RESTORATION OF WESTERN REGIONAL GRID – A CASE STUDY OF 30.7.02

By

Anjan Roy V.K.Veluchamy P.Pentayya R.K.Mediratta Pushpa S Haresh Patel

Western Regional Load Despatch Centre, POWERGRID, Mumbai.

ABSTRACT

The paper discusses in detail the restoration philosophy adopted in Western Region. A case study of restoration following blackout on 30.7.02 is discussed in detail describing the constraints faced and performance of the various start up power sources - black started units, islanded power stations and inter-regional interconnections. Recommendations for improving restoration time as well as to ensure safe restoration are given.

1.0 INTRODUCTION.

A grid disturbance occurred on 30.7.02 at 2011 hrs. The complete restoration was achieved only by 1630 hrs of 31.7.02 i.e after more than 20 hrs. Even though the time taken for restoration is quite normal under such major grid collapses, it is essential to devise measures to reduce the restoration time. WRLDC had developed Recovery Procedures for Western region in consultation with all the constituents and the same was available at all Load Despatch Centres as well as ISGS power stations. The constituents were also to familiarise the sub-station and generating station staff with these procedures and make the documents available. However, it is prudent to review the recovery procedures after each major occurrence to identify the constraints in application of the procedures and to identify delays in restoration and the reasons thereof. Accordingly, the restoration following disturbance on 30.7.02 has been studied in detail as a case study. The salient features of restoration viz., hierarchy of responsibilities, philosophy and approaches for restoration and guidelines are discussed in detail. A brief overview of the Western Regional grid is already available in our companion paper. A power map of the Regional Grid is enclosed at Exhibit-I. The restoration following grid disturbance on 30.7.02 was discussed in detail. Based on the experience of 30th July, various recommendations for improvements are also discussed in the ensuing paragraphs:

2.0 HIERARCHY OF RESPONSIBILITIES

While WRLDC is directly involved in the restoration of the Central sector transmission and generation, it directs, supervises and monitors the restoration of the facilities owned by the states and extends control on the resynchronization/reintegration of the islands that are restored around black start facilities or sources of power energised through inter regional interconnections. Restoration of the loads is under the control of the state utilities and priorities are set by them. More the number of sources, the faster the restoration. WRLDC would try to get emergency assistance from the neighbouring regions at the earliest to speed up restoration process and no constraints are experienced in getting inter regional assistance.

The RLDC is authorised during the restoration process following a black out, to operate with reduced security standards for voltage and frequency as necessary in order to achieve the fastest possible recovery of the grid. (Section 6.8(d) of IEGC)

3.0 GENERATION SECURING & PRIORITIES

3.1 Some of the generating units might have been saved due to successful islanding. Stabilization of such online generation is of top most priority.

3.2 Black start generation usage priorities:-

- provide startup power to hot units
- provide startup power to units that are cool; but capable of rapid restart
- restore stations auxiliary service to generating stations and sub-stations.
- Pick up essential loads.

3.3 Transmission corridors used for startup power should be isolated from any damaged/faulty equipment and are of minimum length and minimum voltage level to reduce line charging.

4.0 RESTORATION APPROACHES

4.1 Approach-I

4.1.1 In systems with a fair dispersal of Generating stations with black start facilities, those generating stations where black start facilities are available, should be started up and islands formed around these generating stations by connecting essential loads. These islands are then interconnected at predefined locations where synchronizing facilities are available. The speed of restoration enhances with increase in number of black start facilities and their dispersal. Gujarat, Chhattisgarh and M.P have considerable number of black start facilities while Maharashtra suffers from lack of adequate number of black start generators. It is required to carefully monitor the operation of the island (re-integration with rest of the grid) due to small stiffness in islands. One engineer shall be specifically assigned to monitor one island.

4.1.2 While adding loads, care should be taken to ensure step by step addition keeping in view load characteristics, ie., variation of load with respect to voltage and frequency and stiffness of island. During cold load pick up sudden starting of motor loads or power plant auxiliaries like BFP, PA fan etc., can cause voltage dips due to drawal of high starting currents. Essential loads can be restarted in steps smaller than 5 MW. It is preferable to restore rotating type loads which contributes to inertia of the island. In any case, load pick up should not cause frequency excursions greater than 0.5 Hz in the island. It is of utmost importance to identify the loads to be restored in advance and document.

4.2 Approach-II

4.2.1 The second approach could be followed in case self start facilities are available at only a few power stations or the start up power has to be imported from neighbouring regions at one or two points. In this approach, the start up power required to be extended to all the generating stations on priority basis while restoring few loads and transformers for voltage control. The start up power available from neighbouring regions at various interconnections have to be seriously explored since considerable assistance can be availed and the restored system is connected to stable external systems. The procedures have to be laid down for quickly harnessing these facilities. The constituent receiving assistance during restoration process should restrict to the agreed quantum only since this may have an adverse effect on healthy system rendering the assistance.

4.2.2 The restoration through this approach could be delayed due to problems in charging the lines, high voltage, lack of synchronising equipment at certain substations etc. and may involve system disturbances during restoration.

5.0 GUIDELINES FOR SAFE AND EFFICIENT RESTORATION.

5.1 Reactive Power Balance

During early stages of the restoration process, it is of utmost importance to keep the system voltage within the allowable range. This can be accomplished through:

- Energisation of lower voltage lines should be given priority
- Energisation of fewer lines
- Operating generators at minimum voltage levels (at lagging p.f)
- Switching off capacitor banks and use of bus reactors, where available
- Charging the shortest lines
- Charging transformers and taking tertiary reactors in service.
- Operating synchronous condensers, wherever feasible.
- Avoid charging of lines with series capacitors
- Use of filters banks at HVDC stations for voltage control

5.2 Active Power Balance

- Achieving load generation balance by restoring minimum and essential loads only.
- Restoring load in small steps keeping in view the load characteristics.
- To get adequate inductive loading to compensate capacitive effect while charging high voltage long line, a concentrated load of large town/ city should be released along with that of Railways.
- Preferably load connected should be balanced on all three phases.
- Bypassing the U/F relays initially until sufficient loads are connected and frequency stabilizes.
- Maintaining frequency close to 50 Hz.
- Paying special attention for traction and other fluctuating loads.

5.3 Coordination and priorities

- Priority to restore power supply to generating stations and load despatch centres.
- Formation of self sustaining islands around the generating stations for which procedures should be laid down in advance.
- Priority to supply start up power to hydro and gas units.
- Priority for providing back up / survival / start up power to nuclear units.

5.4 Communications

- Establishing communication between LDCs, Generating Stations and major substations.
- All important substations only to be kept in touch with and links with unimportant substations to be cut off to avoid draining of batteries.
- All communication channels required for restoration process shall be used for operational communication only till grid normalcy is restored (IEGC 6.8.e)

5.5 Protective Systems

- Sort out problems in closing the breaker due to low gas/air pressure.
- Avoid paralleling islands through weak ties.
- Do not energise suspected faulty equipment.
- Control high voltage during restoration to avoid damage of LAs/CVTs etc.

5.6 Survival Power

Ensuring availability of back up power supplies such as batteries, battery chargers, D.G sets to avoid effect on non operation of circuit breakers, communication systems etc., which can cause delay in restoration.

5.7 Awareness of Restoration Plans

Training and necessary documentation may be provided to Load Despatchers by respective LDCs.

5.8 Exchange of Information

Exchange of information among SLDCs and between RLDC and SLDCs is essential for proper co-ordination.

5.9. General Guidelines

Provision of islanding schemes area-wise, power station-wise and unit- wise would enhance the ability to restore faster. These should be fully exploited.
Synchronisation of the systems to be carefully done when the restoration is carried out from two different sources.

6.0 AVAILING INTER-REGIONAL ASSISTANCE

In case of total blackout in Western region, assistance could be availed from neighbouring regions in addition to utilising black start facilities within the region. The various possibilities of availing start up power from outside sources are described below:

(a) Through 400kV HVDC bypass at Vindhyachal Back-to-Back Station and/or through 132kV Vindhyachal-Rihand and 132kV Vindhyachal-Singrauli lines

The requirement of start-up power of VSTPS is approximately 35 MW for starting station auxiliaries and reviving one unit of 210 MW. The requirement for startup for 500 MW unit is 50 MW. This assistance could be availed through 400kV HVDC bypass or 132kV Vindhyachal-Singrauli-Rihand lines in case of non availability of 400kV HVDC bypass. VSTPS would make use of 35 MW to provide survival power for all the units at VSTPS and starting of one unit. Once one unit at VSTPS starts generating, other units can be started.

(b) UTILISATION OF AC BY-PASS LINKS

Inter-regional tie points especially strong inter-connections enable import of substantial amount of power which can be used to provide start-up power to several power plants in the shortest possible time. Based on the quantum of assistance, power supply to some essential loads could also be restored. Other advantage over black start facilities would be stable operation of the restored part since the same would be connected to strong healthy external system. Two such major options are through bypass AC links at HVDC back to back stations at Vindhyachal & Bhadravati for getting start up power from NR and SR respectively. The start up power could be availed within 30 minutes. Further, experience of restoration from these tie points has been highly encouraging.

7.0 CASE STUDY OF SYSTEM RESTORATION FOLLOWING GRID COLLAPSE ON 30.7.02

7.1 WRLDC initiated restoration of the grid by taking into the service bypass links at HVDC Vindhyachal and HVDC Bhadravati at 2031 hrs and 2038 hrs respectively. Initially, power availed from NR through bypass link was given to Vindhyachal power station and also extended to Korba STPS by charging 400kV Vindhyachal-Korba line. The start up power availed from SR through bypass link was extended to Chandrapur power station of MSEB and subsequently extended to Khaperkheda and Koradi power stations. In MPSEB, hydro power stations of Gandhisagar, Bargi, Tons and Pench were started and start up power extended to Satpura power station from Gandhisagar. In Chattisgarh, Bango units were black started at 2020 hrs and start up power extended to Korba(E) and Korba(W) powerstations. In MP and Chattisgarh, some traction loads were also restored from the black start sources. In Maharashtra, Koyna units were black started and process initiated to extend start up power to Uran and Nasik power stations. In Gujarat, Kawas units were black started and start up power extended to Jhanor and Tarapur. GIPCL Stage-I units were saved from tripping during the disturbance as islanding scheme for Stage-I successfully operated. Start up power to Wanakbori extended from GIPCL. AE Co. (Gas) units also islanded during the disturbance and start up power from these units extended to A.E Co.(Th.), Dhuvaran and Gandhinagar power stations. Ukai (Hy.) units were black started and start up power extended to Ukai (Th.) power station. Further, power from A.E Co (gas units) at Vatwa was extended to areas of Ahmedabad on an urgent basis due to sensitive situation in Ahmedabad. Start up power was extended to all the power stations in Western region by 2230 hrs.

7.2 The restoration plan broadly comprised restoration of power stations in Western Maharashtra from Koyna units and restoration of power stations in Eastern Maharashtra from S.R, restoration of generating stations in Gujarat from the black started units at Kawas and those units saved through islanding at AE Co (Gas) and GIPCL. The restoration plan for M.P comprised extending start up power from black- started hydro units in the state and augment the start up facilities from supply from Northern region by extending N.R supply from Vindhyachal to Amarkantak, Barsinghpur power stations. To hasten the restoration process in M.P, 400kV Vindhyachal-Satna ckt.I was taken into service. The supply from N.R was also used to speed up the supplies to traction substations. In Chattisgarh, the Bango units were supplying start up power as well as essential service requirements in

the state. Hunting of Bango units was reported due to voltage problems and charging of long section of lines. To strengthen and facilitate start up power availability, attempts were made to extend N.R supplies from KSTPS to Raipur. However, the line could not be charged due to indifference of operating personnel at KSTPS. The power supply was extended to Waidhan on 132kV lines to provide supply to coal mines at Waidhan. Start up power to Tarapur was extended from Kawas to Navsari and then through Navsari-Tarapur line. Tarapur was connected to Gujarat system. The Kakrapar units islanded as per the islanding scheme provided which operated successfully at 47.6 Hz. However, after 30 seconds, LBB protection of 220kV bus coupler operated due to wiring problem that led to tripping of all the breakers and KAPS units survived on house load.

7.3 Due to delay in bringing back Vindhyachal units and to connect adequate loads to the system for facilitating synchronization of more units at Vindhaychal and Korba, NR supply was extended from Jabalpur to Itarsi and then to Bhopal/Indore and Satna to Bina. The assistance availed from N.R was upto 250 MW and as the generating units at Vindhyachal and Korba came up, power from WR was fed to NR grid as sufficient loads were not restored in M.P system. Even after repeated pursuations, MPSEB could not restore sufficient loads in their system even though number of units were synchronized at Korba and Vindhyachal as well as at Satpura. Due to this, generation at Korba and Vindhyachal could not be maximized. However, the units ready for synchronization at these power stations were brought on bar by backing down generation on other running units.

7.4 The progress of restoration in Chattisgarh system could not go much further even though one unit came up at Korba(E). In order to speed up restoration of loads in Chattisgarh, 400kV KSTPS-Raipur ckt.I was taken into service at 0137 hrs and 400kV Korba-Bhilai ckt was taken into service at 0235 hrs. The sources at Bhilai and Raipur enabled faster restoration in Chattisgarh. However, some delay occurred as KSTPS agreed for charging of the lines from Korba only after their one generating unit came up on bar. With adequate stabilization in M.P and Chattisgarh systems and sufficient generation levels at Korba and Vindhyachal, the bypass link to NR was brought to floating condition and WR system was disconnected from N.R at 0340 hrs.

7.5 In Maharashtra, the restoration was slow due to difficulties faced in extending supply from Koyna power station after the units were black started. A small island comprising Koyna, Uran and Nasik power stations was developed with Koyna and Uran units on bar and no generation at Nasik. Essential loads like traction at Igatpuri was restored. WRLDC wanted to improve the stability of the island and quicken the restoration process in Western Maharashtra by synchronizing this island with islanded Gujarat system. At 0304 hrs, 220kV Nasik-Navsari ckt.I was taken into service and at 0311 hrs, Nasik-Navsari ckt.II was taken into service. Initially, Western Maharashtra island was drawing around 60 MW from Gujarat. However, at 0358 hrs, Maharashtra drawal increased suddenly to more than 240 MW at frequency of 48.70 Hz. Even after requests, Maharashtra was unable to control their drawal apparently due to tripping of some units at Koyna. Gujarat opened both Nasik-Navsari lines after warning Maharashtra. This had resulted in collapse of the Western Maharashtra island. The units at Koyna were brought back again and start up power given to Nasik and Uran once again. Attempts were again made to charge 220kV Nasik-Navsari line but due to high voltage at Nasik and refusal of GEB, our efforts were not fruitful. Due to high voltage at Nasik, plans were made to synchronise this island with Gujarat system through Borivali-Tarapur line. A lot of convincing had to be done to persuade Tarapur to synchronise Borivali-Tarapur line at Tarapur at 0900 hrs, Borivali-Tarapur line was taken into service. To strengthen the inter- connection further, 220kv Nasik-Navsari D/C were also taken into service at 0910 & 0911 hrs. WRLDC also tried to charge Jhanor-Padghe line but due to high voltage problem at Padghe, the plan had to be postponed. In order to stabilize Gujarat grid, Gujarat system was connected to MP + Chattisgarh + Korba STPS + Vindhyachal STPS system by connecting 400kV Indore-Asoj ckt.II at 0813 hrs on 31.7.02 and ckt.I at 0931 hrs. Gujarat were initially reluctant to connect with M.P grid as they were apprehending overdrawal by MPSEB. However, WRLDC prevailed upon Gujarat as Gujarat system should become stable and wide frequency fluctuations experienced in Gujarat could be reduced.

7.6 In the Eastern part of Maharashtra, about 350 MW generation was restored at Koradi, Khaperkheda and Chandrapur power stations. To speed up the restoration of loads in Eastern Maharashtra and to disconnect multiple supplies (Western Maharashtra and SR), it was planned to disconnect this part system from SR grid and connect to restored W.R grid by charging 400kV Raipur-Bhadravati & Bhilai-Koradi lines. The system build up in Maharashtra was slow due to lack of adequate generation in this area while generating units have come up at KSTPS & VSTPS and generation was not

maximized. Speeding up restoration in Maharashtra system would be possible only by disconnecting from S.R and connecting to rest of the grid. The bypass link at Bhadravati was brought to almost floating condition (25MW towards SR) and WRLDC requested MSEB to maintain load generation balance. However, due to communication problem between LD, Kalwa and Chandrapur, the flow on bypass link could not be controlled at floating level, at the time the breaker was opened. Due to high frequency at the time of opening, the restored system in Eastern Maharashtra collapsed.

WRLDC restored supplies from S.R once again by closing the bypass link at 0205 hrs. Thereafter, start up power was extended to Chandrapur-Koradi-Khaperkheda power stations and about 1950 MW generation was brought up by 1030 hrs on 31.7.02. Even though generation was fast coming up at Chandrapur and Khaperkheda power stations, MSEB was unable to restore loads. Further, the system enlargement could not be extended towards Western side by charging more lines. Parli power station was included in the island and one 210 MW unit was brought into service. Supplies were also extended upto Paras/Bhusawal power stations. Due to slow pace in restoration of loads by MSEB about 500-600 MW power was flowing from this part system of WR to SR. In S.R, a number of 400kV lines were critically loaded (beyond 650 MW). SRLDC repeatedly requested for controlling the exports to SR and SR grid was in alert condition as even tripping of one 400kV line might lead to a grid disturbance. The critical loading of number of lines in S.R grid also resulted in low voltages at several points in S.R grid. WRLDC took up with MSEB and made arrangements to disconnect the bypass link. The flow on bypass link was continuously monitored and load generation balance in MSEB part system was controlled with simultaneous communication continuously on with Bhadravati and SLDC Ambazari/Kalwa. Power flow on the bypass link was reduced to about 25 MW and WRLDC gave instructions for opening of the bypass link at 1025 hrs on 31.7.02 However, the power flow on bypass link suddenly started reversing and power flow increased from 25 MW to SR to 80 MW to WR as MSEB was not able to control load generation balance in the part system. The frequency at the time of opening was 47.70 Hz at 1028 hrs. Due to opening up of the bypass link, the generating units in the islanded Eastern Maharashtra collapsed. About 1950 MW generation was lost with one unit each at Koradi and Chandrapur surviving. At 1002 hrs, 400kV Parli-Lonikhand ckt.II was charged at Lonikhand in order to parallel the eastern Maharashtra and Western Maharashtra systems. While synchronising at Parli, 400kV Indore-Asoj D/C tripped on power swing.

7.7 WRLDC also made preparations to link this islanded system with rest of the grid by charging Bhilai-Koradi, Bhadravati-Bhilai/Raipur lines and Koradi-Satpura lines. At 1052 hrs, Raipur-Bhadravati S/C and at 1053 hrs Bhilai-Koradi s/C were taken in to service. After synchronizing this part system with rest of the grid, the restoration in the Eastern Maharashtra gathered momentum. Difficulties were also faced in integrating Eastern and Western Maharashtra systems due to high voltage problems. However, at 1356 hrs both the part systems of Maharashtra were synchronized by charging 400kV Padghe-Lonikhand s/c line. The islanded TPC/BSES system was operating in a stable manner in islanded mode meeting a demand of about 1800 MW. The synchronization of the islanded Mumbai system with rest of the grid was purposely delayed as the Western Maharashtra system was not sufficiently strengthened. 400kV Kalwa was inter-connected with Padghe, Lonikhand and Bableshwar for this purpose as Kalwa is the main feeding substation to all the inter-connecting points of Mumbai area. At 1539 hrs, the TPC/BSES system was synchronized with the rest of the grid by closing 220kV Kalwa-Salsette line. By 1530 hrs, 14300 MW load was catered in restored W.R grid. Power supply to Goa was restored from Kolhapur at 1629 hrs and complete normalcy was achieved by 1630 hrs. The sequence of restoration is enclosed at Annex-I. All the traction loads were restored by 2330 hrs. Due to collapse of Western Maharashtra and Eastern Maharashtra islands, traction loads were once again disrupted in Maharashtra. The traction loads were once again restored at 0130 hrs on 31.7.02.

8.0 Pre-Restoration scenario

8.1 The following power stations islanded from the grid at the time of the disturbance and saved from collapse :-

8.1.1 Gujarat :

Uran Power Station survived with 82MW load of Kim. GIPCL power station survived after islanding with 65MW load of Nandesari. ESSAR power station survived with 80MW captive load of ESSAR. AE Co. (gas) survived with 44MW load of Vatwa. Both units of Kakarpara APS survived on house load.

Performance of Black start facilities on 30/7/02 (Table –I)

Sr No	Power station	Capacity of D.G set (KVA)	Time taken for black start (Minutes)	Time taken for extending power to the next bus (Min.)	Remarks/ Constraints
1.	Gandhisagar(H) 5 x 23 MW	100 KVA	2	9	After 41 minutes start up power to Satpura power stations was extended. Voltage and MW hunting observed along the 132 kV start up path to Satpura.
2.	Pench (H) 2x80MW	250 KVA	44	54	Start up power extended to Satpura Power station through 132 kV Pench-Seoni-Chhinwara-Satpura path. High frequency problem and voltage hunting observed. Start up power could not be extended to Koradi power station of Maharashtra through 132 kV Pench-Kanhan line due to excessive voltage hunting.
3.	Bargi (H) 2x45 MW	250 KVA	9	9	Power extended up to Jabalpur. Due to high voltage problem power supply could not be extended to Amarkantak. Voltage hunting also observed when 220kV Amarkantak –Jabalpur Ckt. I is charged.
4.	Tons (H) 3x45 MW	250 KVA	16	16	Power supply extended to Satna over 220kV Tons-Satna line. The unit at Tons tripped 3 times due to tripping of transformer at Satna on overfluxing.
5.	Birsingpur (H) 1x20 MW	220 volt. Battery	49	-	The unit tripped and due to fault in CB power supply could not be extended further to Birsingpur TPS.
6.	Bango (H) 3x40MW	250 KVA	9	49	Power supply extended to Korba (E) and Korba (W) power stations. Voltage hunting reported.
7.	Koyna Stage-I 4x70 MW	2000 KVA	39	54	Breaker problem at Kandalgaon S/S delayed start up power supply to Uran. Due to high voltage problem start up power could not be extended to Koyna Stage-IV.
8.	Ukai (H) 4x75 MW	500 KVA	62	79	Start up power extended to Ukai TPS
9.	Kawas (Gas) 3x106 + 2x110 MW	2700 KVA	14	15	Start up power extended to Navsari 220kV unit –1B which was black started tripped at 21:21 hrs due to restoration of more load at Navsari. ESSAR & Kawas power stations were synchronised at 2113 hrs. and start up power to Tarapur APS given at 2113 hrs.
10 (a)	Jhanor (Gas) 3x144+ 1x225 MW	3120 KVA	-	-	The units survived on house load but tripped on charging of 220kV Jhanor –Haldurwa line.
(b)	-do-	-do-	201	201	Hunting of DG observed while black starting. Difficulty faced in extending supply to Halderwa due to breaker problem at Halderwa end

Start up power supply to important power stations (Table-II)

Sr No.	Power Station	Start up power source	Start up path used	Time at which start up power is available	Is the start up path pre-planned
1.	Uran	Koyna I & II	220kV Koyna-Kandalgaon-Khargar-Uran	22.5	Y
2.	Nasik	Koyna	220kV-Uran-Apta-Kalwa-Taps –Nasik	23.57	Y
3.	Chandrapur	SR supply	400kV Bhadravati-Chandrapur	21.00	Y
4.	Koradi	SR supply	220 kV Chandrapur –Warora-Wardha-Koradi	21.28	Y
5.	Khaperkheda	SR supply	220kV Koradi-Khaperkheda	21.40	Y
6.	Bhusawal	SR supply	132kV Koradi-Ambazari-Amaravati-Akola-Paras-Malkapur-Bhusawal	22.40	Y
7.	Parli	SR supply	220 Kv Wardha-Pusad-Parli	23.30	Y
8.	Tarapur	Kawas	220kV Kawas-Navsari-Tarapur	21.13	Y
9.	Satpura	Gandhisagar	132kV Gandhisagar-Ujjain-Shujalpur-Shajapur-Bhopal-Itarsi-Satpura	20.52	Y
10.	Amarkantak	NR supply	132kV –Vindhyachal-Waidhan-Amarkantak	23.10	Y
11.	Birsingpur	NR supply	220kV Amarkantak-Birsingpur	00.04	Y
12.	Korba (E)	Bango (H)	132kV Korba (E)-Bango	21.00	Y
13.	Korba (W)	Bango (H)	220 kV Korba (E)-Korba (W)	21.05/21.37	Y
14.	Ukai (Th)	Ukai (H)	220 kV Ukai (H)-Ukai (Th)	21.30	Y
15.	Wanakbori	GIPCL	132kV GIPCL – Nandesari-Asoj (132kV)-Asoj (220kV)-Wanakbori	20.55	Y
16.	Gandhinagar	A.E Co.	132kV AE Co. –Sabarmati-Ranasan-Gandhinagar	21.30	Y
17.	Kakrapar	Kawas/Essar Island	220kV Kawas-Navsari-Vav-Kakrapar	23.59	Y
18.	Dhuvaran	A.E Co. (Gas)	132kV Watva-Dhuvaran	-	Y

8.1.2 Maharashtra :

TEC & BSES systems islanded together and survived. In TPC system, Trombay units 7A & 7B (180MW gas based units) tripped. However, the island could survive this disturbance. Both the units at Dahanu survived.

8.1.3 No power plants survived in MP & Chhattisgarh states

8.1.4 Central Sector :

Kakrapar units islanded on house load. Both units at Tarapur tripped. None of the units at VSTPS & KSTPS could survive. Kawas units also could not survive while Jhanor units survived on house load.

8.2 Performance of survived islands in extending start up power

8.2.1 TPC & BSES island was not used for extending start up power to other power stations

8.2.2 Start up power to Dhuvaran & Jhanor power stations extended from GIPCL. Start up power from AE Co. (Gas) extended to AE Co. (Thermal), Wanakbori and Gandhinagar Power Stations.

8.2.3 Start up power extended to Tarapur APS from Navsari after synchronising ESSAR & Kawas Power Stations.

8.2.4 Power supply from Utran extended to Vav sub-station and synchronised with ESSAR/Kawas. Power supply also extended to Kakrapar from Vav.

8.3 Performance of black started units.

Several hydro & gas units were black started and power supply extended to other power stations. The performance of the black start facilities alongwith constraints discussed in Table-I

8.4 Sources of start up power from other regions.

The bypass link at HVDC Vindhyachal was taken in to service at 20:21 hrs. and start up power extended to Vindhayachal power station of NTPC at 20:50 hrs. Power availed from NR was further extended to KSTPS through 400kV Vindhayachal-Korba line. From NR supply start up powers extended to Amarkantak power station through 132kV Vindhyachal-Waidhan-Amarkantak line. Start up power to Birsingpur TPS was extended through 220kV Amarkantak-Brisingpur line. Power availed from SR was used for providing start up power to Chandrapur, Koradi, Khoperkheda, Bhusawal and Parli power stations of Maharashtra. MP & CSEB systems operated in synchronism with NR grid and Eastern Maharashtra system operated in synchronism with SR grid.

9.0 RECOMMENDATIONS & CONCLUSIONS:

9.1) Selection of loads to be restored in various islands from black started units should be identified in advance with respect to quantum of load to be restored in each step. This should be consistent with ramp rate and response of the units. Difficulties were faced while restoring loads from Jhanor power station during the occurrence. Unbalancing of loads during the restoration procedure is a very serious phenomena and should be properly dealt with.

9.2) It is essential to interconnect various islands at the earliest possible opportunity as the enlarged islands become more stable. On 30.7.02, tripping of Unit-4 of Ukai thermal power station resulted in collapse of AE.Co- GIPCL-Wanakbori-Gandhinagar-Ukai(H) islands.

9.3) The constituent receiving start up power should exercise proper control over their drawals. At times, the system providing assistance may collapse as this is too fragile. On 30.7.02, power supply was extended to Nasik by charging Nasik-Navsari D/C line at 0304 hrs. At 0355 hrs, Maharashtra drawal increased beyond 240 MW with frequency of the restored Gujarat system touching 47.7 Hz. To save the restored part of Gujarat, GEB opened Nasik-Navsari lines (after warning) resulting in collapse of the Western Maharashtra islands comprising power stations of Koyna, Uran & Nasik.

9.4) On 31.7.02 at 1000 hrs, 400kV Indore-Asoj lines tripped while synchronising Western Maharashtra system with the rest of the grid. To avoid power swings while synchronising, the phase angle difference should be minimal preferably around 10 degrees (or through synchro check relays) and frequency difference as small as 0.1 Hz.

9.5) Koyna units were black started at 2020 hrs but power supply could be extended to Pedambe only at 2145 hrs. The delay was due to high voltages and lack of load at Pedambe. It is essential to identify loads at Pedambe so that power supply to Uran can be extended within a short duration as units at Uran can be brought back quickly.

9.6) Maintaining load generation balance through step by step restoration of loads is essential so that the islands restored will not collapse. On 30.7.02, the restored Koyna-Uran islands collapsed at 2245 hrs due to load generation mismatch. Further, frequency should be maintained around 49.50 Hz to avoid tripping of units on low frequency. At 0117 hrs on 31.7.02, Uran Units-5 & 6 tripped on under frequency protection. At 0358 hrs, Uran Unit-5 once again tripped on high frequency. However, the restored part did not collapse.

9.7) After availing start up power from Southern region through bypass link, MSEB restored units at Chandrapur, Bhusawal, Khaperkheda and Koradi. About 350 MW generation, loads in Nagpur area and traction supplies were restored by 0100 hrs on 31.7.02. The bypass link was brought to floating conditions. At the time of opening 25 MW power was flowing towards SR. While disconnecting from SR, the islands collapsed with all generating units restored tripping on over frequency. It is therefore essential:

a. To bring the bypass link to floating (MW as well as MVAR) before disconnection.

b. Operating the units of Chandrapur /Koradi /Khaperkheda on free governor to reduce the frequency fluctuations. In case the units are on free governor mode, the over frequency could have been avoided due to automatic reduction of generation on various units.
c. MSEB also could have continued operating with Southern region for some more time as the restored part of Maharashtra is connected to a stable grid.

9.8) On 31.7.02, Maharashtra once again availed start up power from Southern region at 0202 hrs. Start up power was extended to Chandrapur, Koradi, Khaperkheda, Parli and Bhusawal power stations by 0350 hrs. Traction loads were also restored fully in Eastern Maharashtra by this time. By 1000 hrs about 1950 MW generation and loads were restored. However, due to delay in restoration of loads, power upto 600 MW was exported to SR. This had caused alert situation in SR as number of 400kV lines got critically loaded and low voltages were also reported. At 1028 hrs, the bypass link was once again opened to take this island into the main western Grid, but the restored part of Eastern Maharashtra collapsed on low frequency. At the time of opening, MSEB was restoring loads to keep the bypass link floating. Due to addition of more loads, power reversed with about 80 MW power flow towards Maharashtra system while frequency dropped to 47.7 Hz. When the bypass link was opened, 80 MW over load caused further frequency decay and collapse of the island. It is therefore essential to:

i. Bring the bypass link to floating level and keep frequency around 49.5 Hz.
ii. Proper communication among SLDC, Kalwa, SLDC Ambazari, Bhadravati HVDC stations and WRLDC has to be ensured. Once the link is brought to floating condition with frequency around 49.5 Hz, code for opening of the bypass link can be issued and no loads should be restored till the link is opened.

9.9) During the restoration on 30.7.02, 220kV Kolhapur-Belgaum lines were not used. It would be prudent to avail start up power from SR through these lines also and connect the restored system from Koyna black started units to SR. This would enable stability of the restored grid in Western Maharashtra. Further, since both Western and Eastern parts of Maharashtra are connected to SR, the problems of inter mixing of supplies and frequency matching problems shall not arise.

9.10) There was considerable delay in extending power supply to Sikka Thermal Power station and Panandro. Islanding schemes for these stations would help in faster restoration. The existing islanded scheme for Panandro should be reviewed while scheme for Sikka to be prepared.

9.11) The progress of restoration in Chattisgarh could be enhanced by restoring loads through assistance rendered by NR. Since start up power was extended from black started Bango units only and some of the essential loads were restored, hunting of Bango units was reported due to voltage problems and charging of long lines.

9.12) After the units at Vindhyachal and Korba were restored through availing start up power from NR, it is essential to connect as much load as possible from MP and Chattisgarh system to avoid power injection into NR grid as well as to bring up more generation at these stations. The generation available at VSTPS and KSTPS was not properly utilized. On 30.7.02, neither MP nor Chattisgarh were able to restore loads.

9.13) In MP, the restored parts from black started Gandhisagar units as well as those from Bargi and Tons black started units should be quickly inter connected with each other as well as to NR supplies. This would hasten the restoration process in MP. On 30.7.02, considerable delays were experienced in connecting restored islands in MP to NR grid. The utilisation of Ujjain-Kota 220kV inter connection during restoration should also be studied.

9.14) Considerable delays experienced while providing start up power to Nasik, and extending supplies from Jhanor Power station due to breaker problems. All the line sections involved in start up power transmission should have properly maintained breakers to avoid delays.

9.15) At the time of islanding, the gas units at Trombay (7A & 7B) tripped due to high frequency. Free governor mode of operation on all the units could have avoided such trippings upon islanding. The frequency shot up to 51.66 Hz leading to tripping of the units. The automatic reduction of

generation through FGMO might have contained such frequency rises. It is particularly important to avoid tripping of gas units on full load as such trippings reduce the life of the units.

9.16) The synchronisation of Mumbai system (TPC & BSES system) with the rest of the grid was purposefully delayed due to delays in strengthening of Maharashtra system. It is not advisable to operate islanded systems for such long durations due to the continuous frequency excursions and prolonged alert situation. The wide frequency fluctuations during islanded operation can be seen in the enclosed Exhibit-II. Mumbai system was synchronised with MSEB system at 1541 hrs on 31.7.02. It is therefore essential to speed up the restoration of the grid so that the survived islands could be saved from further trippings/collapse. It is also essential that TPC-BSES systems island together as it happened on 30th July so that the island survives properly and in case of delays in reconnection to the grid, the prolonged islanded operation may be secure with frequency/ voltage flunctuations minimised due to large size.

9.17) Power supply to Goa was restored from Kolhapur at 1629 hrs. The delay in restoration of loads could have been cut down if Goa extend adequate power supplies from S.R and this can be easily done.

9.18) It is essential to provide black start facilities at Uran Power Station to speed up restoration in Western Maharashtra.

9.19) One unit each at Pench Hydro station(2X80MW) can be used to provide start up power to MP and Maharashtra and both the supplies could be delinked by connecting one unit to each bus with the bus coupler open at Pench.

9.20) Along the start up paths, some load is restored to control high voltage problem. But controlling the load restoration and communication with sub-stations where load is restored is an important aspect. Effective communication and careful load control are most essential.

9.21) Due to high voltage problems, start up power from Koyna I&II could not be extended immediately to Koyna-IV. If Koyna-IV units are restored, voltages could be controlled by running one or more units in synchronous condensor operation also. With large power available in minutes from Koyna-IV (4X280MW), restoration could be speeded up in Western Maharashtra.

9.22) Provision of bus reactors at New Koyna would help in availing start up power by Koyna Power Station from Dabhol (self start facility available) on 400kV Dabhol-New Koyna and thereafter on 220kV paths to Koyna I & II. This would help in faster restoration. Running Koyna-IV machines in synchronous condenser mode also can help in voltage control while availing startup power from Dabhol.

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