
- 19:49 110 KV Dharavi – Mahalaxmi taken in service

2. Review of Protections System and Islanding Scheme

The committee has come out with following suggestions and recommendations by discussing various aspects of protection and islanding scheme.

1. The group discussed the possibility of employing auto-reclosure for 220 kV level. The concerns for employing auto-reclosure are:
    a. Generator-Turbine shaft stress at the Trombay generators.
    b. If the fault happens to be a permanent one, then stability may be jeopardized due to the additional disturbance.
    c. There are several network branches with both overhead lines and cables. Auto-reclosure for cable faults is not recommended since they are unlikely to be temporary in nature. The current and voltage measurements at the two ends of the combination may not be able to discriminate whether a fault is in the cable segment or in the overhead line section.
    d. Some lines pass through slum areas and danger to humans is apprehended.

   Investigation of these concerns will involve a detailed study. TPCL is investigating these issues. However, auto-reclosing may be considered which do not involve cables. The findings may be notified to the committee/commission.

2. The current carrying capacity (thermal limit) of the short transmission lines and cables is different for various utilities. For all the short lines in the Mumbai region, the utilities should use appropriate formulae to determine these limits under various environmental conditions (ambient temperature, wind speeds etc.) as well as the age of the lines, and the condition of the peripheral equipment like joints/clamps etc. The overall limit of a network branch is the minimum of the limits imposed by the line/ cable and its peripheral equipment. *Respective utilities are expected to work on preparing this data based on above mentioned criteria.* Using realistic limits as per the ambient conditions will ensure that the operators are not overly conservative during real-time operation. This data should be available to all system operators (load dispatchers) for all the short lines in the Mumbai region. For reference purpose the

document published by Central Board of Irrigation and Power (CBIP) is attached in Annexure-I. This document describes capacity of line conductors in Amperes based on aging and ambient temperature.

3. If potential tripping of a transmission line can lead to overloads in other lines in the Mumbai region, all load dispatchers may be alerted. For this purpose, online contingency analysis may be carried out periodically. For example, if there are two lines in parallel, each of them should have some set values and all operators should be "Alert Mode" if the line current on any line exceeds the set value. The following action is recommended: Check out if any relief in current flow can be obtained by either real (generator active power) power and reactive power scheduling (generator voltages, taps etc). Unfortunately, in the Mumbai system the amount of leverage on current flow by this rescheduling is not expected to be significant. Nonetheless the operators should explore possibilities for the same. *For sustained overload utilities should take corrective actions depending up on the severity. All utilities may develop action-plan for corrective actions such as load trimming, special protection scheme (SPS), etc.*
4. It is suggested that, in order to avoid unintended tripping of transmission lines, all utilities should internally recheck the relay configuration. Mainly, the overload signal should not be configured to trip the line, rather it should generate appropriate alarm signal. The Numerical Relays have an overload function with default "ON" settings. - All utilities are requested to recheck respective relays settings, particularly for "Overload" function.
5. Regarding the islanding scheme the following issues may be revisited by WRPC:
    a. Mumbai islanding scheme has been devised considering a disturbance external to Mumbai system. Sanity checks may be done on the islanding and load shedding logic for situations where disturbances are within the TPCL/R-Infra network.
    b. 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 any islanding of Mumbai system, TPCL and R-Infra should try to stay together as far as possible, forming a bigger island.

   c. R-Infra and TPCL should study the post-islanding automatic load restoration (in case of higher frequency) and load tripping scheme (in case of lower frequency) of each other.

6. The efficacy of prime mover controls under islanded conditions depends on actual parameters (gains, time constants, deadbands, limits etc). The utilities should explore if the model parameters, block diagrams and actual settings of their prime mover controllers can be obtained from the manufacturers, which can facilitate a simulation study.
7. There is a case for "Better Situational Awareness" for a system operator both in terms of increased data rate and synchronized phasor information at various buses. Option of installing PMU as a pilot project can be explored for this purpose.

3. Contingency Study on Mumbai Network

Contingency study has been a very important step to get insight of network loading conditions in various possible scenarios. A deeper study can also help in finding out possible ways to get prepared for similar emergencies. Following the disturbances in Mumbai system on 18th and 21st November 2010, MERC has directed IIT Bombay to carryout study of N-1 compliance of the Mumbai system. The committee has decided to study the contingency in two phases,

1. Existing network (for short-term findings and actions)
2. Proposed (approved) network (for long-term findings and actions)

Base Case Preparation

Although, Mumbai system has been the central focus, whole Maharashtra network is taken into account to capture its effect of loading condition on Mumbai system. Figure 1. shows Mumbai system network and interconnection between various utilities. It can be seen that the response of Maharashtra network will be captured at three points viz.„ Kalwa, Borivali, and Boisar.

The first step to create the complete Maharashtra system was to combine network database of all the three utilities supplying power to Mumbai, namely, MSETCL, TPCL, and R-Infra. For model validation purpose, the network components, generations and loading conditions are configured as per the condition of 18th November 2010. The validation of the model was done by comparing MW loading of various 220 kV transmission lines and ICTs, and Voltage level at important buses with those recorded on SCADA during the time of disturbance.

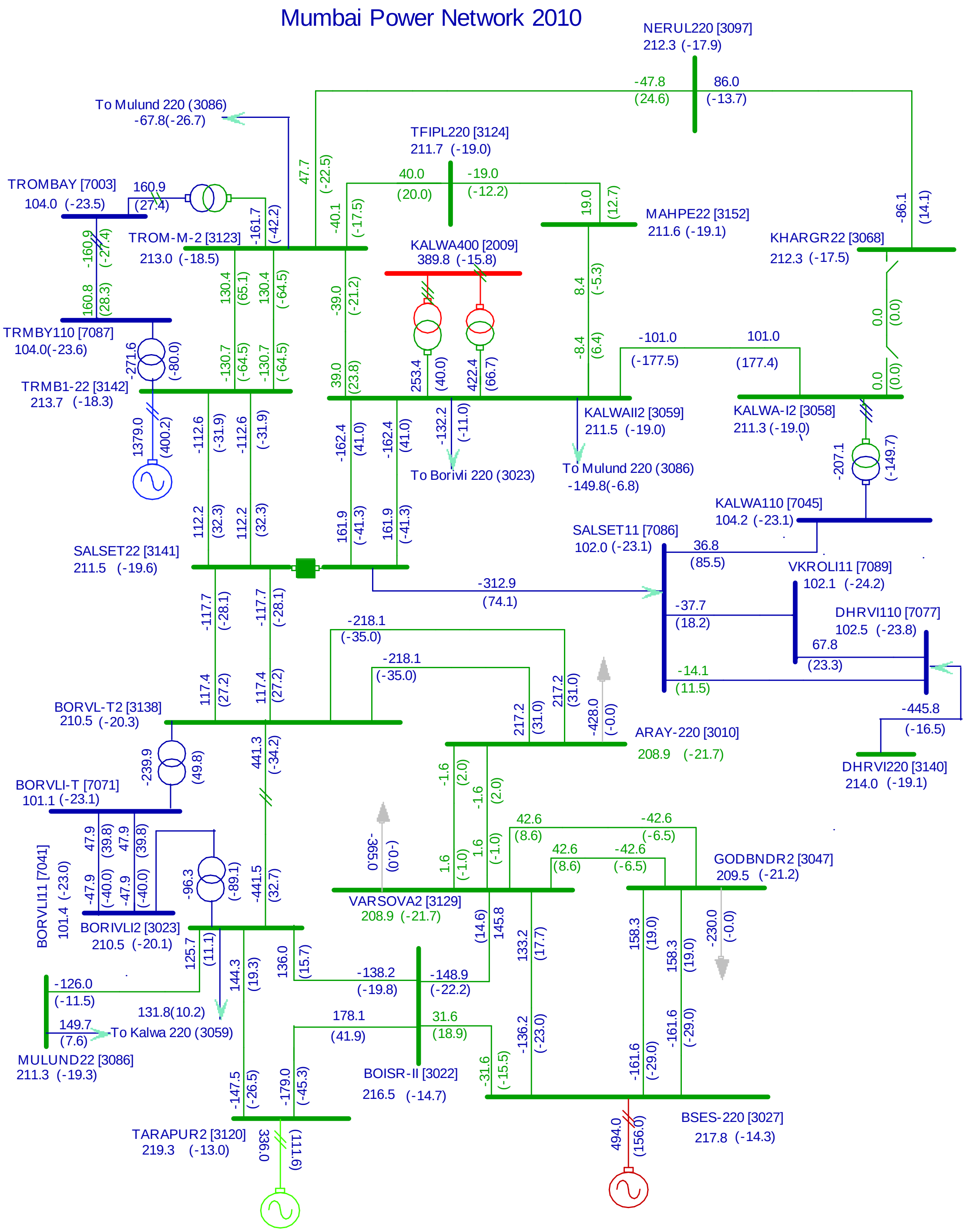

Fig. 1. Mumbai Power System Network – Base

*Note: Borivali-Borivali 220 kV double circuit lines are taken into account

To prepare base cases for contingency studies of the Existing System, the network and loading conditions are modified as follows,

1. All generating plants are running at full capacity (Ex-bus generation).
2. Renewable energy generation (wind power) is shown as negative injections at appropriate buses.
3. Mumbai peak loading condition is adjusted to 3150 MW by proportionately increasing demand from various utilities. This was decided based on the historical demand met in Mumbai network as on 10th May 2010.
4. Maharashtra network demand is set to its peak value so as to simulate the worst case scenario having simultaneous peak in Mumbai system and Maharashtra system. The total power generation of system is 16,107 MW, including 350 MW of wind generation. Total system demand is 15,453 MW with losses of 654 MW.

The committee decided to simulate various contingency studies in four scenarios, forming the base cases as listed below,

Scenario 1: Salsette B/C: ON and Borivali-Borivali 220 kV Line: ON

Scenario 2: Salsette B/C: ON and Borivali-Borivali 220 kV Line: OFF (N-1)

Scenario 3: Salsette B/C: OFF and Borivali-Borivali 220 kV Line: ON (N-1)

Scenario 4: Salsette B/C: OFF and Borivali-Borivali 220 kV Line: OFF (N-2)

In each of the above mentioned scenarios, line outage and generator outages are studied as listed below,

Line outages

1. Trombay-Salsette 220 kV ckt 1out
2. Trombay-Salsette 220 kV ckt 1 and 2 out
3. Kalwa-Salsette 220 kV ckt 3 out
4. Kalwa-salsette 220 kV ckt 3 and 4 out
5. Dahanu – Ghodbundar 220 kV ckt 1out

6. Dahanu – Ghodbundar 220 kV ckt 1 and 2 out
7. Borivali-Salsette 220 kV ckt 1out
8. Borivali-Salsette 220 kV ckt 1&2 out
9. Borivali-Aarey 220 kV ckt 1 out
10. Boisar-Versova 220 kV ckt out
11. Boisar-Dahanu 220 kV ckt out
12. Dahanu-Varsova 220 kV ckt out
13. Borivali-Kalwa 220 kV ckt out

Generator unit outages

14. Dahunu Unit-1 is out
15. Trombay Unit-5 is out

The contingency studies are carried out by multiple run of load flow analysis with above mentioned scenarios and outages. The Observations, Findings and Suggestions from the study are as follow,

1. It is observed that, irrespective of the Salsette Bus-Coupler position (On or Off), whenever the Borivali-Borivali 220 kV line is out of service, i.e., Scenario-2 and Scenario-4, the load flow solutions result into multiple corridors being overloaded heavily, leading to practically infeasible condition. This indicates that, with Borivali-Borivali 220 kV line out of service, Mumbai system may not be able to survive in peak loading condition. Further, the committee decided to study various outages only for Scenario-1 and Scenario-3 and subsequent suggestions/comments are related only to Scenario-1 and Scenario-3.
2. Studies show that, in case both the Aarey-Borivali 220 kV lines are out, the simulations do not converge indicating the infeasible situation for Mumbai system.
3. In almost all the studies, it is observed that, Aarey-Borivali 220 kV lines are carrying more than 200 MW per circuit, leaving little margin for further loading. Increased loading beyond 250 MW is presently controlled by load trimming scheme at R-Infra. It is suggested that, to cater peak demand in summer season, some of the Aarey load

may be shifted to TPCL substations. Further feasibility studies may be carried out for this alternative.

4. Borivali-Borivali 220 kV line plays an important role in almost all events, and carrying substantial amount of power (generally in tune of 500 MW and above). Although, the current carrying capacity of the line is very high, the same is not true for associated in-feed lines including substation. It is recommended that these in-feed lines and substation equipments should be upgraded to handle higher loading.
5. It is observed from the studies that, outage of one of the two circuits of a double circuit line overloads the remaining line. However, rest of the network is marginally affected by the outage. In case both the lines are out, the situation deteriorates and couple of lines gets overloaded. In any overloading condition, corrective actions by the respective utility should be initiated to avoid tripping.
6. Outage of any line on which power is imported to R-Infra network i.e., Boisar-Varsova 220 kV line (Ref. Annexure-II, Contingency-10), severely loads Aarey-Borivali lines.
7. In case of outage of one of the units of Dahanu power station (Ref. Annexure-II, Contingency-14), Aaray-Borivali 220 kV lines gets overloaded, getting feed mainly from Borivali-Borivali 220 kV line. Rest of the network is marginally affected. Further overloading situations can be controlled with the load shedding scheme at R-Infra.
8. In case of reduction of generation Trombay by 50 % (Ref. Annexure-II, Contingency-15), Kalwa ICT supports the system carrying more than 850 MW of power.

4. Remedial Measures

Following are the immediate actions/measure which can be taken up.

1. Current carrying capacity of all 220 kV transmission lines in the Mumbai region should be calculated base on the criteria mentioned in the interim-report and the same should be available to the operators for ready reference.
2. At all possible locations, option of auto-reclosure on 220 kV overhead line should be explored.
3. All relay configurations to be rechecked by respective utilities for avoiding overload tripping and configure the same for Alarm signal.
4. The alternative of load shedding at higher frequency than the present setting of 48.0 Hz can be discussed with WRPC board.
5. Alternative of shifting Aarey load to TPCL substation should be explored by the utilities to marginally relieve Aarey-Broivali 220 kV line loading.

5. Summary

In general, the committee has observed that, existing Mumbai network is quite fragile. This can be observed from the fact that for Scenario-2 and Scenario-4 base cases without any contingency, multiple lines in the network are overloaded. In view of this, it is envisaged that, network strengthening should be taken up on the higher priority. In the detailed report it is proposed to carryout studies on the MERC approved augmented network to find out the possible improvements in the N-1 compliance.

Annexure – I

Ampacity of Conductors (Source: CBIP Technical Report 77 of May 1991)

ACSR Zebra (54/3.18 mm AL + 7/3.18 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: up to one year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1090.3	1126.5	1140.5	1193.8
2.5	1067.8	1105.2	1119.5	1174.8
5.0	1044.9	1083.4	1098.4	1155.0
7.5	1021.4	1061.4	1076.8	1134.9
10.0	952.0	998.3	1013.1	1078.0
12.5	897.8	945.5	963.6	1030.5
15.0	839.4	891.2	910.5	982.4
17.5	784.9	840.7	861.6	963.1
20.0	766.2	823.4	844.8	947.8
22.5	708.9	771.3	794.4	903.6
25.0	658.3	724.1	749.1	864.1
27.5	604.0	701.2	728.0	826.6
30.0	541.7	647.5	877.2	783.2
32.5	503.8	596.1	628.7	742.6
35.0	495.0	588.9	622.0	737.3
37.5	378.6	495.6	535.1	667.4
40.0	352.2	477.6	518.6	654.3

ACSR Zebra (54/3.18 mm AL + 7/3.18 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: one to ten year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1147.8	1187.4	1202.8	1261.2
2.5	1124.8	1165.5	1181.1	1241.5
5.0	1101.2	1143.1	1159.4	1221.4
7.5	1076.9	1120.4	1137.2	1200.7
10.0	1003.8	1051.8	1070.0	1138.9
12.5	948.8	998.5	1018.2	1091.3
15.0	885.4	941.4	962.5	1040.9
17.5	828.1	888.5	911.1	1018.2
20.0	809.0	870.8	894.0	1002.7
22.5	748.7	616.2	841.2	956.4
25.0	693.8	768.7	793.8	915.2
27.5	639.2	740.5	769.0	876.0
30.0	571.1	694.1	716.2	830.5
32.5	530.6	630.1	685.2	788.3
35.0	522.4	623.2	658.8	783.0
37.5	397.2	524.7	567.2	709.5
40.0	371.9	506.2	550.3	696.2

ACSR Zebra (54/3.18 mm AL + 7/3.18 mm Steel); Region: Northern; ; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade; Conductor age: Beyond ten year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1168.3	1207.0	1222.6	1282.8
2.5	1143.1	1184.9	1201.0	1263.0
5.0	1119.3	1162.3	1179.1	1242.8
7.5	1094.8	1139.4	1156.7	1221.9
10.0	1022.3	1071.4	1090.1	1160.6
12.5	965.7	1018.4	1038.5	1113.3
15.0	904.6	961.7	983.2	1063.3
17.5	847.7	909.1	932.2	1040.4
20.0	828.1	891.0	914.6	1024.5
22.5	768.3	836.7	862.2	978.4
25.0	713.5	787.5	814.9	937.3
27.5	659.5	760.9	790.7	898.2
30.0	594.2	704.9	737.3	853.0
32.5	551.9	651.3	686.6	810.8
35.0	542.1	643.2	679.9	804.6
37.5	420.5	546.6	589.0	732.0
40.0	394.3	527.1	571.1	717.9

ACSR Moose (54/3.53 mm AL + 7/3.53 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: up to one year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1259.0	1301.8	1316.0	1379.8
2.5	1234.0	1277.2	1293.6	1357.6
5.0	1207.5	1252.1	1269.4	1335.1
7.5	1180.3	1226.7	1244.6	1311.8
10.0	1098.3	1149.7	1169.3	1242.3
12.5	1034.5	1089.9	1110.9	1188.7
15.0	965.5	1025.9	1048.3	1132.0
17.5	901.2	968.3	990.6	1080.2
20.0	880.0	948.7	971.6	1083.4
22.5	812.3	885.2	912.2	1011.0
25.0	750.3	829.7	858.9	964.4
27.5	689.2	775.9	807.4	920.3
30.0	614.6	711.7	746.4	868.8
32.5	541.1	650.4	688.5	821.1
35.0	534.5	645.0	683.6	817.1
37.5	384.9	530.1	577.3	732.6
40.0	358.4	511.7	580.5	719.5

ACSR Moose (54/3.53 mm AL + 7/3.53 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: one to ten year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1328.6	1374.5	1392.2	1460.3
2.5	1302.0	1349.3	1367.5	1437.6
5.0	1274.7	1323.4	1342.4	1414.4
7.5	1246.8	1297.3	1316.8	1390.5
10.0	1160.3	1216.2	1237.5	1317.5
12.5	1093.2	1153.4	1176.3	1261.5
15.0	1020.7	1086.1	1110.6	1202.1
17.5	953.1	1023.7	1050.1	1148.0
20.0	931.4	1003.7	1030.7	1130.9
22.5	860.3	939.2	968.5	1076.1
25.0	795.3	881.1	912.7	1027.5
27.5	731.2	824.5	858.9	961.4
30.0	652.9	757.5	795.0	927.6
32.5	575.7	693.3	734.4	677.8
35.0	569.4	688.1	729.7	874.0
37.5	412.3	567.5	618.1	785.4
40.0	384.9	548.4	600.8	771.9

ACSR Moose (54/3.53 mm AL + 7/3.53 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: Beyond ten year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1350.7	1397.9	1418.1	1488.2
2.5	1323.9	1372.4	1391.1	1483.3
5.0	1296.4	1346.4	1365.8	1439.9
7.5	1268.1	1319.9	1340.0	1415.6
10.0	1182.4	1239.5	1261.4	1343.5
12.5	1115.7	1177.2	1200.6	1287.8
15.0	1043.8	1110.4	1135.4	1228.9
17.5	976.7	1048.5	1075.4	1175.2
20.0	954.4	1027.9	1055.4	1157.5
22.5	883.9	963.9	993.7	1103.1
25.0	819.3	906.1	938.1	1054.7
27.5	755.7	850.1	884.6	1008.8
30.0	678.5	783.5	821.2	955.3
32.5	602.5	719.6	761.2	905.8
35.0	594.3	713.6	754.9	900.7
37.5	443.2	595.4	645.8	913.5
40.0	414.6	575.0	627.1	798.9

ACSR Bersimis (42/4.57 mm AL + 7/2.54 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: up to one year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1498.6	1548.7	1568.0	1641.7
2.5	1467.9	1519.5	1539.3	1615.4
5.0	1436.5	1489.7	1510.4	1588.6
7.5	1404.2	1459.5	1480.8	1561.0
10.0	1304.6	1365.9	1389.3	1476.5
12.5	1227.1	1293.4	1318.6	1411.7
15.0	1143.4	1215.6	1242.6	1342.8
17.5	1065.3	1143.5	1172.7	1280.2
20.0	1040.6	1120.6	1150.5	1260.6
22.5	958.4	1046.1	1078.5	1197.1
25.0	883.2	978.8	1014.0	1140.9
27.3	809.0	913.7	951.7	1087.6
30.0	718.0	835.7	877.6	1025.3
32.5	627.9	761.1	807.4	967.7
35.0	622.1	756.4	803.1	964.2
37.5	434.8	614.6	672.3	860.9
40.0	404.2	593.9	653.5	846.3

ACSR Bersimis (42/4.57 mm AL + 7/2.54 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: one to ten year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1583.1	1638.0	1659.2	1740.6
2.5	1551.5	1608.0	1629.7	1713.6
5.0	1519.0	1577.2	1599.9	1686.0
7.5	1485.8	1546.1	1569.4	1657.6
10.0	1380.8	1447.6	1473.2	1569.0
12.5	1299.5	1371.6	1399.0	1501.2
15.0	1211.4	1289.9	1319.4	1429.2
17.5	1129.5	1214.3	1246.1	1363.7
20.0	1104.1	1190.9	1223.4	1343.7
22.5	1017.8	1112.8	1148.1	1277.4
25.0	938.9	1042.4	1060.5	1218.7
27.5	861.2	974.3	1015.5	1163.1
30.0	765.8	892.6	937.9	1098.1
32.5	671.5	814.6	864.5	1037.0
35.0	665.8	810.0	860.3	1034.5
37.5	470.1	661.7	723.4	926.5
40.0	438.3	640.7	703.9	911.4

ACSR Bersimis (42/4.57 mm AL + 7/2.54 mm Steel); Region: Northern; Maximum design temperature: 60, 65,67, and 75 degree Centrigrade, Conductor age: Beyond ten year

Ambient temperature (Deg. C)	Ampacity (amperes) (60)	Ampacity (amperes) (65)	Ampacity (amperes) (67)	Ampacity (amperes) (75)
0.0	1610.2	1666.7	1688.5	1772.3
2.5	1578.3	1636.4	1658.8	1745.1
5.0	1545.6	1605.4	1628.7	1717.3
7.5	1512.0	1573.9	1597.9	1688.8
10.0	1407.9	1476.3	1502.5	1600.8
12.5	1327.1	1400.8	1428.9	1533.5
15.0	1239.8	1319.8	1349.9	1462.1
17.5	1158.5	1244.8	1277.2	1397.2
20.0	1132.4	1220.7	1253.8	1376.5
22.5	1046.9	1143.2	1179.0	1310.7
25.0	968.7	1073.3	1111.9	1252.2
27.5	891.6	1005.6	1047.2	1196.9
30.0	797.6	924.8	970.4	1132.3
32.5	705.0	847.6	897.7	1072.4
35.0	696.9	841.0	891.6	1067.5
37.5	509.5	696.6	757.9	961.3
40.0	476.3	693.3	736.7	944.8

Annexure-II

Contingency Studies and Results

List of Contingency

Contingency Number	Scenario-1	Scenario-3
	Base Case	
1	Trombay-Salsette 220 kV ckt 1out	
2	Trombay-Salsette 220 kV ckt 1 and 2 out	
3	Kalwa-Salsette 220 kV ckt 3 out	
4	Kalwa-salsette 220 kV ckt 3 and 4 out	
5	Dahanu – Ghodbundar 220 kV ckt 1out	
6	Dahanu – Ghodbundar 220 kV ckt 1 and 2 out	
7	Borivali-Salsette 220 kV ckt 1out	
8	Borivali-Salsette 220 kV ckt 1&2 out	
9	Borivali-Aarey 220 kV ckt 1 out	
10	Boisar-Versova 220 kV ckt out	
11	Boisar-Dahanu 220 kV ckt out	
12	Dahanu-Varsova 220 kV ckt out	
13	Borivali-Kalwa 220 kV ckt out	
14	Dahanu unit 1 out	
15	Trombay unit 5 out	

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Base Case			

The total power generation of system is 16,107 MW, including 350 MW of wind generation. Total system demand is 15,453 MW with losses of 654 MW. It can be observed that in case of Scenario-1, when all components are in service and Senario-3, when Salsette Bus-Coupler is out, all line flows are within limit except, Aarey-Borivali 220 kV line carrying approximately 218 MW on each circuit.

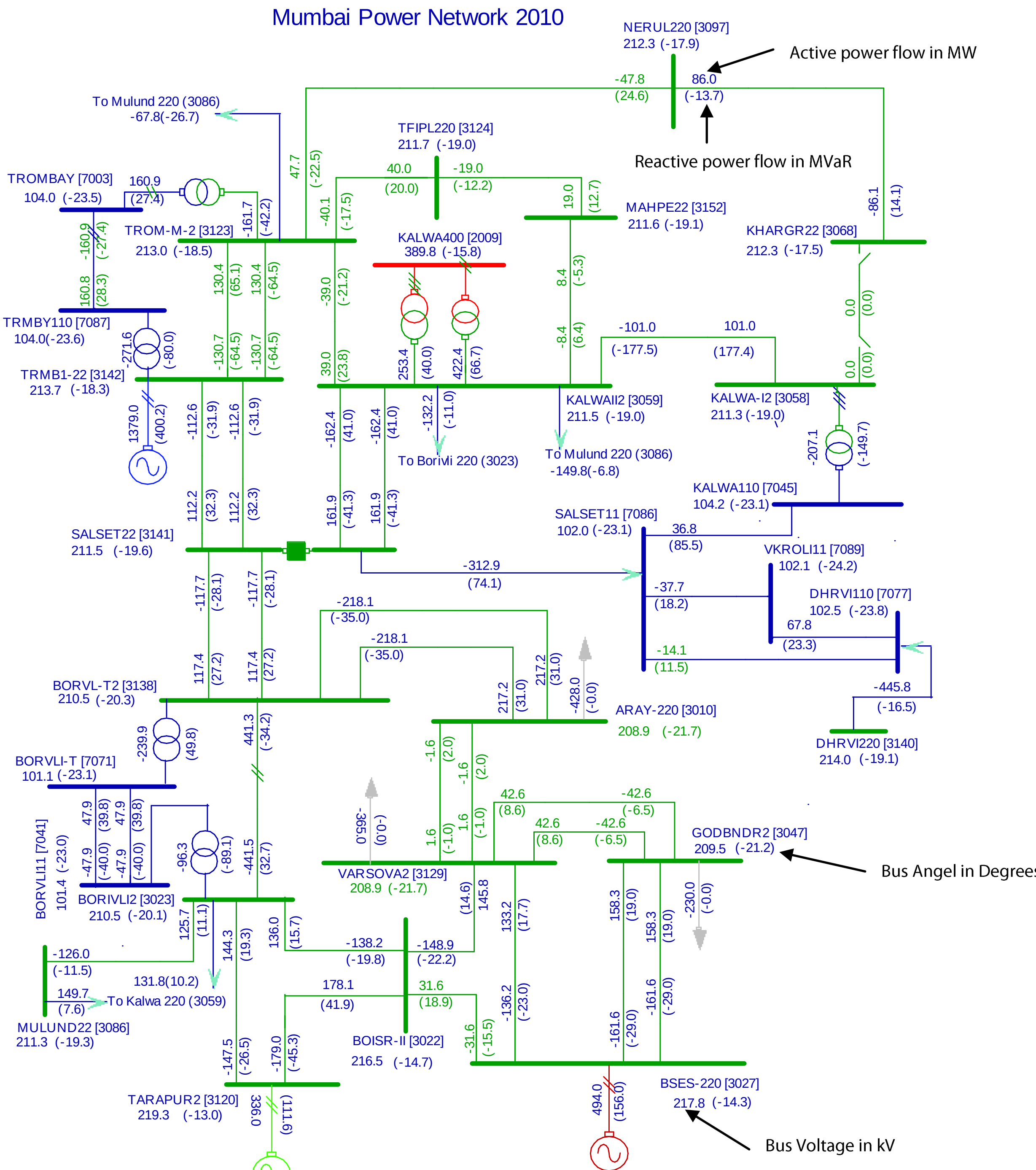

Fig. 1. Base Case of Scenario-1

Note:

- All lines flow values are in MW
- All values in "()" indicates reactive power flow in MVaR or bus angle in degrees
- "-" (minus) sign of power flow indicates "From End"

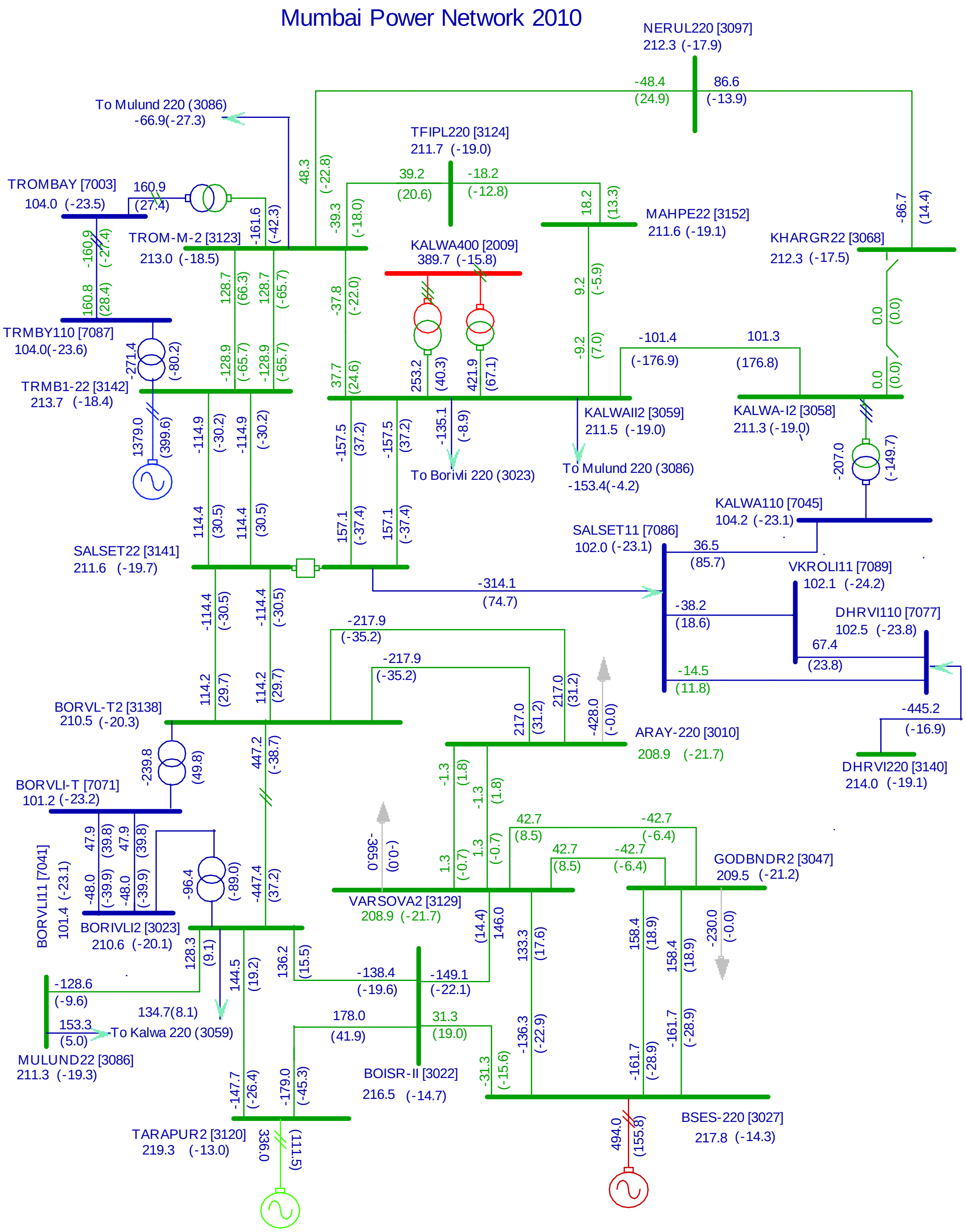

Fig. 2. Base Case of Scenario-3

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Trombay – Salsette-1 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Outage of single circuit (ckt) of Trombay – Salsette can be successfully handled by the system.
- Aarey – Varsova corridor is floating carring very small amount of power.
- Borivali – Aarey corridor (double circuit) is near to its loading limit.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- System is able to handel outage of Trombay – Salsette single ckt line.
- Although flow over all the lines are in control, loading of Borivali-Borivali line and Borivali-Kalwa lines increase by little amount as compared to the previous case. This indicates that with contingency, Kalwa will have to handle higher amount of power.

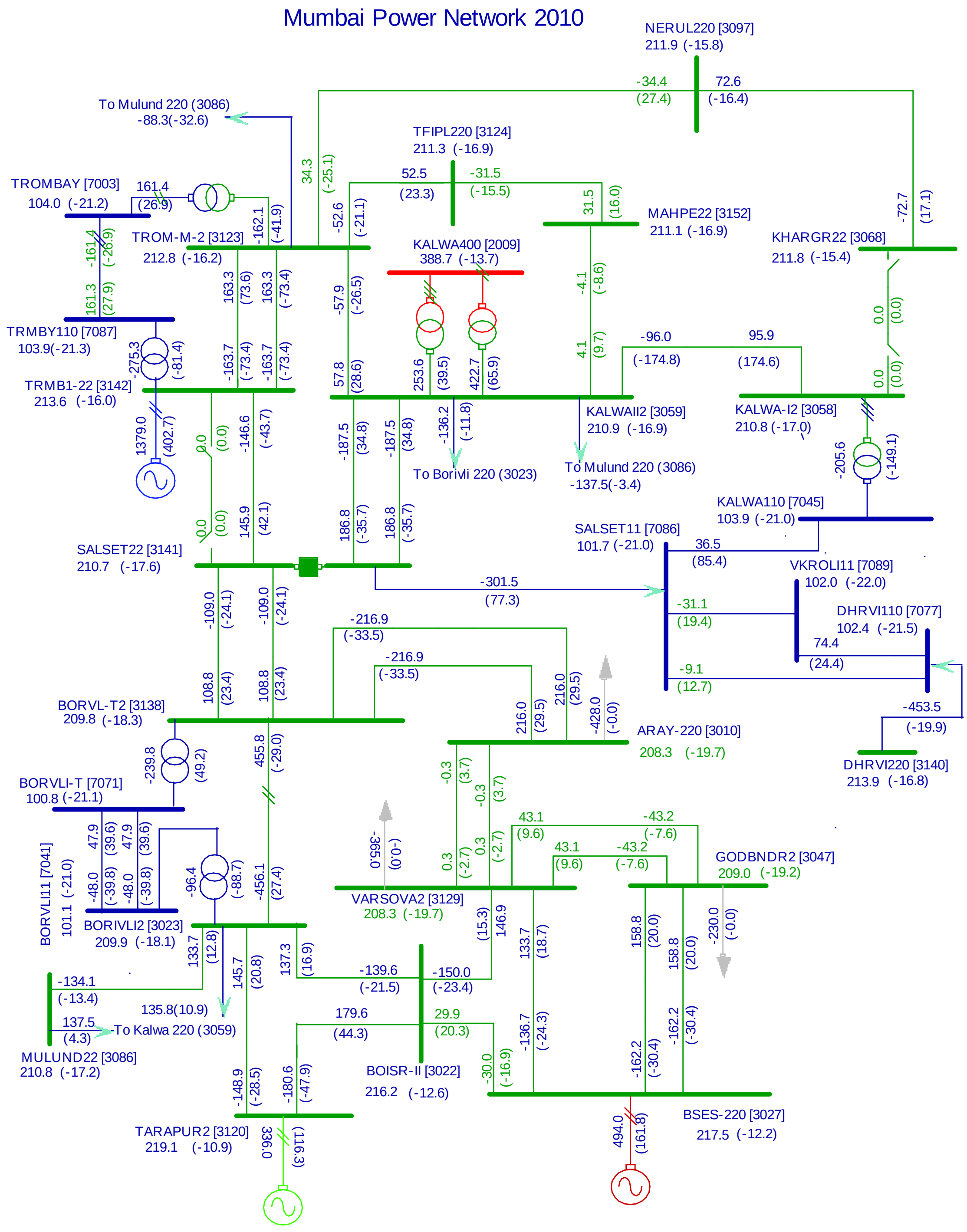

Fig. 3. Base Case of Scenario-1 with Trombay-Salsette 1 ckt out

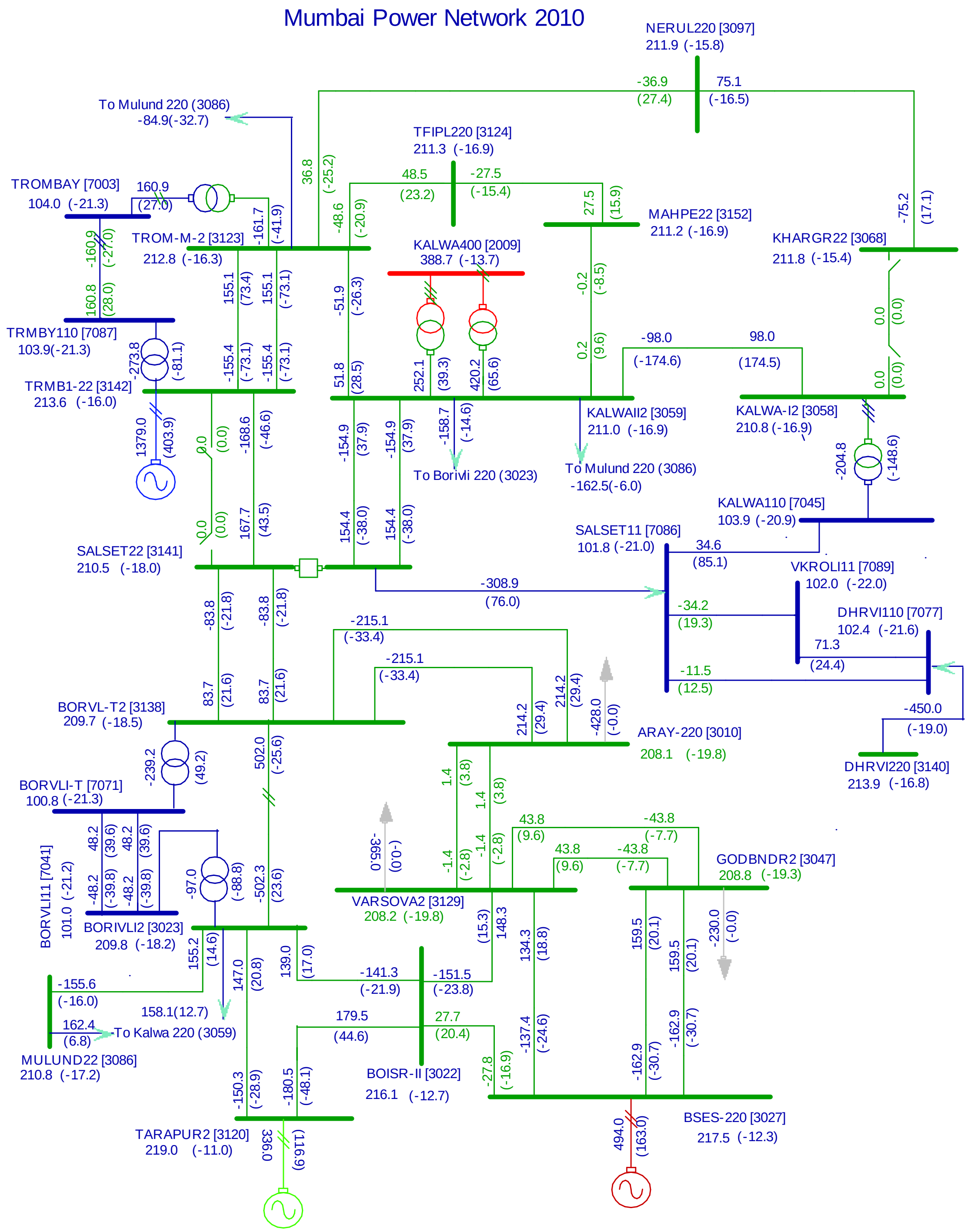

Fig. 4. Base Case of Scenario-3 with Trombay-Salsette 1 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Trombay – Salsette-1&2 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow over Kalwa-Salsette line increases from 162 MW (base case) to 234 MW with both the Trombay-Salsette lines out.
- Flow over Trombay-Trombay line increases from 131 MW (base case) to 225 MW.
- Aarey – Varsova corridor is flooting carring very small amount of power.
- Borivali – Aarey corridor (double circuit) is near to its loading limit.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Flow over Trombay-Trombay line increases from 129 MW (base case) to 228 MW.
- Borivali-Borivali line carries 656 MW (over loaded). Although Borivali-Borivali line may be able to carry that power safely, the equipment at either end should be upgraded to handle the same amount of power.
- Kalwa-Borivali carries power in the tune of 225 MW.

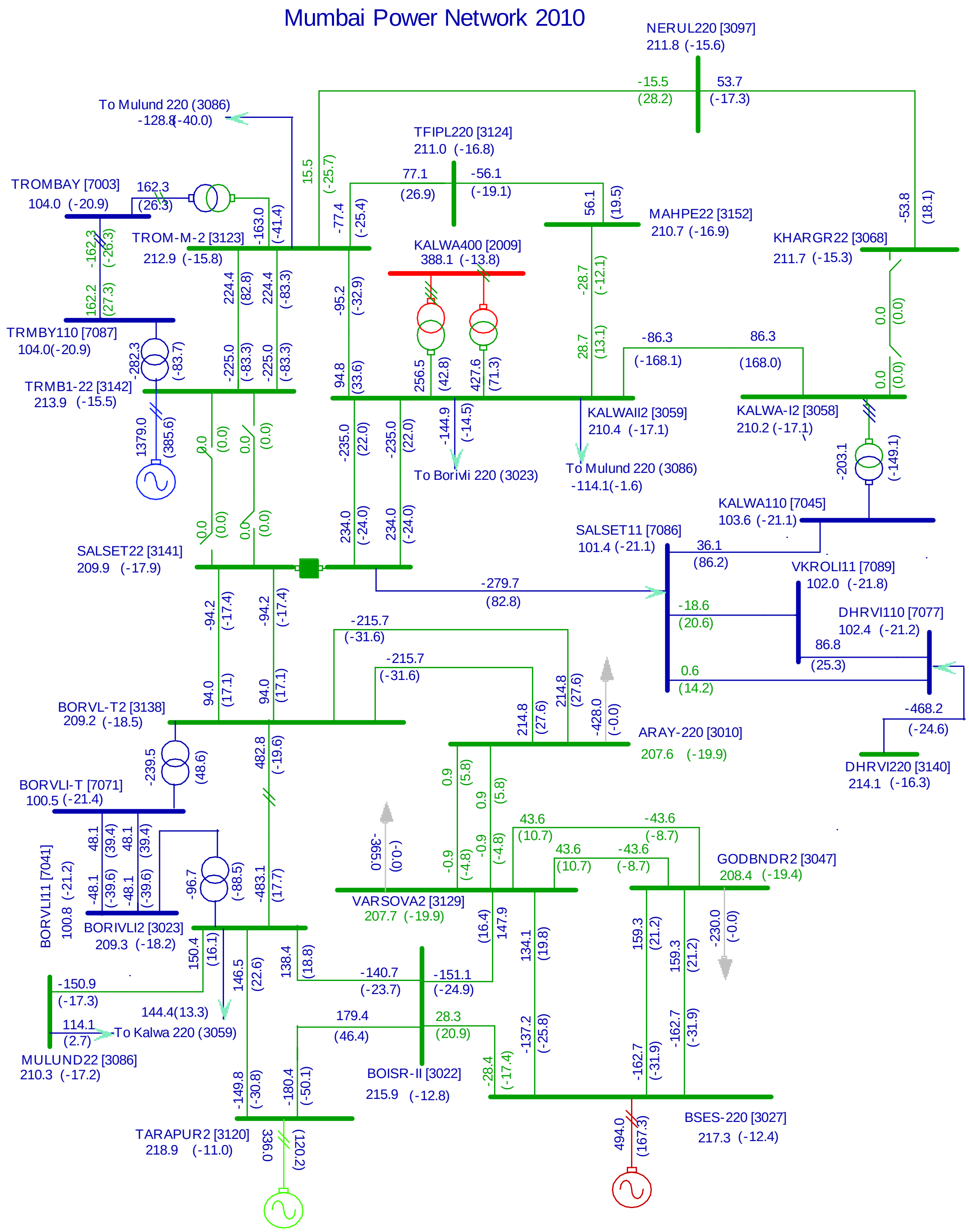

Fig. 5. Base Case of Scenario-1 with Trombay-Salsette 1&2 ckt out

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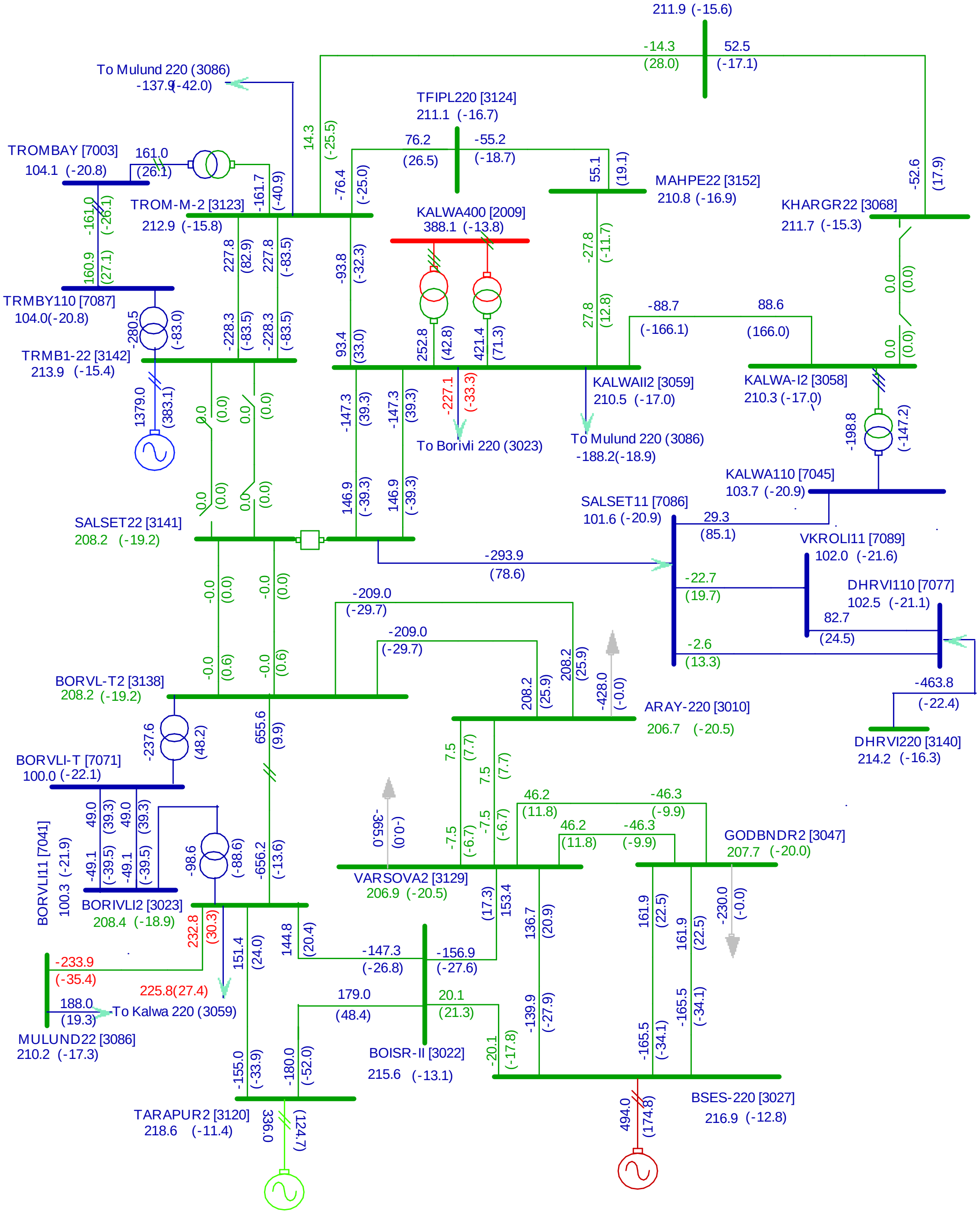

Fig. 6. Base Case of Scenario-3 with Trombay-Salsette 1&2 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Kalwa – Salsette-3 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow over Kalwa-Salsette line increases from 162 MW (base case) to 246 MW. Rest of the lines are loaded more or less same as the base case.
- Aarey – Varsova corridor is flooting carring very small amount of power.
- Borivali – Aarey corridor (double circuit) is near to its loading limit.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Flow over Kalwa-Salsette line increases from 157 MW (base case) to 295 MW. Rest of the lines are loaded more or less same as the base case.
- Rest of the lines are loaded more or less same as the base case.

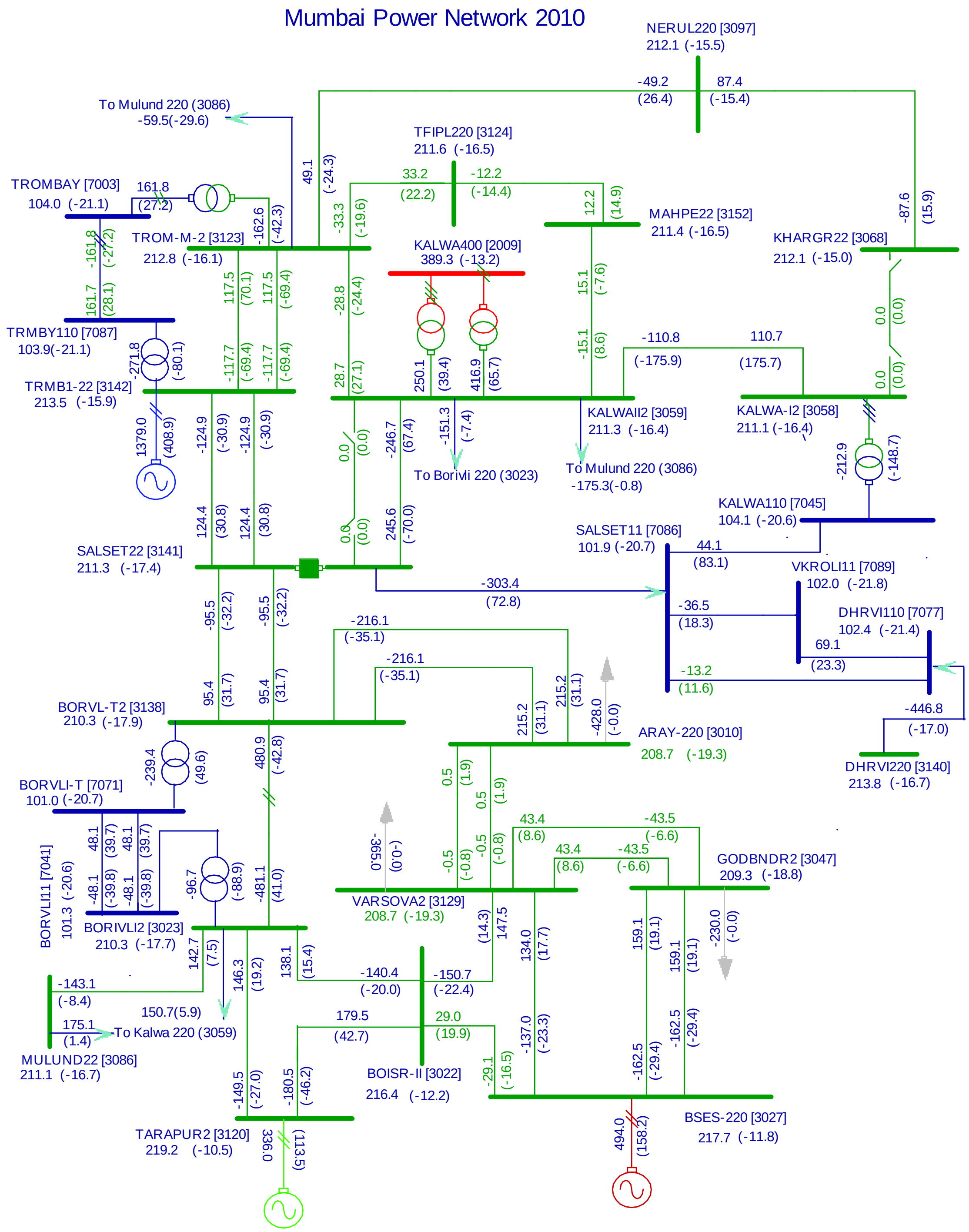

Fig. 7. Base Case of Scenario-1 with Kalwa-Salsette 3 ckt out

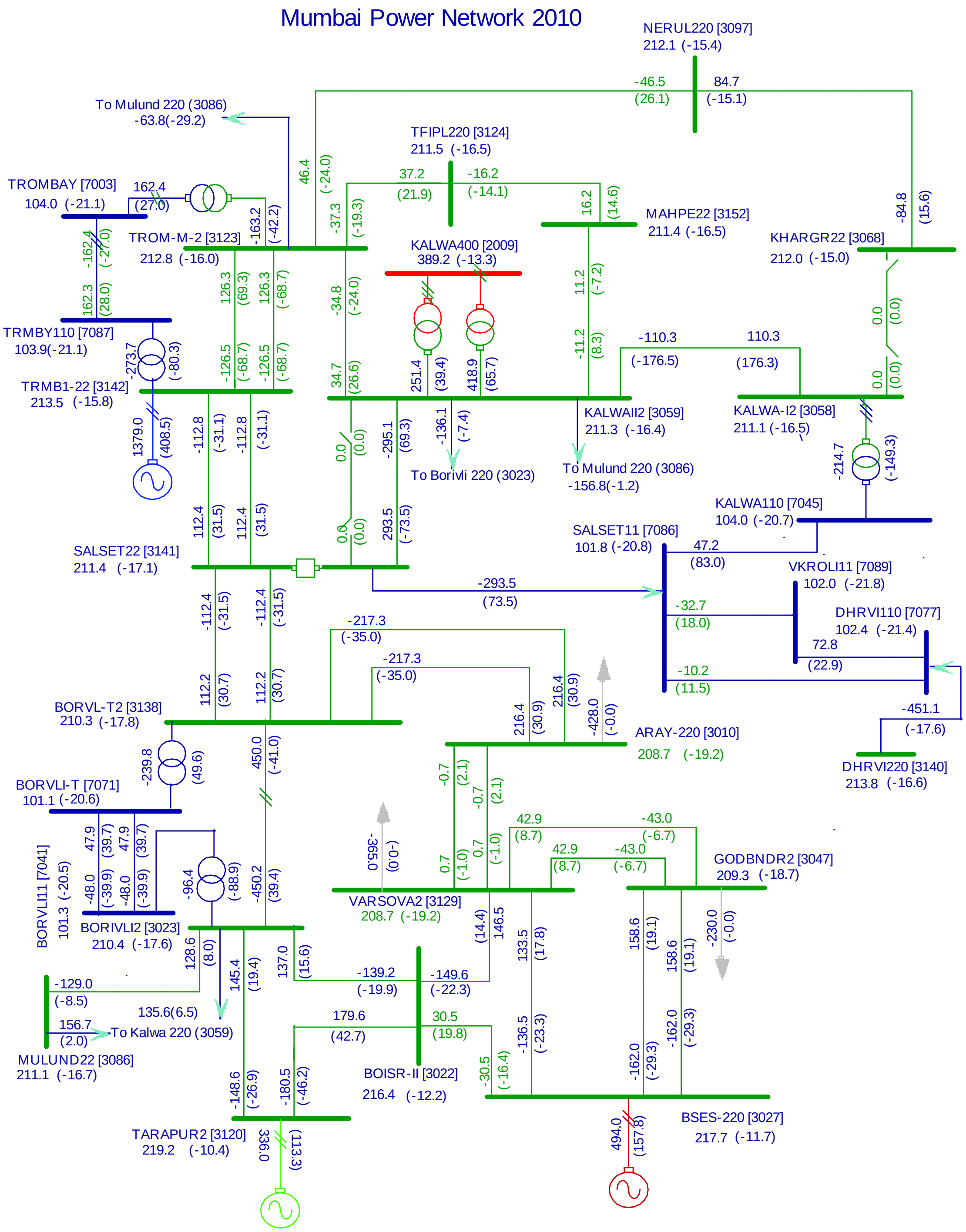

Fig. 8. Base Case of Scenario-3 with Kalwa-Salsette 3 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Kalwa – Salsette-3&4 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- With bus-coupler in service , Salsette ICT keeps feeding Vikhroli, Dharavi, and other radial load.
- Borivali-Borivali lines carry more than 600 MW.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- With Bus-couple out of service, Salsette ICTdoesn not get feed.
- Loading of Kalwa-Kalwa interconnector line increases from 101 MW (in base case) to 247 MW with the contingency.

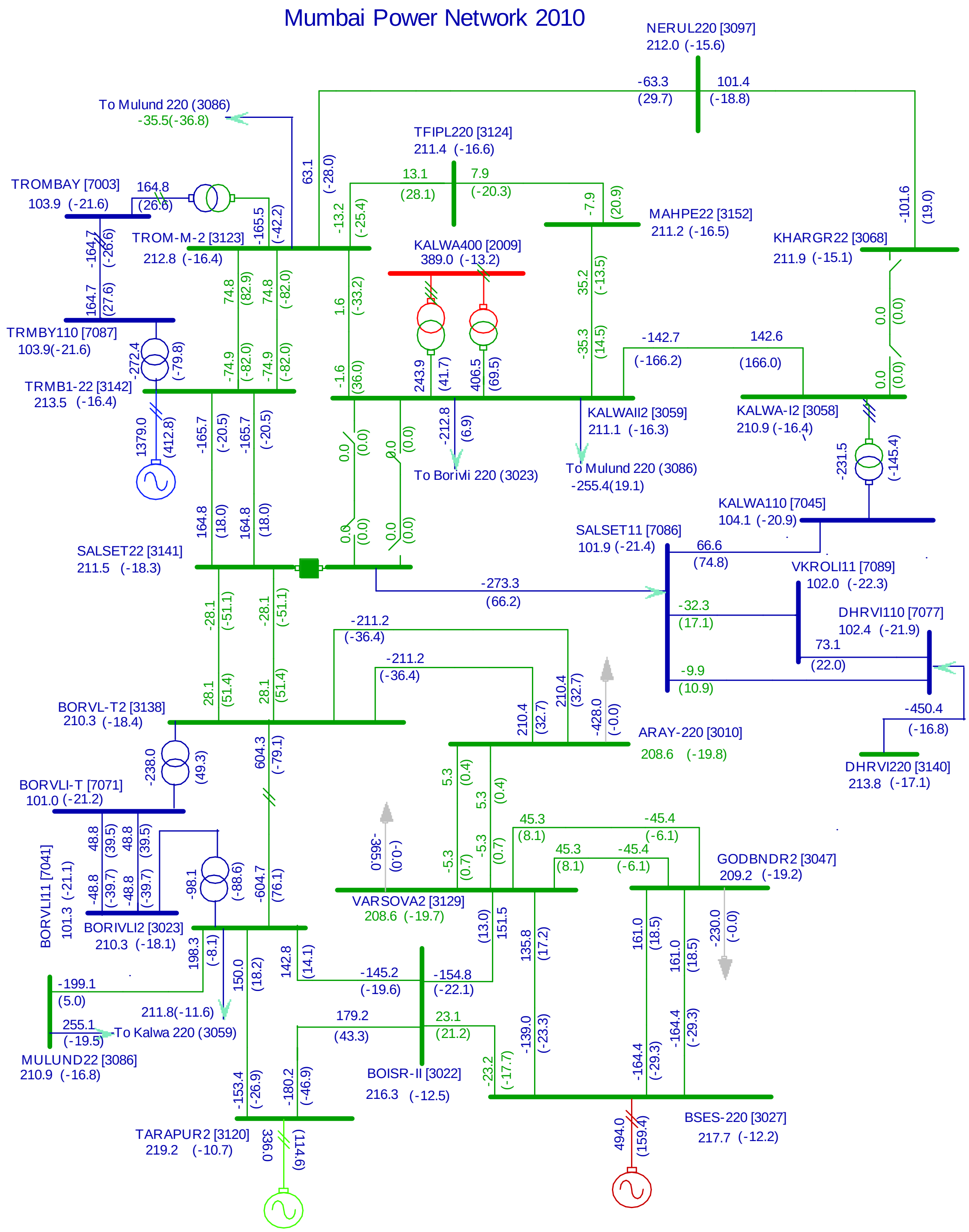

Fig. 9. Base Case of Scenario-1 with Kalwa-Salsette 3&4 ckt out

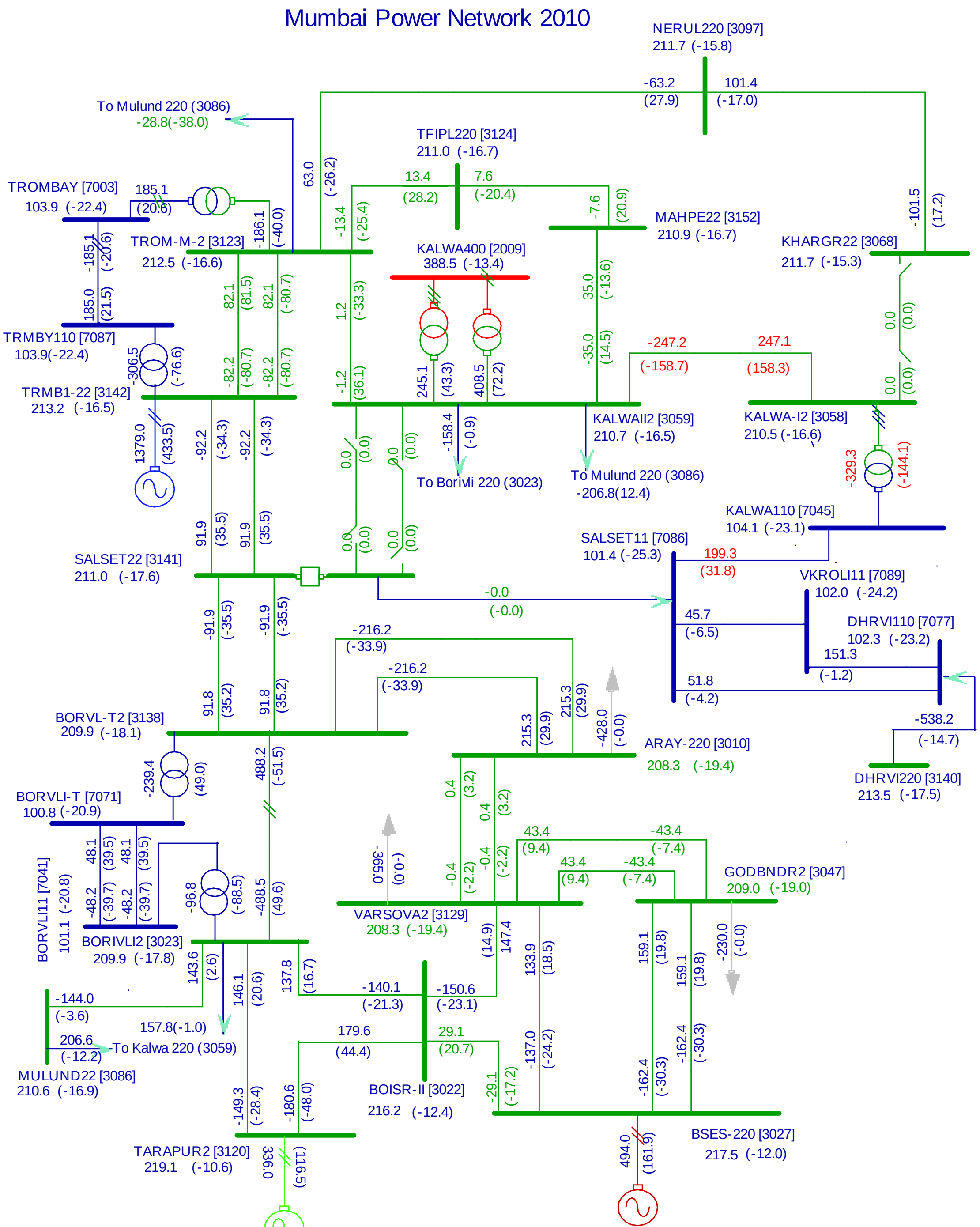

Fig. 10. Base Case of Scenario-3 with Kalwa-Salsette 3&4 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Dahanu – Ghodbundar-1 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow over 2nd circuit of Dahanu – Ghodbundar increases.
- Aarey-Varsova line, which was amost floating in earlier cases, now carries 39 MW of power to support Varsova load.
- Aareay-Borivali line hits the upper limit of 255 MW, carrying 256 MW each circuit. R-Infra's load trimming scheme will be activated at 255 MW loading condition.
- No major flow variations are observed in rest of the network.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- The situation is similar to that of above, however the flow over Borivali-Borivali line increase marginally.

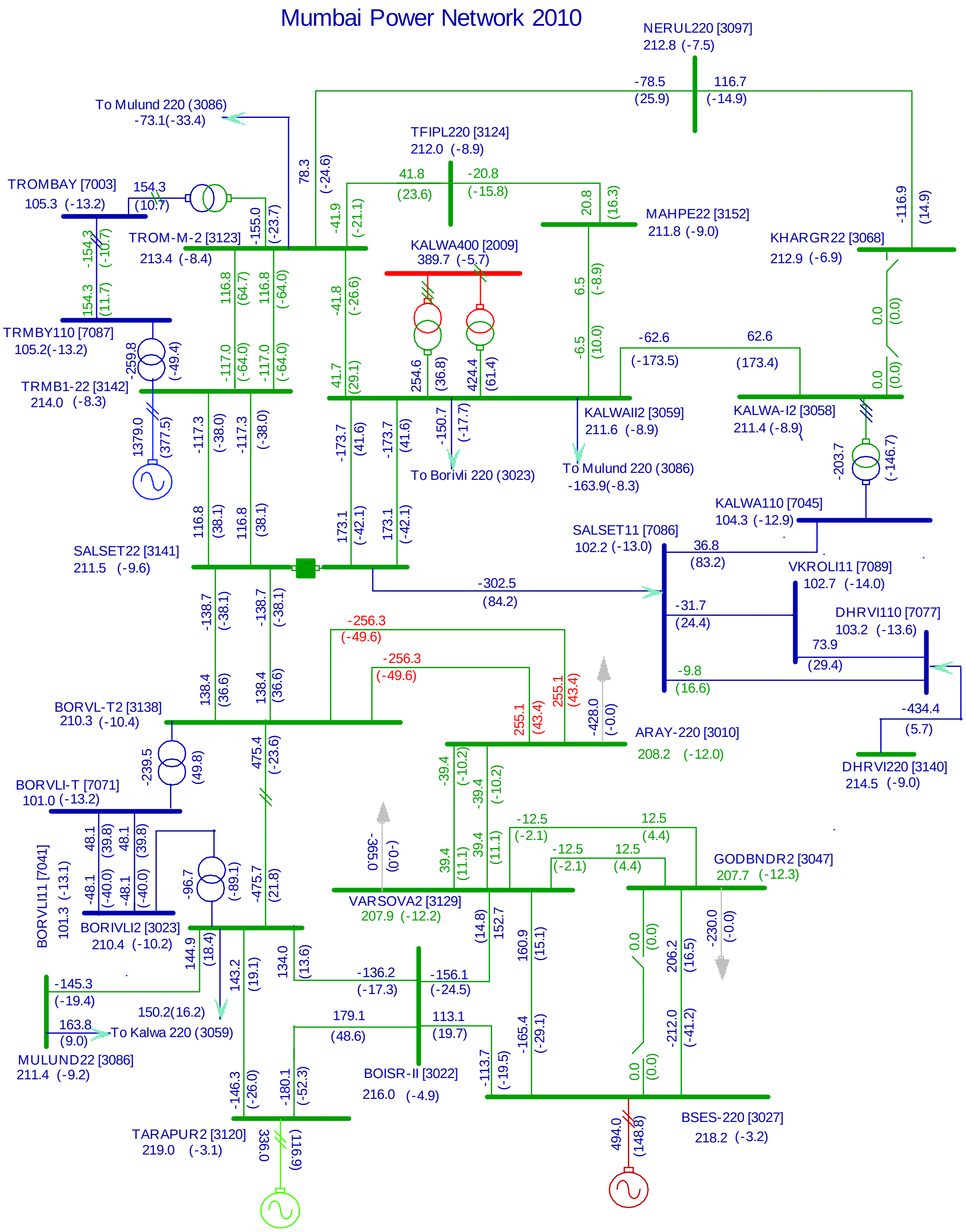

Fig. 11. Base Case of Scenario-1 with Dahanu-Ghodbundar 1 ckt out

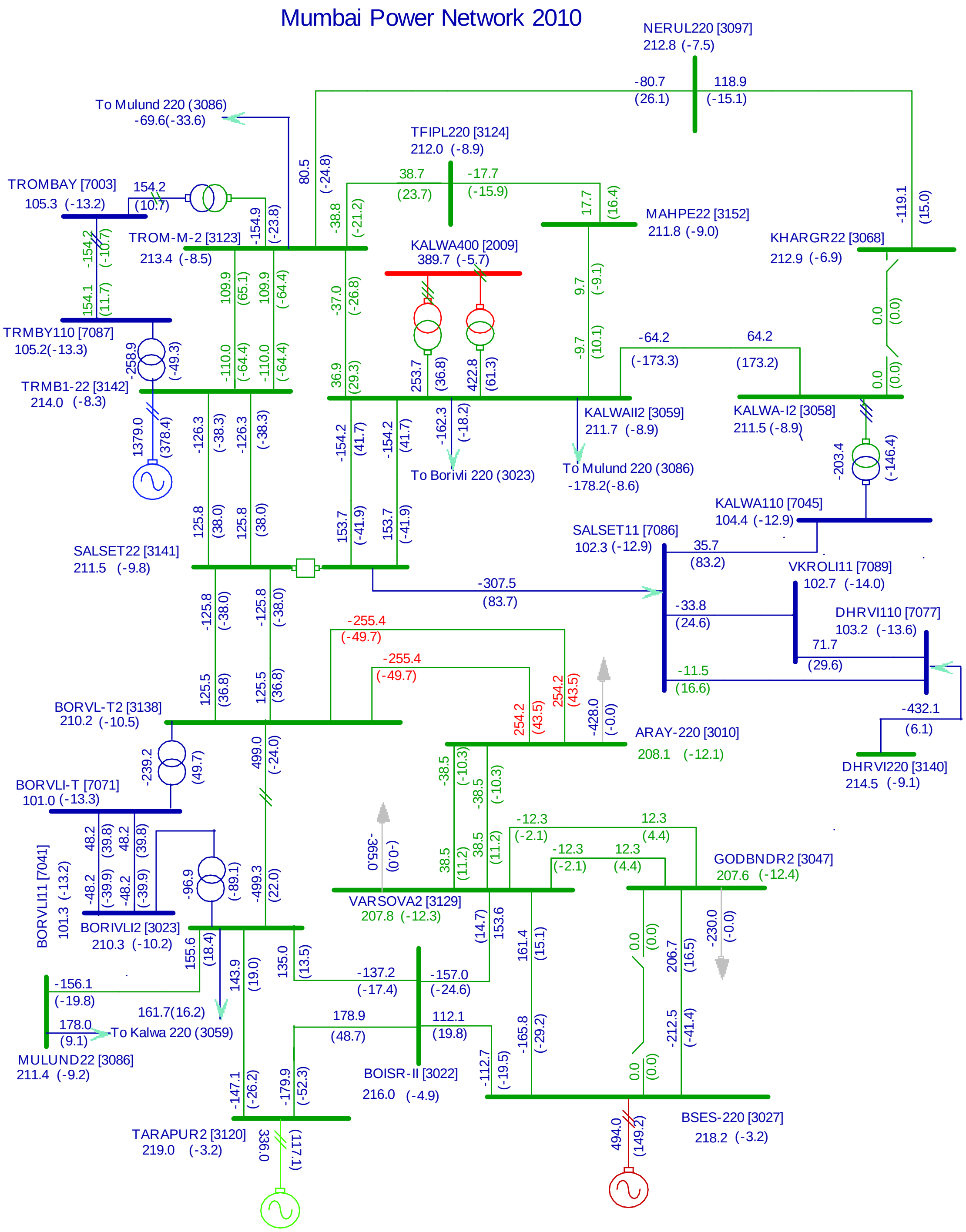

Fig. 12. Base Case of Scenario-3 with Dahanu-Ghodbundar 1 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Dahanu – Ghodbundar-1&2 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow over Dahanu-Boisar line increases from 32 MW (in base case) to 253 MW with the contingency.
- Flow over Dahanu-Varsova line increases from 136 MW (in base case) to 234 MW with the contingency.
- Flow over Godbundar-Varsova line increases from 43 MW (in base case) to 116 MW in reverse direction feeding Ghodbundar load.
- Aarey-Varsova line, which was amost floating in earlier cases, now carries 94 MW of power to support Varsova load.
- Aareay-Borivali line is over loaded carrying 312 MW.
- Borivali-Borivali line carrynig slightly less than 550 MW.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- The situation is similar to that of above, however the flow over Borivali-Borivali line increase up to 590 MW and flow of Kalwa-Borivali line increases from 135 MW (in base case) to 187 MW.

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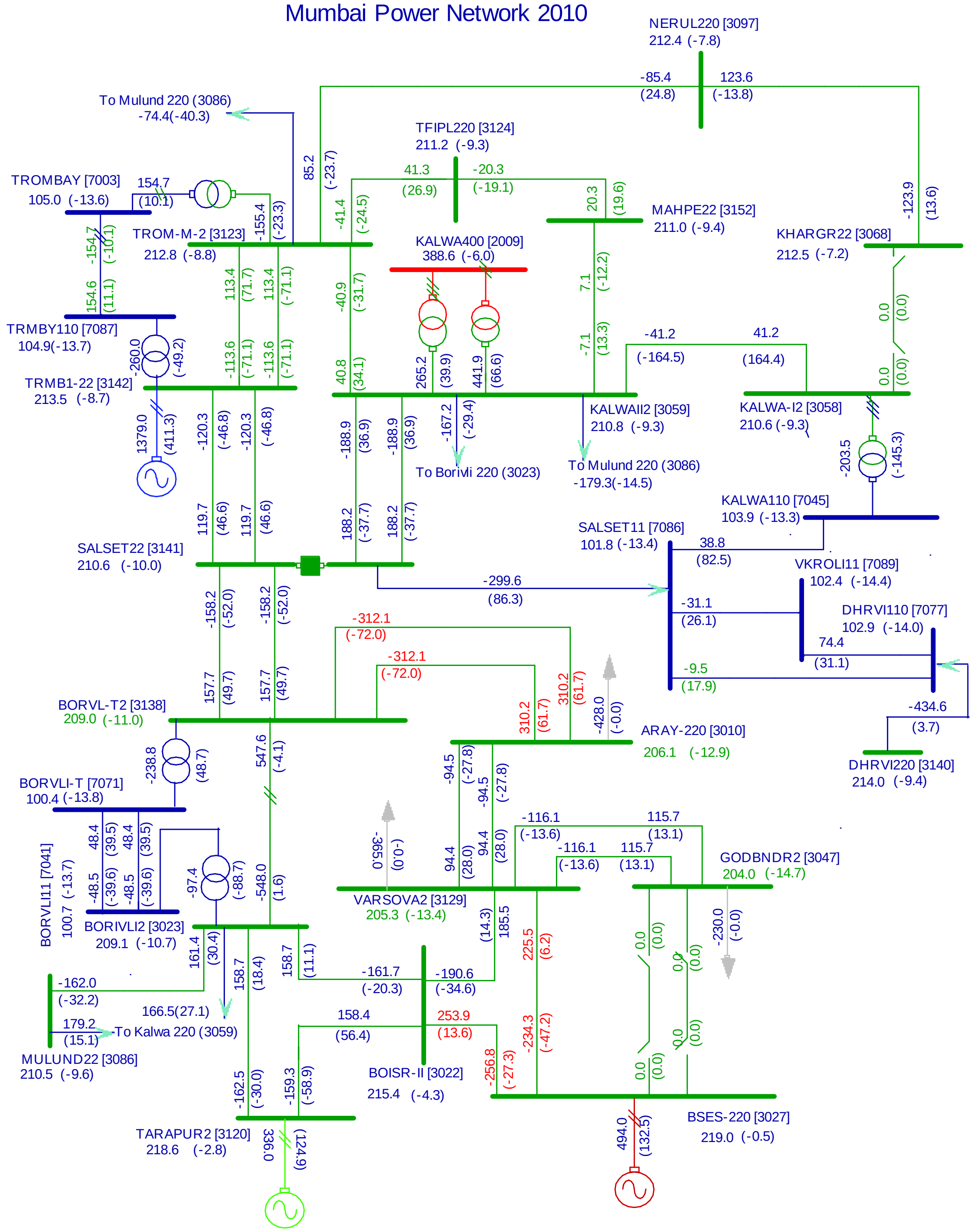

Fig. 13. Base Case of Scenario-1 with Dahanu-Ghodbundar 1&2 ckt out

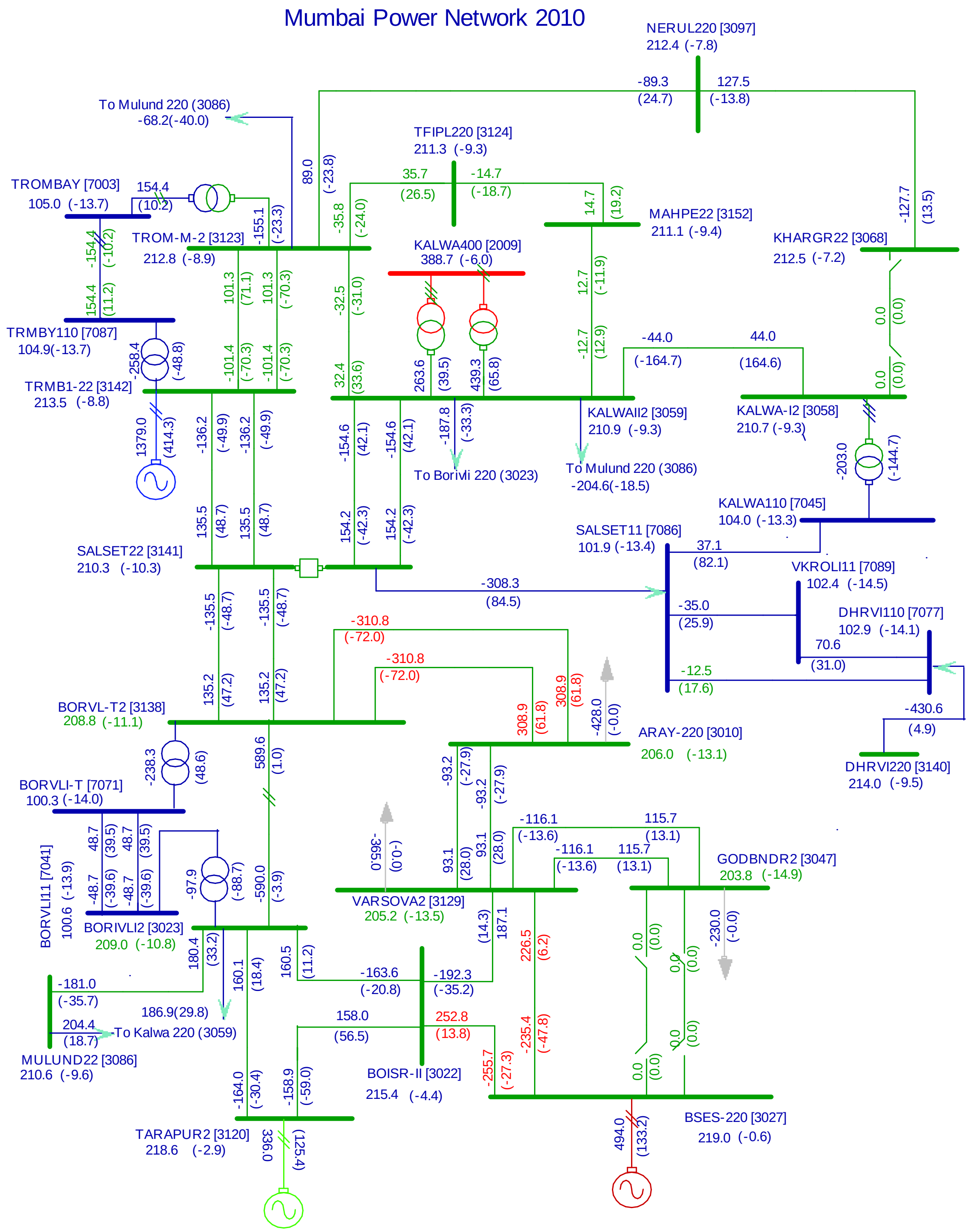

Fig. 14. Base Case of Scenario-3 with Dahanu-Ghodbundar 1&2 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Borivali –Salsette-1 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow on 2nd ckt of Borivali-Salsette line increase up to 172 MW.
- Loading condition on rest of the network does not change substantially from the base case.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Flow on 2nd ckt of Borivali-Salsette line increase up to 172 MW.
- Loading condition on rest of the network does not change substantially from the base case.

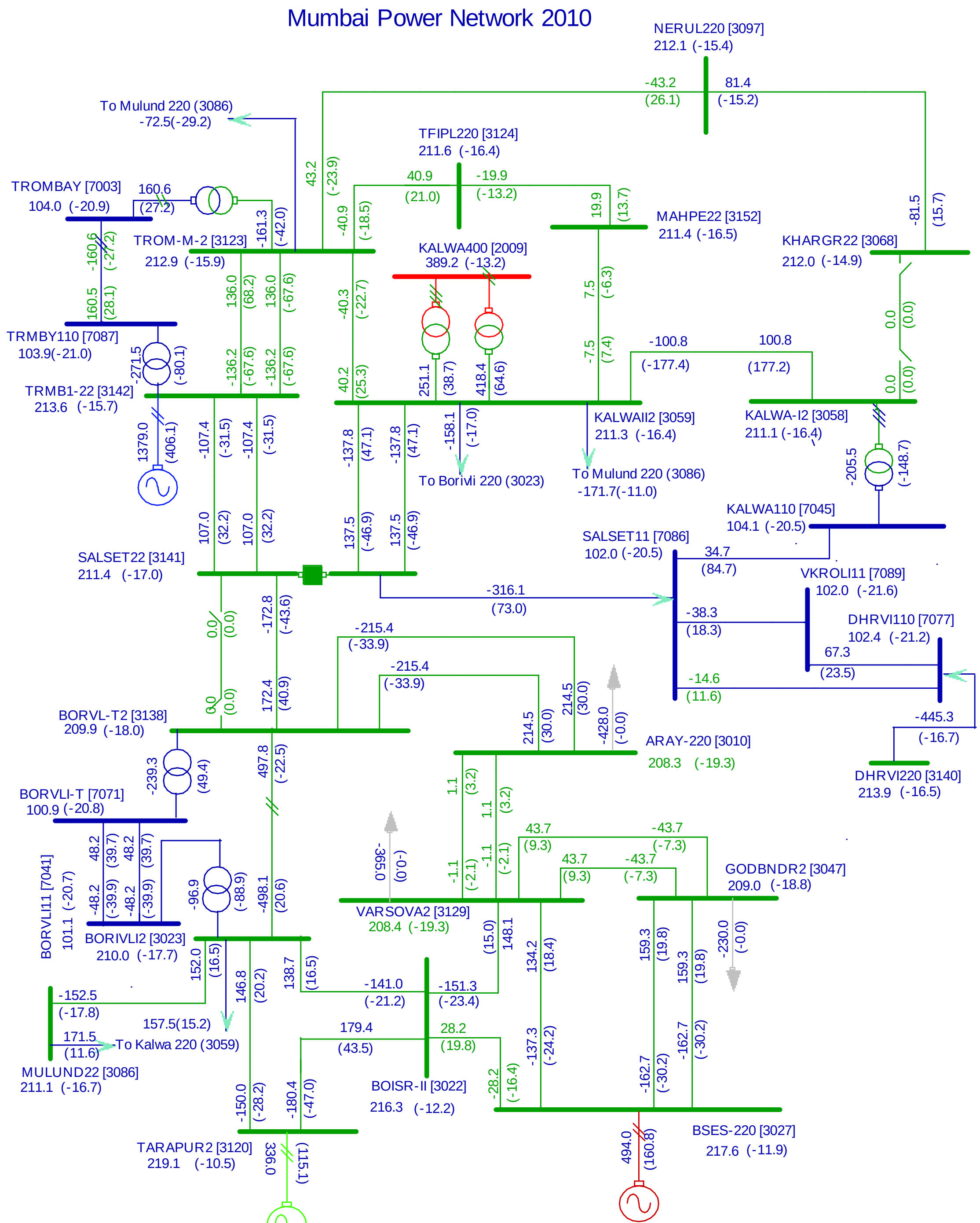

Fig. 15. Base Case of Scenario-1 with Borivali – Salsette 1 ckt out

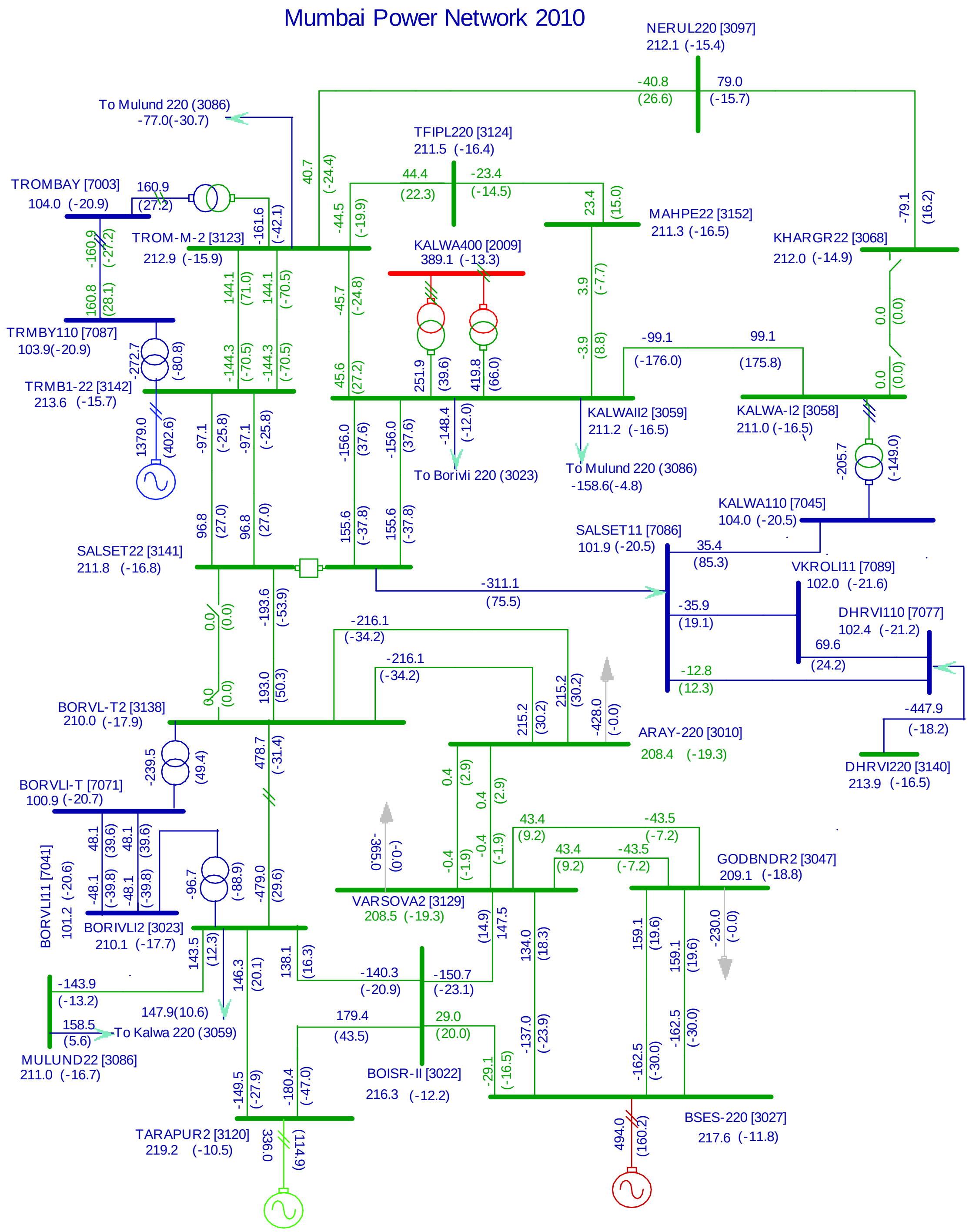

Fig. 16. Base Case of Scenario-3 with Borivali – Salsette 1 ckt out

<table>
<tr><td>Borivali-Borivali 220 kV In Service</td><td>Salsette Bus Coupler In Service</td><td>Borivali-Borivali 220 kV In Service</td><td>Salsette Bus Coupler not in Service</td></tr>
<tr><td colspan="2">Scenario-1</td><td colspan="2">Scenario-3</td></tr>
<tr><td colspan="4">Borivali –Salsette-1&2 Out</td></tr>
</table>

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Borivali-Borivali lines get overloaded carrying 657 MW.
- Borivali – Mulund line carries 229 MW as compared to 126 MW in base case.
- Loading of Aarey-Borivali lines decreases marginally.
- Borivali – Kalwa line carries 231 MW as compared to 132 MW in base case.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- With Salsette B/C out of service, Trombay-Salsette and Salsette-Borivali corridor becomes radial, carrying no power.
- Borivali-Borivali line gets overloaded carrying 657 MW.
- Borivali – Mulund line carries 234 MW as compared to 128 MW in base case.
- Borivali – Kalwa line carries 226 MW as compared to 135 MW in base case.

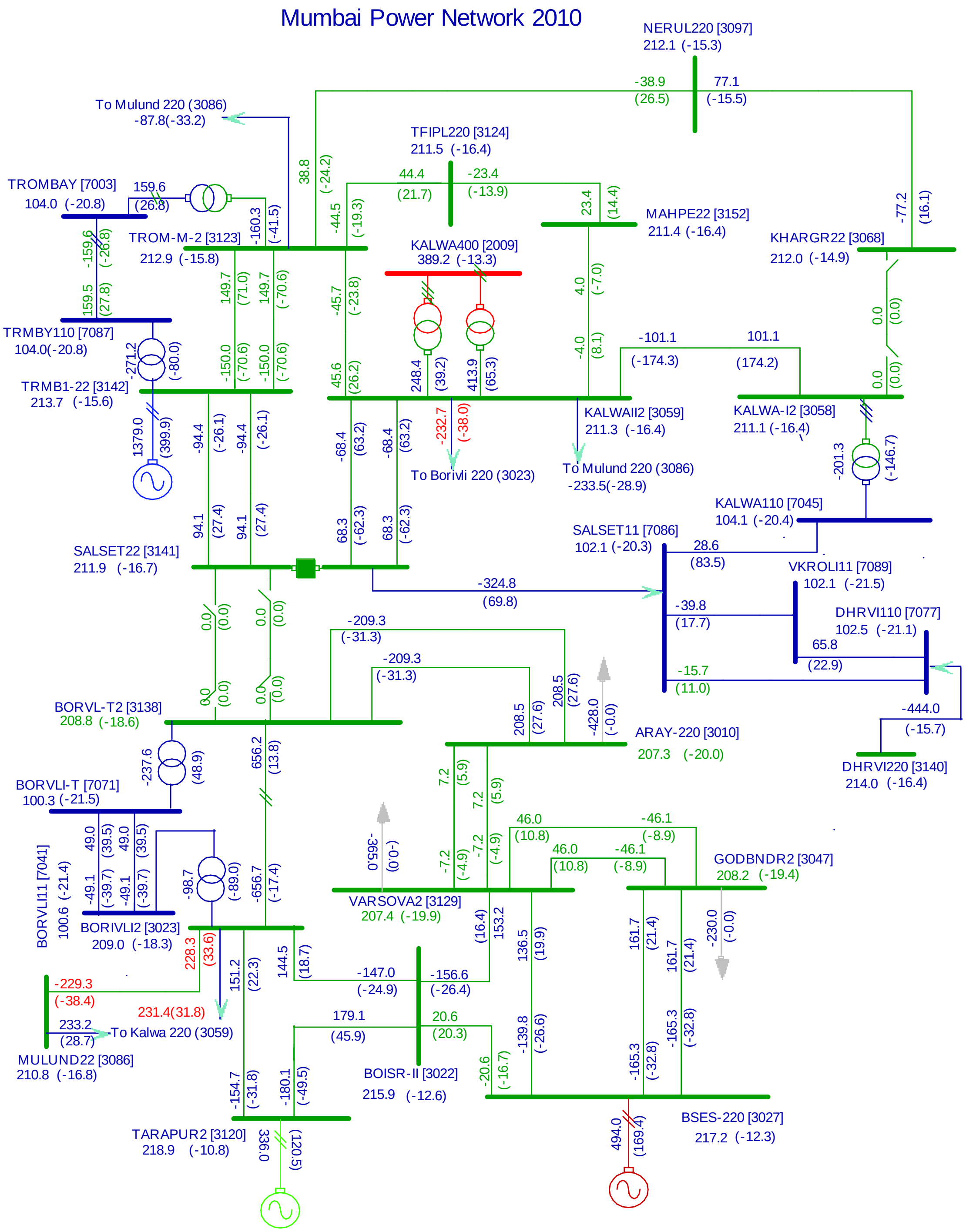

Fig. 17. Base Case of Scenario-1 with Borivali – Salsette 1&2 ckt out

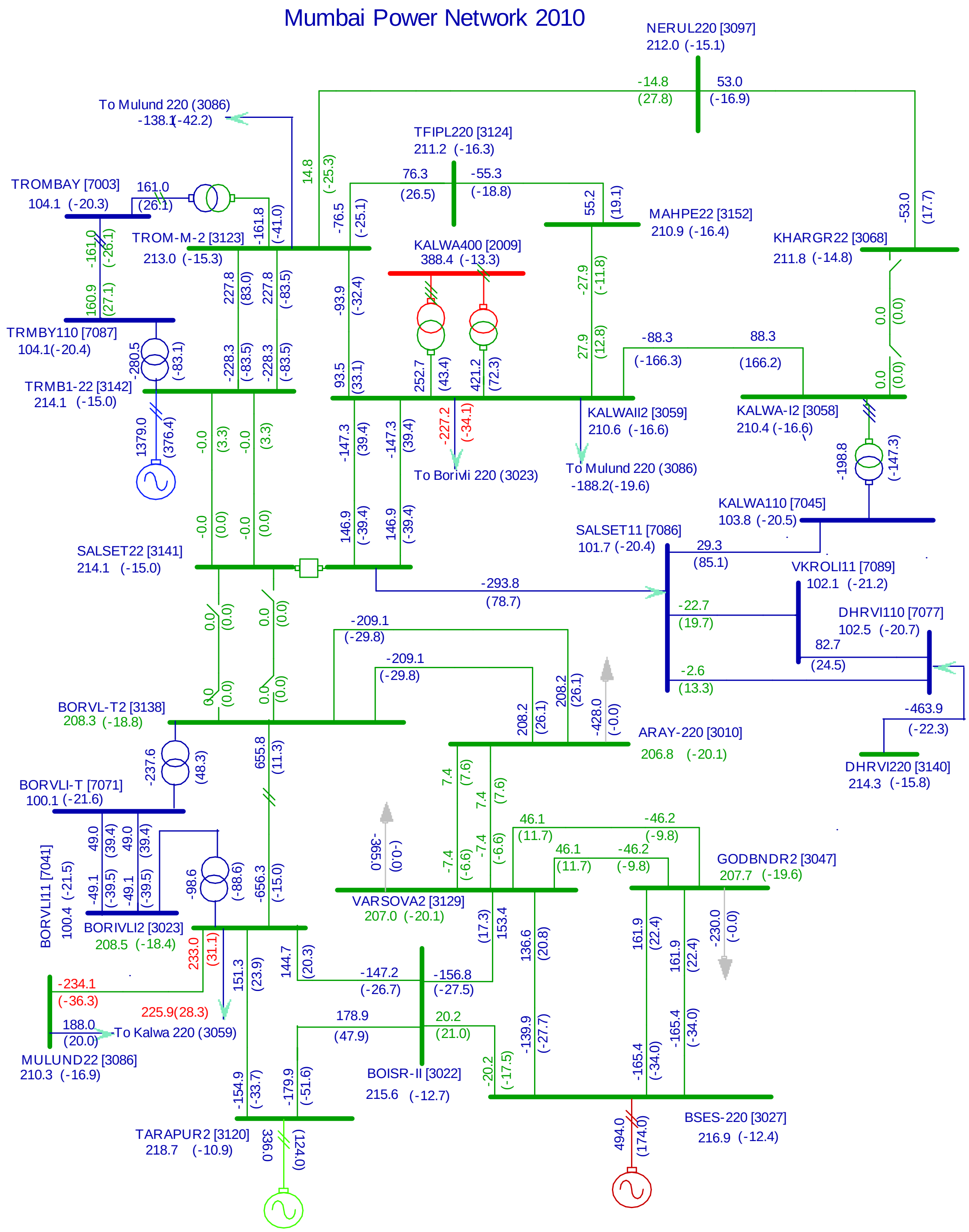

Fig. 18. Base Case of Scenario-3 with Borivali – Salsette 1&2 ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Borivali –Aarey-1 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Aarey-Borivali 2nd ckt is over loaded with more than 400 MW.
- Flow in rest of the network is marginally affected.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Aarey-Borivali 2nd ckt is over loaded with more than 400 MW.
- Flow in rest of the network is marginally affected.

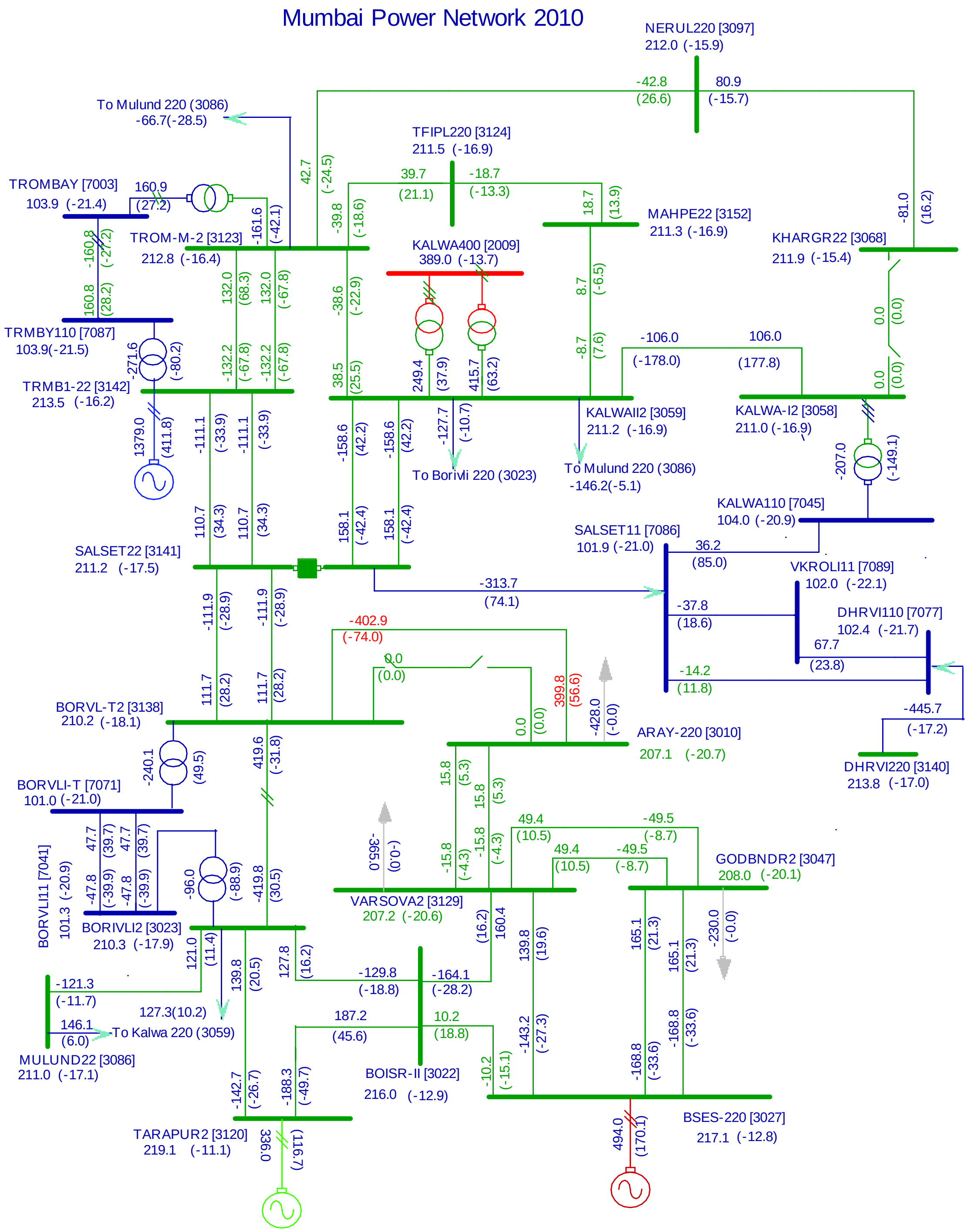

Fig. 19. Base Case of Scenario-1 with Borivali – Aarey ckt 1 out

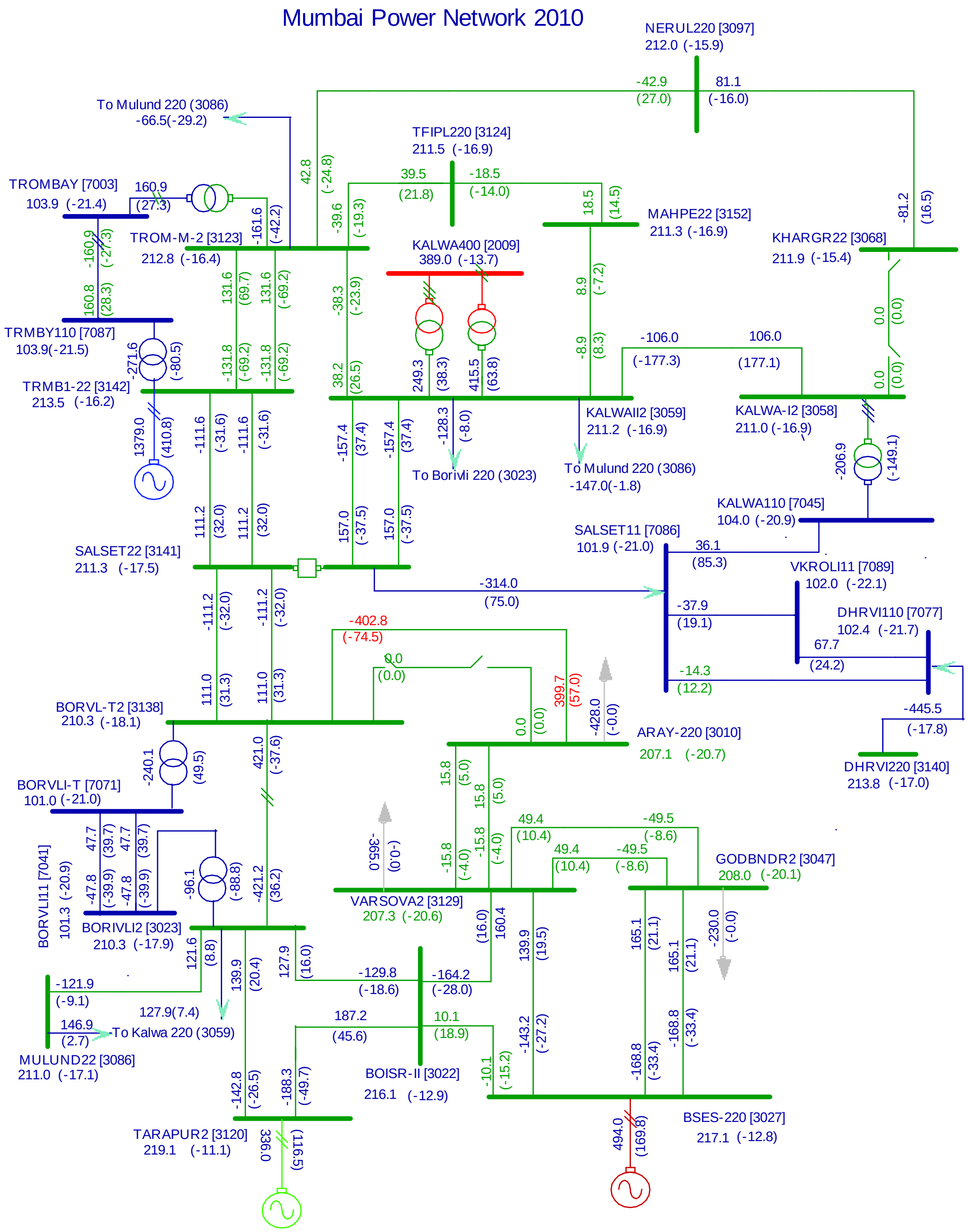

Fig. 20. Base Case of Scenario-3 with Borivali – Aarey ckt 1 out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Boisar – Varsova Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Aarey-Borivali overloaded with each circuit carring 267 MW.
- Aareay-Varsova line supports varsova load carrying more than 50 MW.
- Flow in rest of the network is marginally affected.
- Flow on Borivali-Borivali lines increase approximately by 50 MW.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Aarey-Borivali overloaded with each circuit carring 267 MW.
- Aareay-Varsova line supports varsova load carrying more than 50 MW.
- Flow in rest of the network is marginally affected.
- Flow on Borivali-Borivali lines increase approximately by 50 MW.

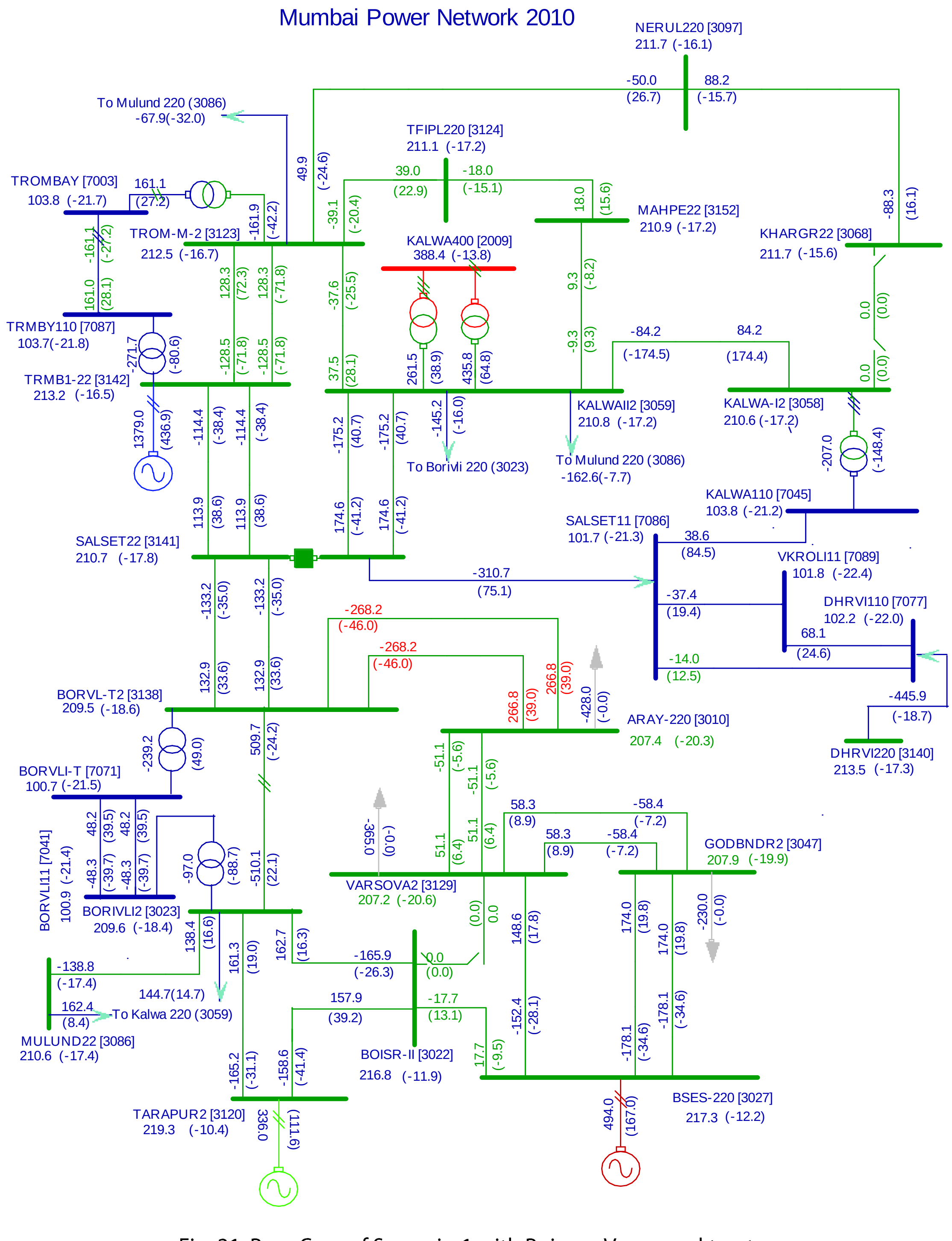

Fig. 21. Base Case of Scenario-1 with Boisar – Varsova ckt out

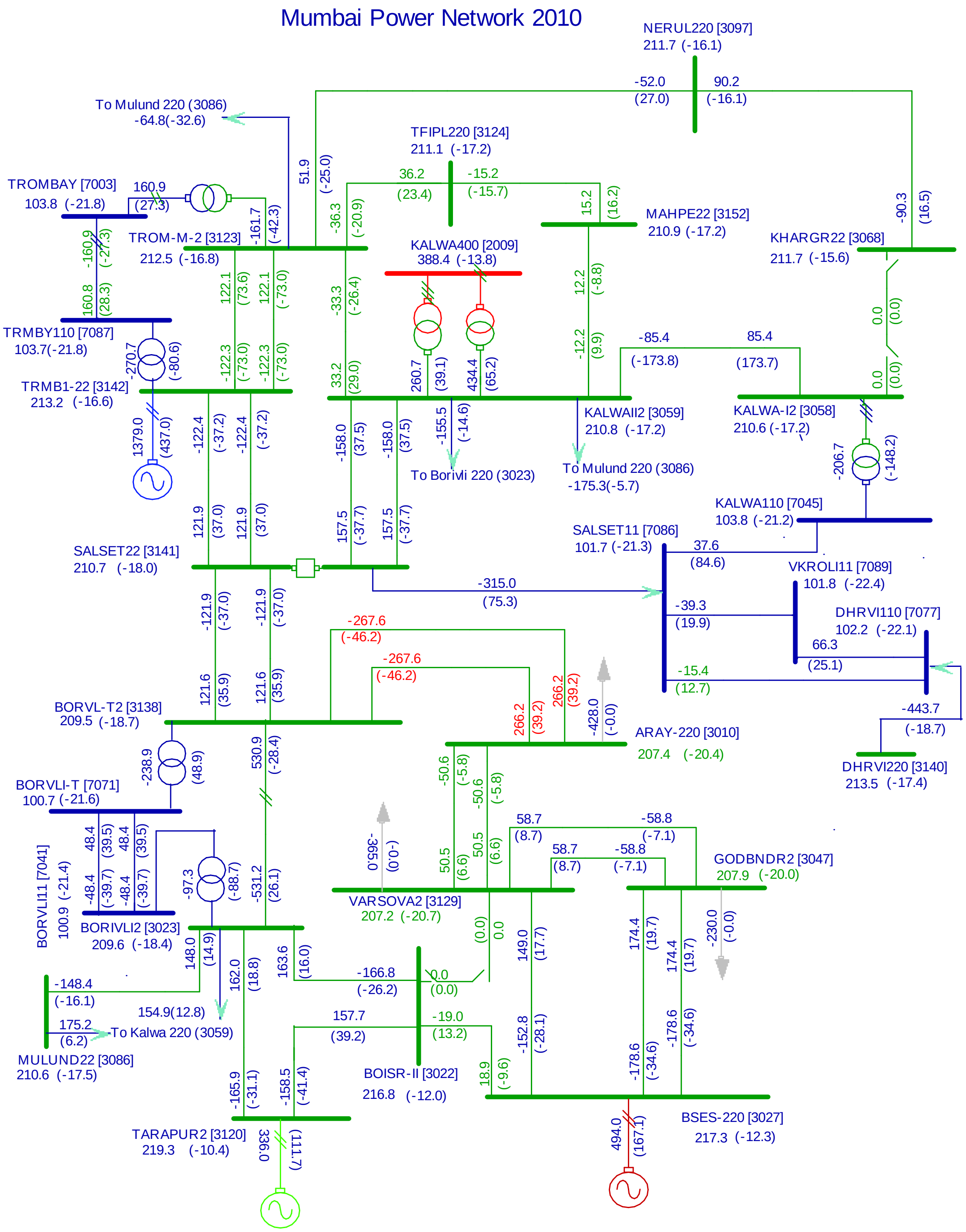

Fig. 22. Base Case of Scenario-3 with Boisar – Varsova ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Dahanu – Varsova Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Aarey-Borivali touches loading limit, carries 243 MW.
- Loading of Aarey-Varsova and Ghodbundar-Varsova increase marginally.
- Loding of rest of the network is within limit.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Aarey-Borivali touches loading limit, carries 243 MW.
- Loding of rest of the network is within limit.
- Loading of Aarey-Varsova and Ghodbundar-Varsova increase marginally.

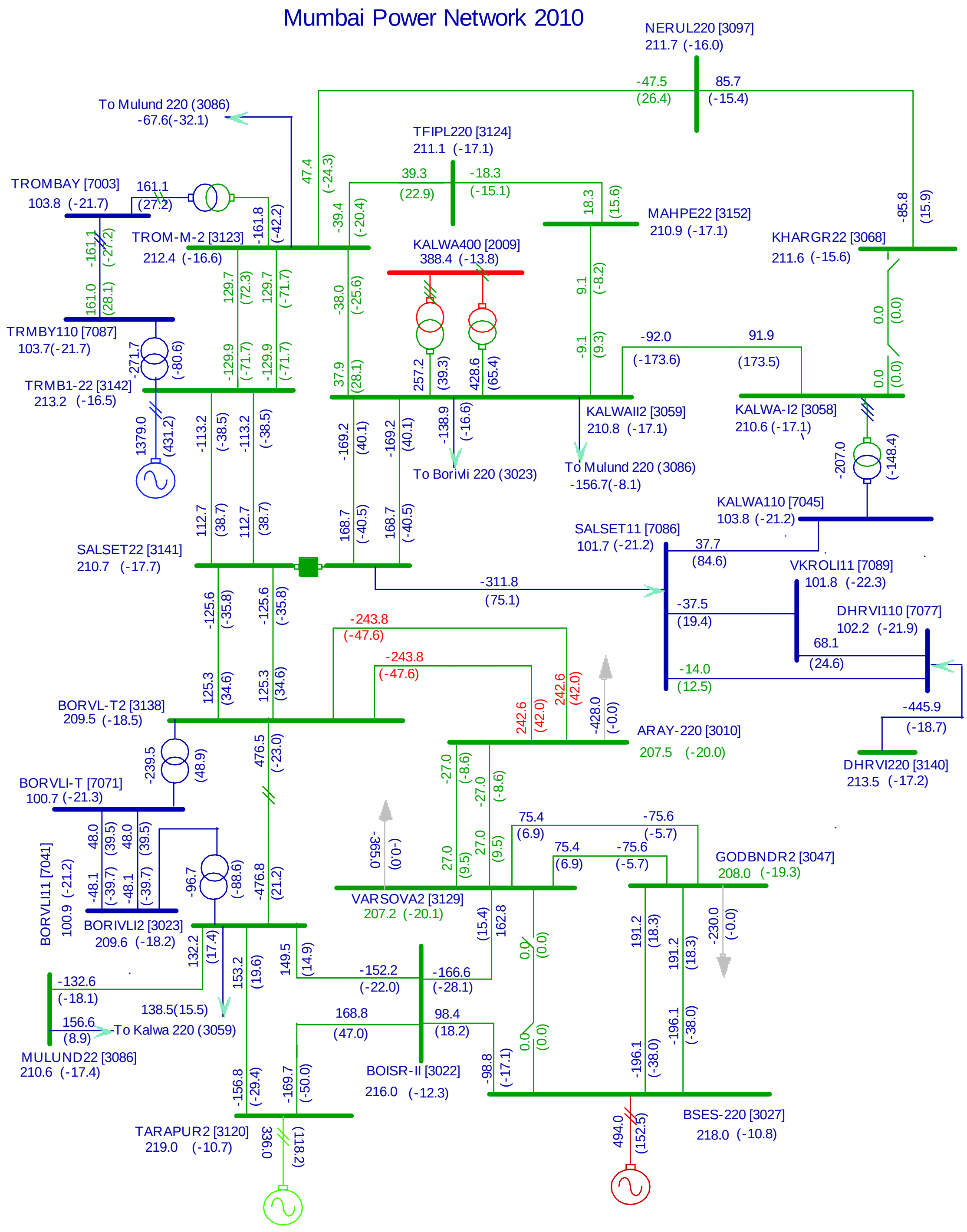

Fig. 23. Base Case of Scenario-1 with Dahanu – Varsova ckt out

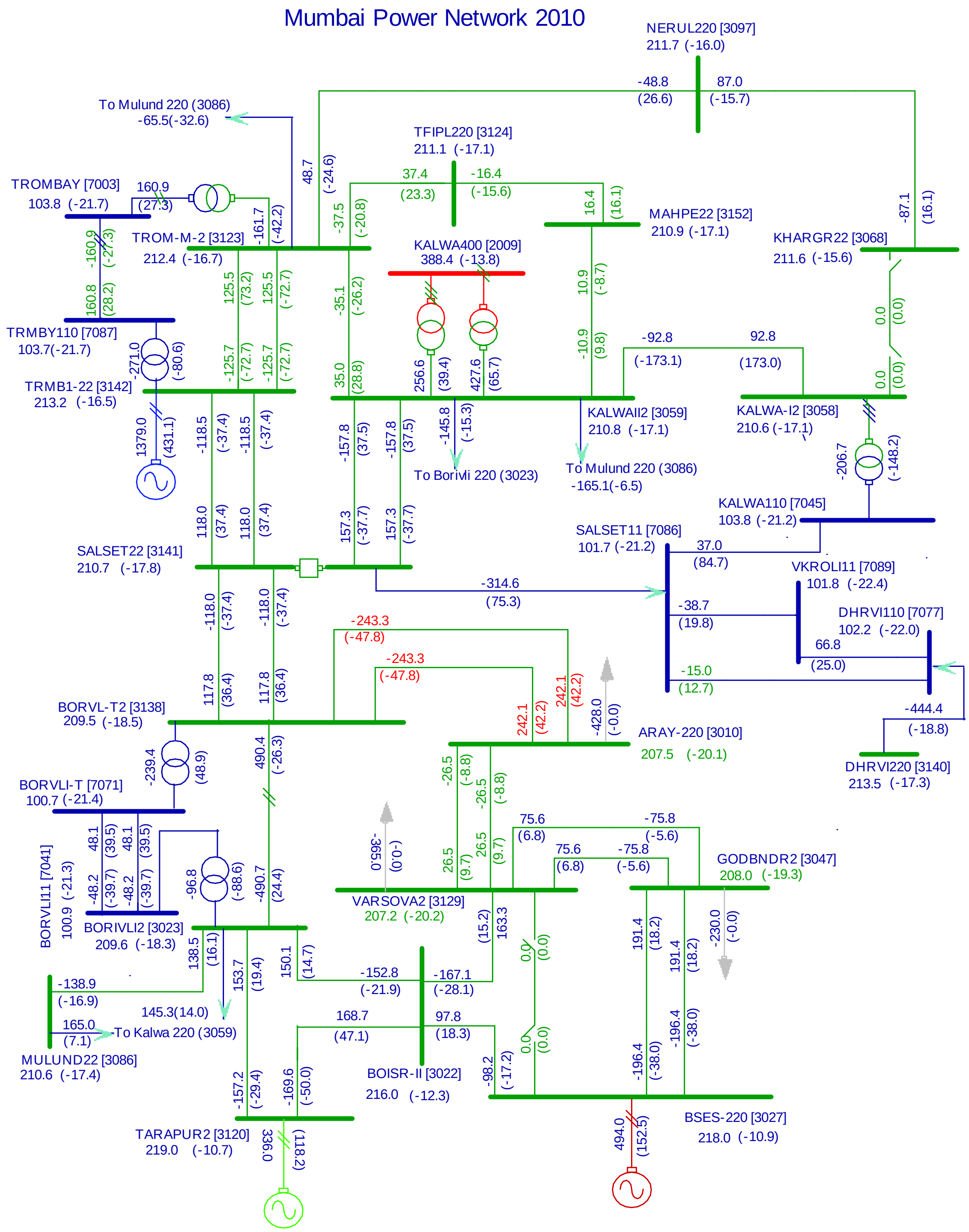

Fig. 24. Base Case of Scenario-3 with Dahanu – Varsova ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Dahanu –Boisar Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow over all the lines change marginally and within limit.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Flow over all the lines change marginally and within limit.

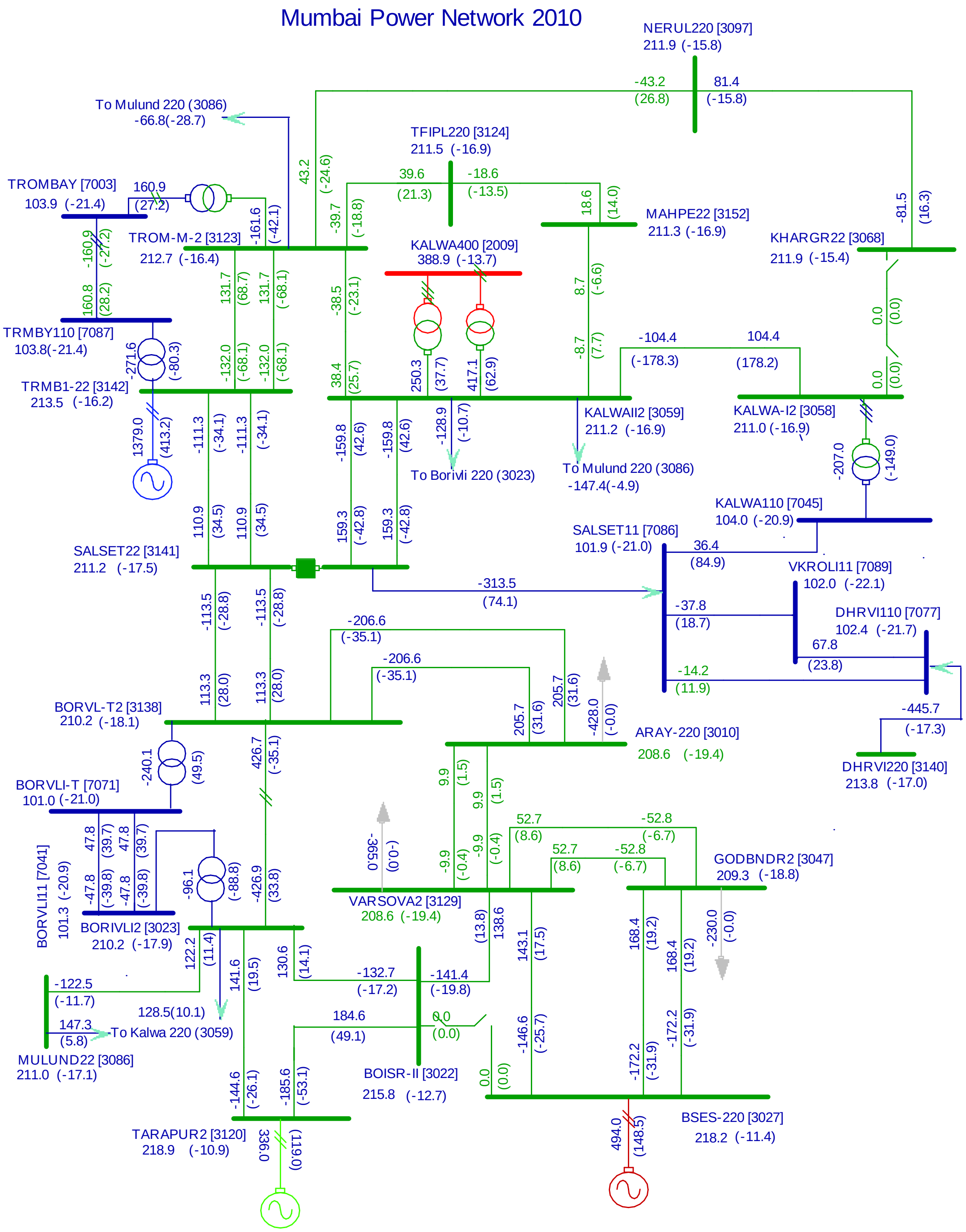

Fig. 25. Base Case of Scenario-1 with Dahanu –Bosiar ckt out

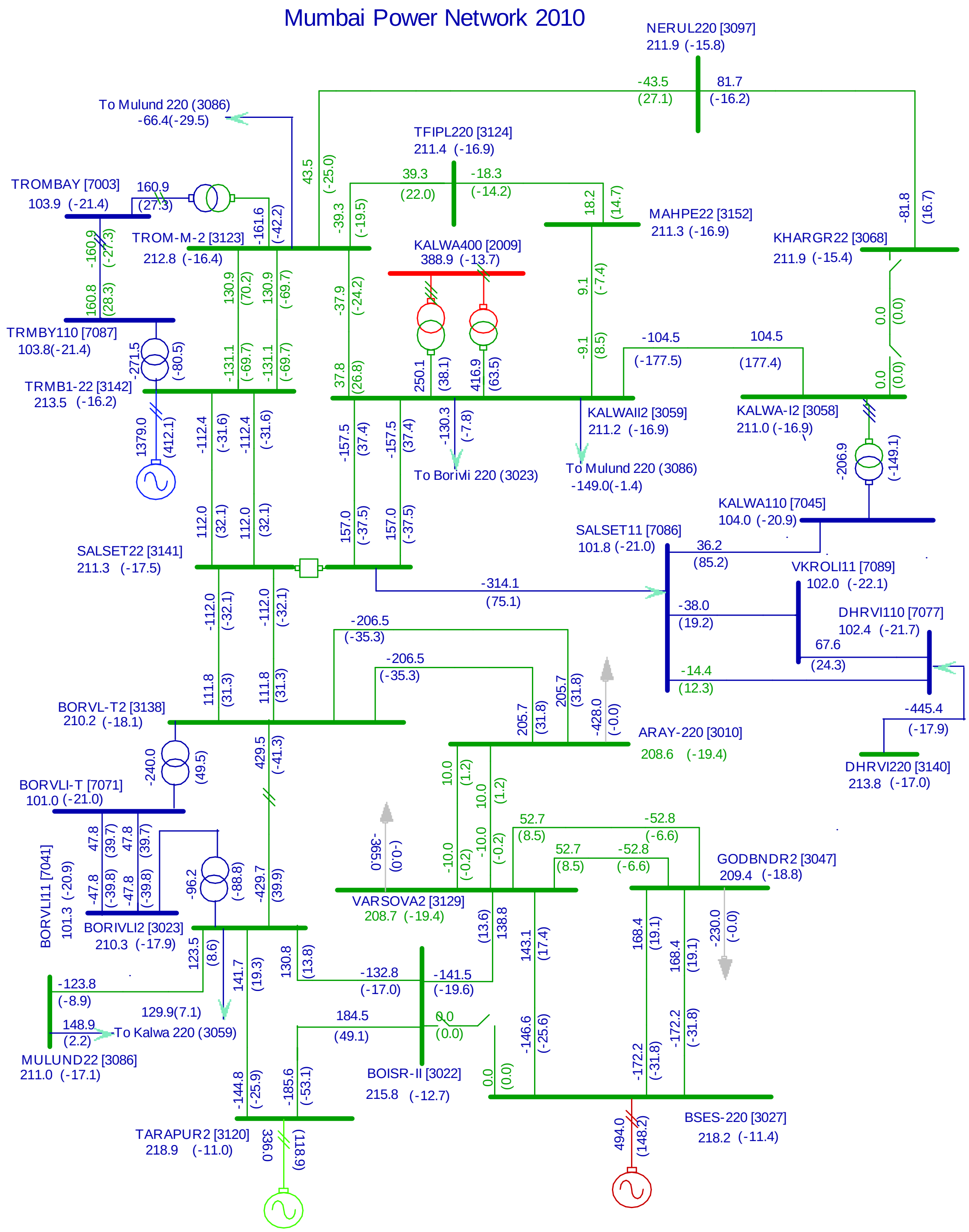

Fig. 26. Base Case of Scenario-1 with Dahanu –Bosiar ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Borivali –Kalwa-1 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Flow over all the lines change marginally and within limit.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Flow over all the lines change marginally and within limit except Borivali – Mulund 220 kV line carrying 224 MW.

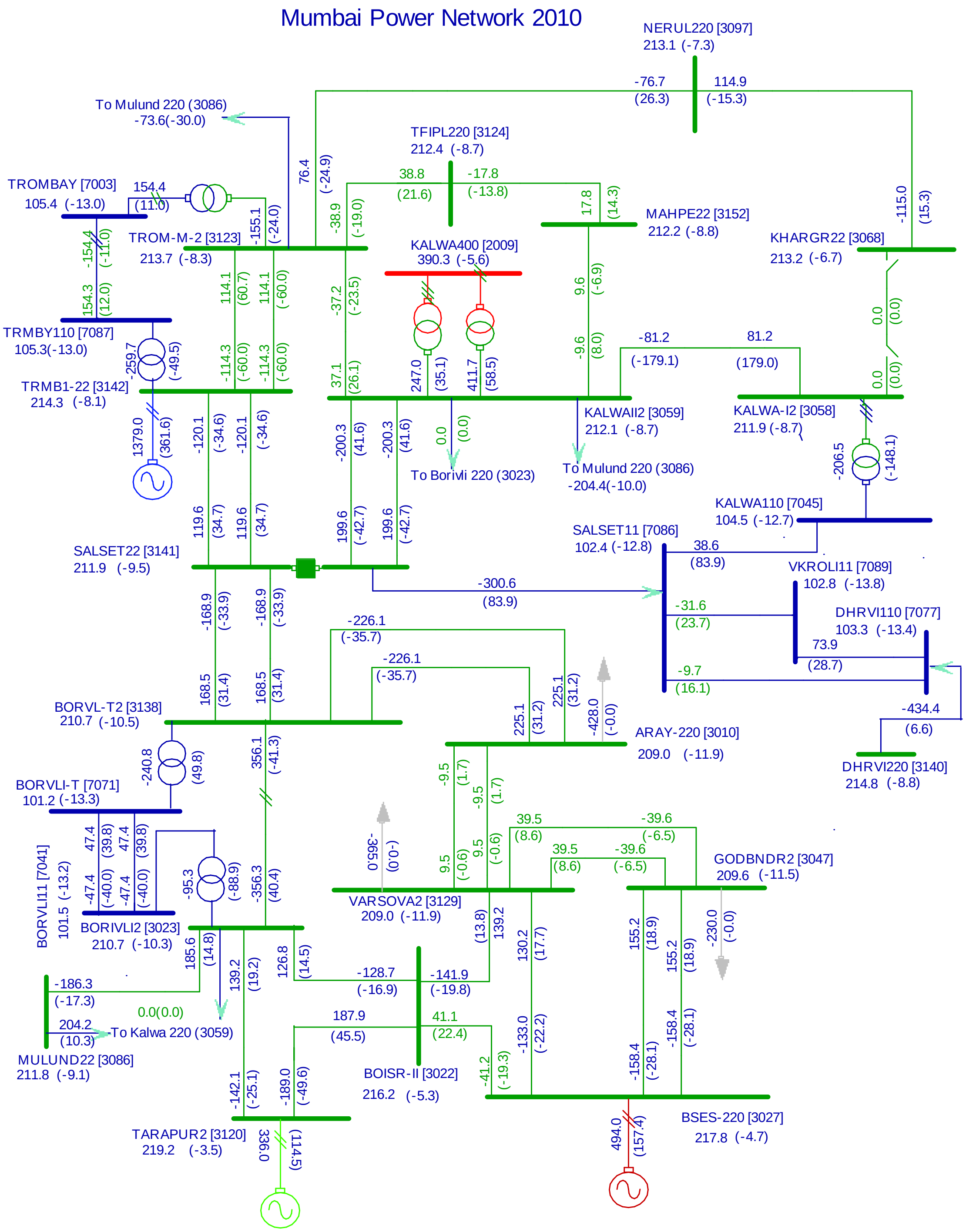

Fig. 27. Base Case of Scenario-1 with Borivali–Kalwa ckt out

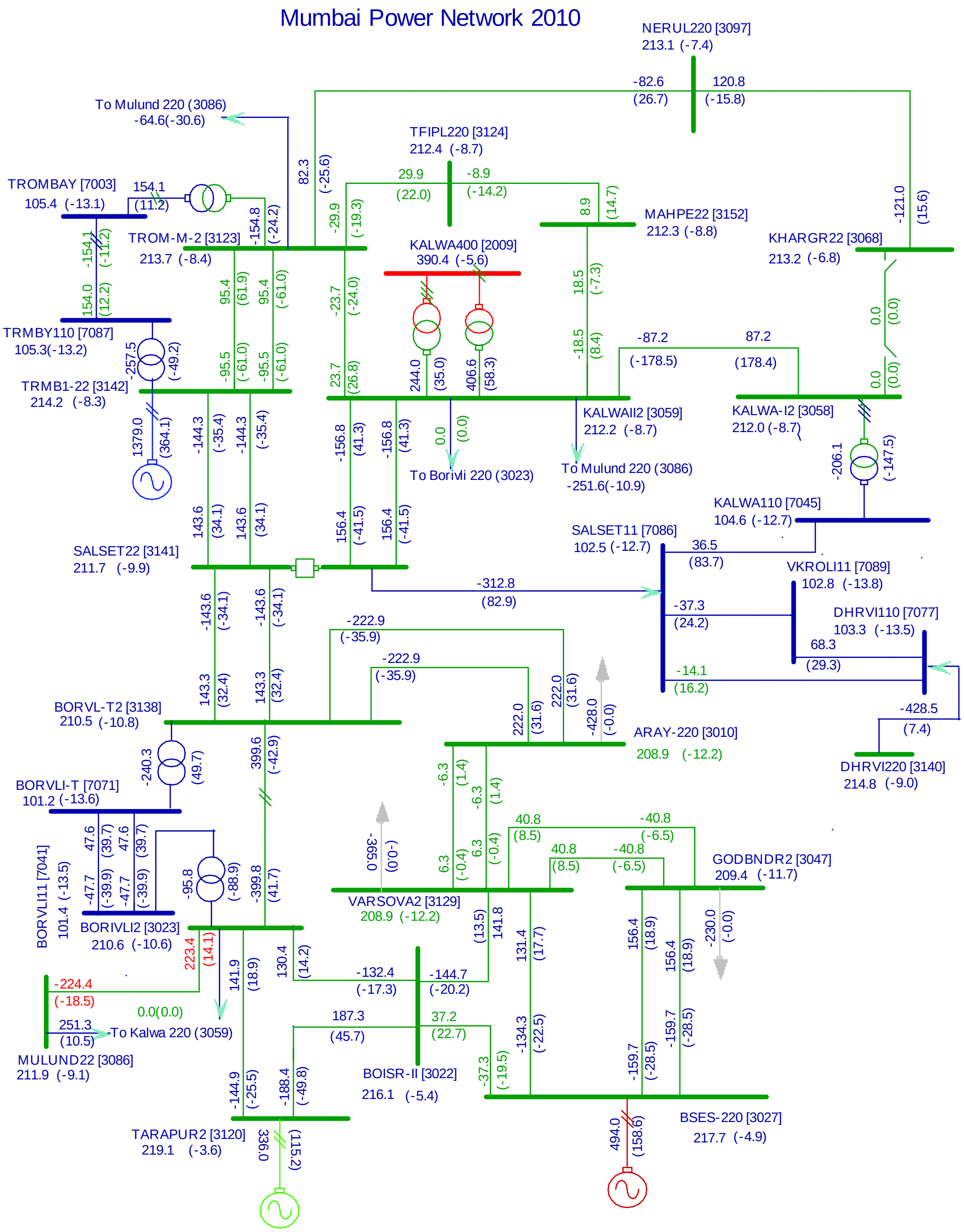

Fig. 28. Base Case of Scenario-3 with Borivali–Kalwa ckt out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Dahanu Unit-1 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Aarey-Borivali line gets over loaded carrying more than 273 MW.
- Flow over rest of the lines change marginally and within limit.
- Flow reversal on Boisar-Dahanu 220 kV line is observed.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Aarey-Borivali line gets over loaded carrying more than 273 MW.
- Flow over rest of the lines change marginally and within limit.
- Flow reversal on Boisar-Dahanu 220 kV line is observed.

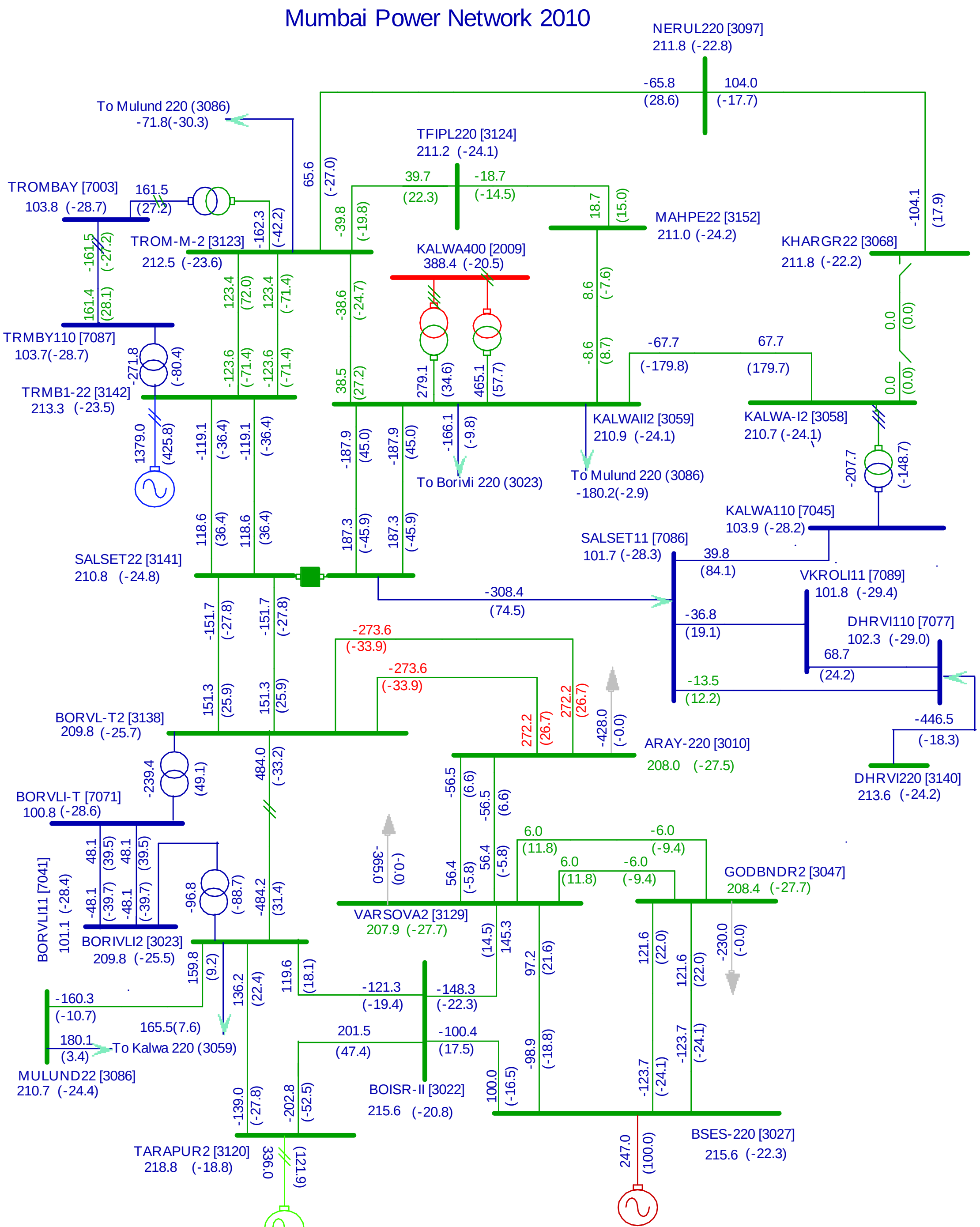

Fig. 29. Base Case of Scenario-1 with Dahanu unit-1 out

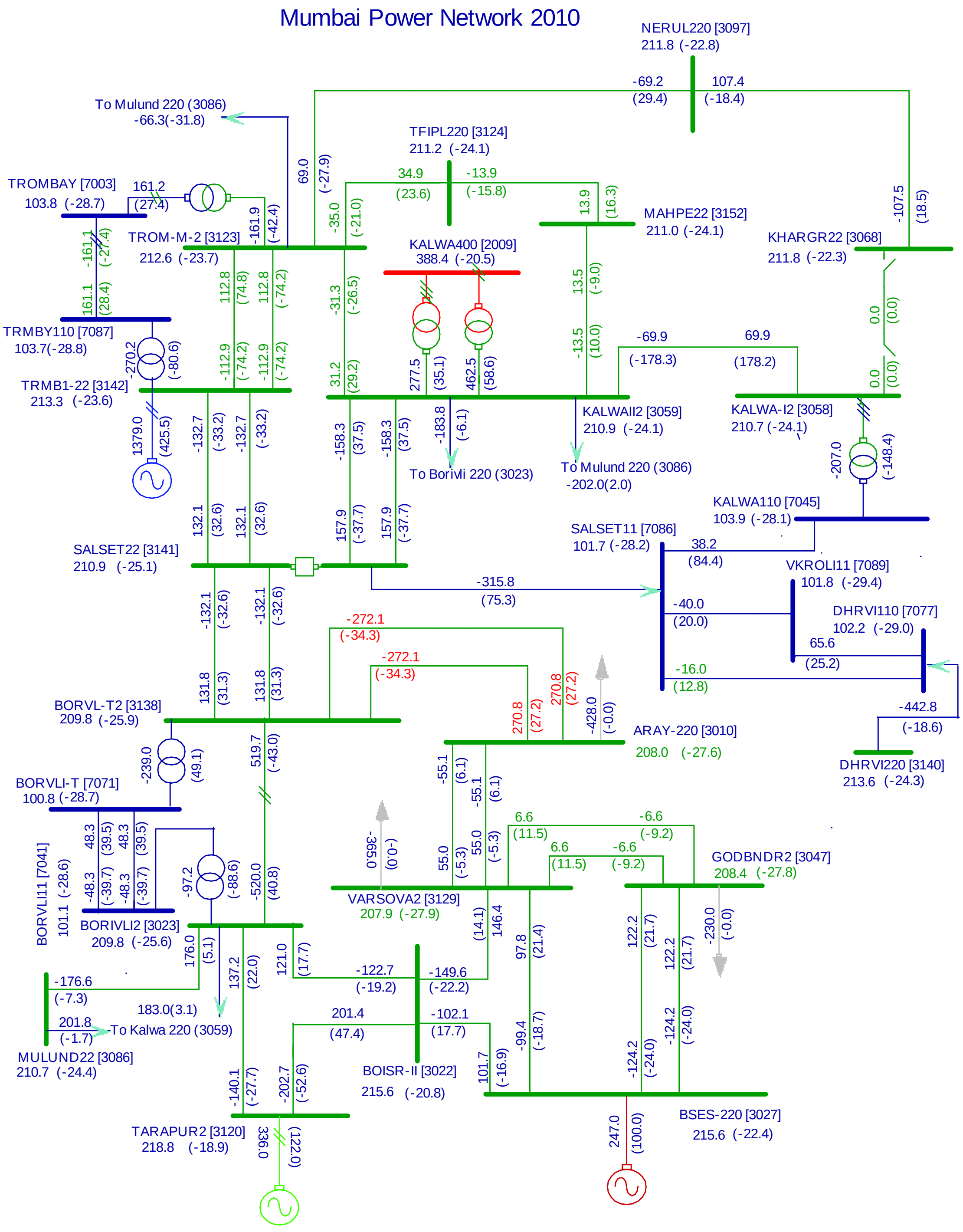

Fig. 29. Base Case of Scenario-3 with Dahanu unit-1 out

Borivali-Borivali 220 kV In Service	Salsette Bus Coupler In Service	Borivali-Borivali 220 kV In Service	Salsette Bus Coupler not in Service
Scenario-1		Scenario-3	
Trombay Unit-5 Out			

With Borivali-Borivali 220 kV line in service and Salsette B/C in service

- Kalwa ICT carries more than 850 MW.
- Borivali-Borivali corridor is loaded with 470 MW.
- Flow over rest of the lines change marginally and within limit.
- Flow over Kharghar-Nerul 220 kV line increse from 86 MW (in base case) to 171 MW.

With Borivali-Borivali 220 kV line in service and Salsette B/C out of service

- Kalwa ICT carries more than 850 MW.
- Borivali-Borivali corridor is loaded with 536 MW.
- Flow over rest of the lines change marginally and within limit. Flow over Kharghar-Nerul 220 kV line increse from 86 MW (in base case) to 177 MW.

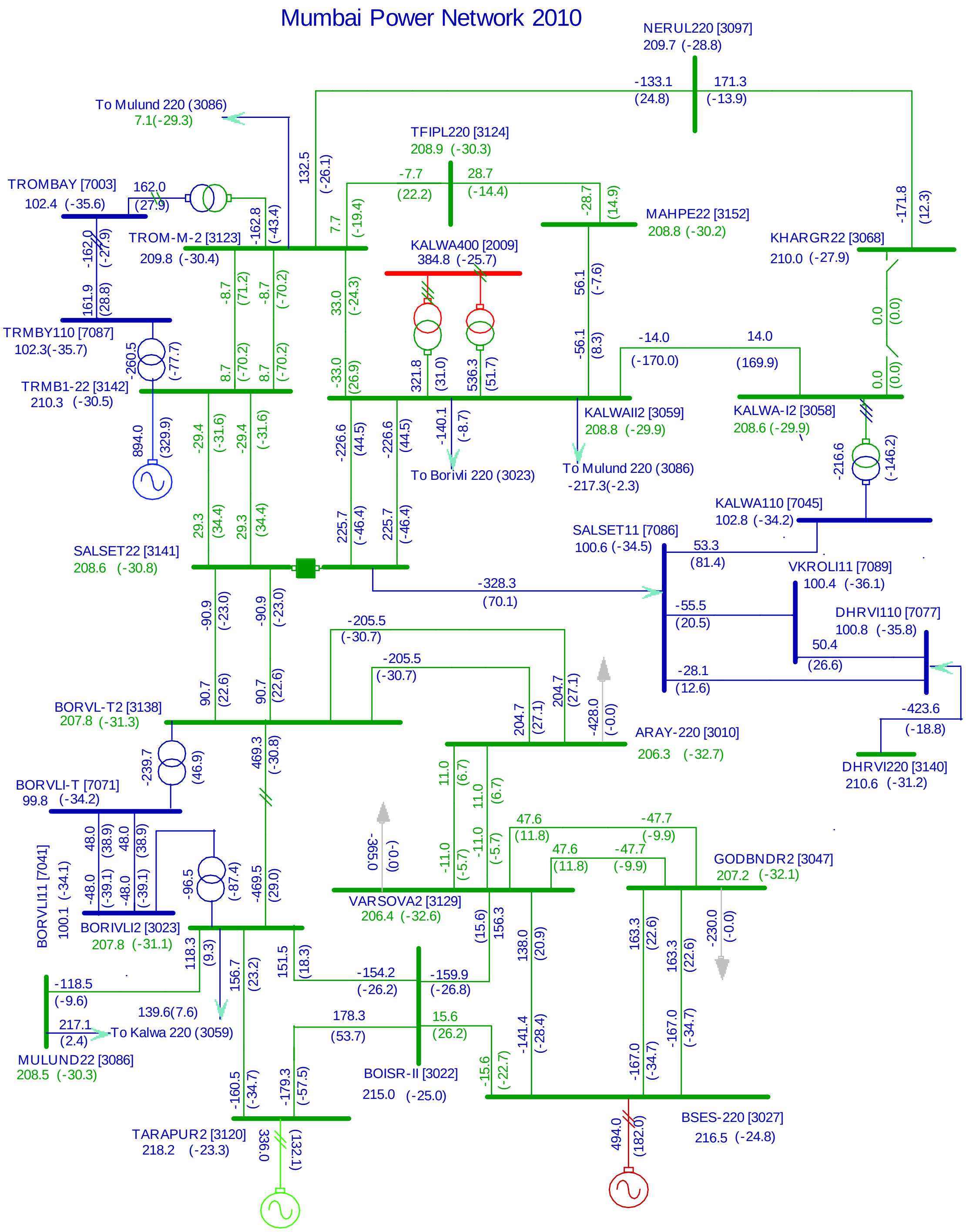

Fig. 31. Base Case of Scenario-1 with Trombay unit-5 out

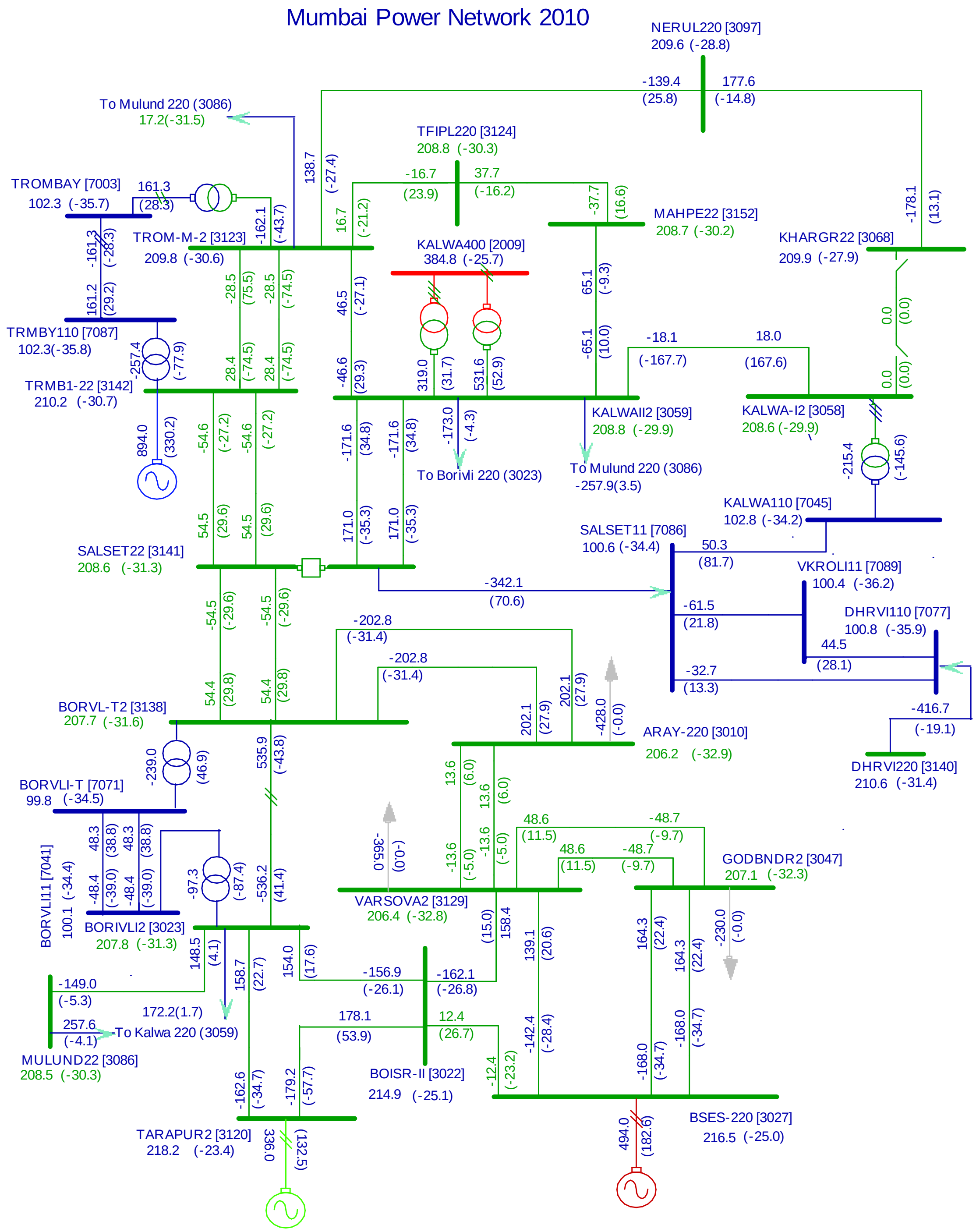

Fig. 32. Base Case of Scenario-3 with Trombay unit-5 out