AN OVERVIEW OF SYSTEM DISTURBANCES IN WESTERN REGION DURING THE PERIOD 1988-2001

Anjan Roy **M.G.Raoot** **P.Pentayya** **R.Chaturvedi**
Western Regional Load Despatch Centre, Powergrid, Mumbai

SYNOPSIS

The paper identifies various significant features that are revealed during system disturbances that occurred during the period 1988-2001. A statistical analysis has been made to study the impact of pre-fault conditions, initiating causes, compounding effects, system splitting, performance of islanding schemes etc. on the extent of system disturbances. A defence plan for averting grid disturbances has been drawn up to reduce the recurrence of system occurrences.

1.0 INTRODUCTION

Maintaining security of large power grids is an onerous task especially in the Indian context. In India, five regional power grids have been operating. Due to severe shortages of power in almost all the regions, the operational discipline is on a low ebb and the grids are operating with adverse frequency and voltage profiles coupled with over and under drawals by one or other states. Transmission constraints and critical loadings of equipment are also not unusual. The pre-fault conditions can have far reaching effect on the extent and duration of the grid disturbances.

Generally, the initiating causes such as tripping of a heavily loaded line/transformer or a bus fault could trigger a disturbance. Due to operation of the high speed protection systems, the faults would be cleared discriminately and thus get localized. However, at times, due to factors such as power swings on transmission lines, relay mal-operations, tripping of equipment on overload etc., could spread the disturbance affecting larger areas. Due to system splitting and formation of islands, the pockets with adverse load generation balance collapse. This was mainly due to the non implementation of the agreed upon Automatic Under Frequency Load Shedding Scheme. The islanding schemes also operate at 47.6 Hz and some parts of the grid are saved from collapse.

An attempt has been made to study the dynamics during the several grid disturbances that took place in Western Region (India) during the period 1988-01.

2.0 WESTERN REGIONAL GRID

The Western regional grid comprises generation and transmission systems owned by Gujarat Electricity Board, Maharashtra State Electricity Board, Madhya Pradesh State Electricity Board, Chattisgardh State Electricity Board, TEC, BSES, AE.Co., and Goa along with the generating stations of NTPC and NPC and the transmission systems owned by POWERGRID crisscrossing the entire regional transcending state boundaries. Three major 400kV East-West corridors form the backbone of the grid with large power flows in the East-West direction. 500kV HVDC link between Chandrapur and Padghe also runs parallel to the above AC corridors. This is mainly due to the non spatial distribution of generation in the region with more generation located at the pit heads in the East. The main load centers are located in the Western part of the grid. With number of IPPs coming up in Gujarat and with the commissioning of Dabhol and Koyna IV power stations (744 MW and 1000 MW) in the Western part, the transmission constraints in the East-West corridors could be removed.

The geographical extent of the Western grid covers the States of Maharashtra, Gujarat, Madhya Pradesh, Chattisgarh, Goa and the Union Territories of Dadra & Nagar Haveli and Daman & Diu. The Western Regional Power Grid is one of the largest in the country with an installed capacity of 30548 MW as on 31.3.01 and catering to a demand of 22000 MW. All the states in the region have entitlements in the Central Sector projects (ISGS) of Korba, Vindhyachal, Kawas, Jhanor, Tarapur and Kakrapar. WRLDC prepares generation schedules for the ISGS stations and drawal schedules for the states and monitors the deviations (over drawals at low frequency and under drawals at high frequency). The Regional Load Despatch Centre and the State Load Despatch Centres were equipped with SCADA systems to monitor the grid. A grid map of Western regional grid is enclosed at Exhibit-I.

Due to severe capacity shortage of around 5000 MW, the unrestricted demand of about 27000 MW was suppressed to around 22000 MW through power cuts, restrictions, roastering of loads and load shedding. Operating on the edge, the forced outages cause severe low frequency operation. However, during the monsoon months high frequency operation prevails due to absence of agricultural loads. Due to inadequate investments and reluctance, the reactive compensation is not adequate to ensure good voltage profile. The degradation of parameters makes the grid prone to disturbances.

The paper analyses the data acquired by WRLDC on the major grid failures in the Western region and identifies the dynamics of events involved in grid collapse. The paper also suggests a defence plan to avert grid occurrences.

3.0 AN OVERVIEW OF SYSTEM DISTURBANCES IN WESTERN REGION

In 1983, one major disturbance affecting total power supply in the entire Western Region occurred on 13.7.1983. Thereafter, though several major grid disturbances took place, the extent of interruptions on power supply was only in one or more areas. This was due to adoption of various defence schemes and the islanding schemes by the constituents. During occurrences that took place on 10.11.95 and 9.12.95, the entire grid was affected except a few islanded parts that survived.

Significant features observed during these disturbances are described below:

3.1 In most of the cases, prior to the system disturbance, grid was operating in the ‘alert state’ due to outage of transmission elements and consequent low voltage profile especially in Western part of the grid.

3.2 In some of the occurrences, low frequency operation persisted prior to the occurrence mainly due to multiple forced outages in the grid and generation constraints on account of partial outages and fuel related problems. The long term capacity shortages in the grid coupled with short term forced/partial outages caused persistent low frequency operation. Further, bypassing of U/F relays led to low security levels. During October/November, 2000 grid frequency touched 47.65 Hz and led to islanding of BSES system (part of Mumbai city) on three occasions. At 47.50 Hz, nuclear units, gas units and several thermal units are set to trip on U/f relay protection. Even tripping of a 210 MW unit at 47.65 Hz can lead to a total grid collapse.

3.3 In certain cases, due to power cuts, manual load shedding primarily targeted on agricultural loads or absence of agricultural loads during parts of the year had the effect of reduced stiffness of the system and reduced load damping effects. Loss of significant generation under such a scenario has the effect of large frequency deviations.

3.4 Due to inadequate transformation capacity, the tripping of a major ICT resulted in overloading of the other ICT’s and eventual cascade trippings (23^{rd} & 24^{th} November 1990)

3.5 The 400kV lines in the East-West corridor, especially 400kV Indore-Asoj D/C lines and 400kV Bhusawal/Bableshwar D/C lines had tripped on power swings.

3.6 The maloperation of certain protection systems like inter tripping schemes, bus bar protection, etc., had also resulted in system collapses in MP system.

3.7 The vulnerability of 220kV grid in MP in the event of outage of 400kV Bhilai-Satpura S/C line had resulted in system collapse in MP system.

3.8 In most of the cases, Western Maharashtra system separated from the grid and collapsed due to adverse load generation balance, but after commissioning of Dabhol (744 MW), Koyna-IV (1000 MW), Chandrapur-Padghe HVDC, 400kV Itarsi-Dhule, 400kV Gandhar-Padghe , the situation has improved.

3.9 Bombay system had islanded from grid and survived several times. However, on certain occasions, the Bombay island could not sustain due to problems in the control system of 500 MW units or tripping of lines between North and South Bombay.

3.10 The Eastern Maharashtra and MP systems survived in most of the occurrences due to high generation and low load in these parts of the grid and some generating units tripped on high frequency.

3.11 The tripping of 400kV Indore-Asoj D/C lines on power swings and 220kV ties between Gujarat and Western Maharashtra either on power swings or operation of RPUF relays on these ties had led to islanding of Gujarat system in most of the occurrences. Gujarat system, however, survived due to adequate U/F load shedding whenever it got isolated from MP and Maharashtra grids.

3.12 At times, system occurrences took several minutes as lines and generating units tripped due to overloading and high reactive power generation respectively. Voltages at several buses dipped to critical values and the lines tripped on power swing or voltage instability.

3.13 A system disturbance occurred in Gujarat system on 25.11.91 while restoring the system from a disturbance that occurred earlier on the same day.

3.14 The system disturbance that occurred on 28.5.93, 15.6.92 and 25.11.91 were due to operation of the system under severe transmission constraints. On all these occasions, certain major 400kV lines were under outage due to collapse of towers.

3.15 The AE Co-C, AE Co-CCPP, GIPCL and one unit at Dhuvaran islanded during occurrences and survived with almost 100% success rate for the first three.

3.16 There were multiple occurrences while restoring the system particularly after the disturbances on 10.11.95 and 9.12.95 in all the constituent systems causing considerable delay in restoration.

3.17 In 1995 eight major grid disturbances took place in Western Region and on two occasions the entire WR grid collapsed. While on the remaining occasions, major part of the grid collapsed. After clearance of the fault that triggered the events, the system got depleted in terms of generation and transmission causing large degradation in grid parameters. Under such post-fault conditions, oscillations of 0.4 Hz were observed which led to power swings on tie lines and on all the three major East-West transmission corridors leading to operation of distance relays on power swings / load encroachment. Transient stability simulations revealed inter-area oscillation between two groups of machines one group in the East and one group in the West.

3.18 On the occurrence on 19.4.95 a single phase to ground fault occurred on 400 kV Indore-Itarsi ckt.2 and was cleared from both the ends. Due to delayed resetting of distance relay at Itarsi, breaker failure relay operated leading to tripping of all 400 kV lines emanating from 400 kV Itarsi S/S. Due to tripping of parallel 220 kV corridors on overload, Eastern part of M.P separated from the grid. The Western part of MP was connected to Gujarat. While the Eastern part of MP connected to Maharashtra. Several 400 kV lines in the middle and bottom corridors tripped on power swings. WR grid split into two parts viz., Western Maharashtra + Western M.P + Gujarat and Eastern MP + Eastern Maharashtra and both parts survived for about 15 minutes. In the Western part, onset of loads due to evening peak caused export of power to Western Maharashtra and tie lines tripped on reverse power under frequency relay operation. Inter area oscillations between generators in the East and generators in the West led to tripping of the three 400 kV line in the middle and bottom corridors and caused system splitting as described above.

3.19 On 1.5.95 bus fault at 220 kV Indore S/S caused transmission depletion and power swings were observed on all the three major corridors leading to system splitting and collapse of western Maharashtra system. In this case, also in the post fault scenario, inter area oscillation of 0.4 Hz caused tripping of three 400 kV line in the major corridors. Computer simulation of both events (1.4.95 and 1.5.95) was carried out with the assistance of CPRI which revealed inter area oscillation of about 0.4 Hz with two groups of machines oscillating anti-phase. The provision of power system stabilizers at these units damped out the 0.4 Hz mode as can be seen from the computer simulation.

3.20 In two occurrences (9.12.95 & 16.12.98), tripping of 220kV lines in Eastern part of M.P led to islanding of an area with 5100 MW generation comprising the power plants of Korba(E), Korba(W), Bango, Birsinghpur, Amarkantak, Korba STPS and Vindhyachal STPS. Presently, the 220kV network is strengthened in this area.

3.21 On the second occasion, oscillations were observed during November / December,1997. Certain modes were excited with bulk load shedding of one group of agricultural loads of about 700 MW at 1200 hrs. At the same time, a new group of agricultural feeders amounting to about 700 MW were energised. The load disconnection was almost instantaneous while the loads from the new group came gradually over a period of half an hour. The oscillations died down after substantial amount of agricultural loads in the 2nd group got re energized (due to the effect of inertia and damping provided by the rotating loads). The oscillations were observed all over the grid with higher amplitude in the areas in which load shedding was implemented.

3.22 On 28.2.97, a bus fault took place at 400 kV Bableshwar S/S leading to loss of lines in one of the major East-West corridor. To avoid over loading on other parallel corridors,. load shedding of 2000 MW was carried out. This sudden Load shedding triggered oscillations which were observed even in the interstate tie lines. Gujarat system got isolated from the grid due to tripping of tie lines on power swings.

3.23 On 17th May,2001 oscillations of .011 Hz were observed. In this case, the oscillations were coherent and observed all over the grid. The simultaneous outage of four important 400kV lines viz., Jhanor-Padghe S/C, Satpura-Bhilai s/C, Indore-Nagda ckt.II and Vindhyachal-Korba S/C caused weak inductive coupling (weak ties) to the generators and negative damping to certain modes. Triggering cause of oscillations was due to normal changes in loads and oscillations are spontaneous. Oscillations persisted for long duration of more than 4 hours. The power system stabilizers provided on some generating units could not sense these oscillations. The oscillations were ultimately damped out due to reduction of reactive power on Satpura units. Field simulations carried out on the same day to create the oscillation and arrest them through the same corrective action were successful.

4.0 STATISTICAL ANALYSIS.

4.1 During the period 1988-01, twenty three major disturbances (category-A: affecting more than one state or the entire grid) and thirty two other disturbances (category-B: affecting one state or system) took place. Most of these occurrences took place during pre-monsoon/monsoon period. Tables I to IV describe the effect of pre-fault conditions, nature of initiating causes, impact of compounding events, etc., for category-A and category-B occurrences.

4.2 Pre-fault conditions

As can be seen from table IV, transmission constraints, low voltages and low frequency persisted before occurrences. It is pertinent to point out that in some cases, these adverse conditions viz., low voltages, low frequency and transmission inadequacy persisted simultaneously and the system was operating in 'Alert' state with grid operational discipline at low ebb:

4.3 Initiating Events

Table IV reveals that bus faults and tripping of transmission elements on overload were the major causes of triggering of grid disturbances.

4.4 Compounding Factors

In most of the cases, the extent of system disturbance became widespread due to several factors like:

1. Operation of reverse power under frequency relay (RPUF) on inter-state tie lines.
2. Operation / mal-operation of inter tripping schemes
3. Non / mal-operation of protection schemes
4. Tripping of lines and ICT's on overload
5. Tripping of major lines on power swings

4.5 System Separation

* In 21 out of 23 the grid failures of category-A occurrences Western Maharashtra system collapsed.

*On 19 occasions, Mumbai system islanded from the grid and actually survived on 9 occasions.

5.0 DEFENCE PLAN FOR AVERTING DISTURBANCES IN INTER CONNECTED POWER SYSTEMS

As can be seen from the above analysis of occurrences that occurred during 1988-2001, in most of the cases the Eastern part of the grid separated with surplus generation capacity after snapping of the major transmission corridors on power swings and overloading leading to high frequency in the Eastern part and eventual tripping of units on over-speed. The Western part collapsed due to low frequency.

This brings about the following deficiencies in the present system.

a) Poor voltage and frequency profile (Alert state of operation)
b) Slow response of generating units (governors blocked with dead bands)
c) Absence of adequate U.F load relief
d) Inadequate transmission system
e) Non availability of FACTS (Flexible AC transmission system) devices.
f) Non spatial distribution of generating capacity all over the grid

The defence plan to avert major grid disturbances should address the above deficiencies and improve the capability of the grid to sustain the credible contingencies and constraints that are inherent in the regional grid.

5.1 POOR VOLTAGE AND FREQUENCY PROFILE

In the present scenario, the grid parameters are not maintained thereby jeopardizing the system security. This can be corrected through scrupulous implementation of IEGC (Indian Electricity Grid Code) and its complementary commercial mechanism in the form of ABT (Availability Based Tariff). In the ABT, there are provisions for incentives for maximizing generation and curtailing the drawal during low frequency regime and dis-incentives to generation above schedule or to under drawals during high frequency regime. There is also a provision for reactive power charges for VAR exchanges from the ISTS (Inter State Transmission System) or for VAR exchanges between two states outside the voltage range of 97% and 103%.

The ABT would require the States to forecast their demands precisely and furnish requisitions from the Central Sector plants. ABT also binds the States to follow the drawal schedules and Central Sector generating stations their injection schedules thereby improving grid discipline. The built-in incentive/disincentive mechanism helps in maintaining frequency in close band. The states are also induced to install shunt capacitors and other reactive compensation devices to maintain the voltage profile. The ABT would also give commercial signals to capacity addition, optimum usage of available resources, power trading, usage of bottled up IPP/CPP (captive power plants) generation in the region.

5.2 RESPONSE OF GENERATING UNITS (Through Free Governor Mode Of Operation)

The tripping of the units on over-speed in the Eastern part due to surplus generation could be averted by adoption of free governor mode of operation. Frequency in this part would have been stabilized by immediate reduction of generation through “free-governor” mode of operation.

Due to wide variations in frequency in the band of 48 Hz to 51.5 Hz, the governors on most of the units have been made inoperative. The units continue to deliver the same power output irrespective of whether the frequency is going up or down. The units in the Western part would have picked up additional load through instantaneous generation response (upto 105% of MCR) without any delay and the frequency dip would have minimized during the occurrences.

With atleast 10,000 MW of generation, operating in the free governor mode (4% droop) out of 20000 MW of generation on bar at any time, the system stiffness would increase from the present 200-800 MW / Hz (primarily due to load damping) to about 2700 MW to 3300 MW/Hz and contain frequency fluctuations.

5.3 ABSENCE OF ADEQUATE LOAD RELIEF THROUGH A.U.F.L.S

The collapse of power deficit Western part due to low frequency would have been averted had adequate under frequency load shedding taken place and would have regained load generation balance and stabilized at a safe level of frequency. However, most of the under frequency load shedding relays have been made inoperative. With the implementation of ABT and free governor mode of operation, the need for the bypassing U/F relays by the constituents in the present scenario does not exist as frequency is expected to remain in a tight band around 50 Hz. Even the first stage of U/F load shedding can be started from 48.5 Hz with five frequency steps to optimize the load shedding and improve the security margins. The islanding schemes can also operate at 47.8 Hz instead of 47.6 Hz at present. The AUFLS scheme can be designed to take care of the contingency of loss of generation of 5100 MW due to bottling up of generation at KSTPS, VSTPS, Korba(W)-Korba(E) complex, SGTPS and Amarkantak as a result of snapping of East-West transmission corridors.

5.4 INADEQUATE TRANSMISSION SYSTEM

During the pre 1997 occurrences, there was severe transmission constraints on the East-West corridor, separation of Eastern & Western part was a certain eventuality. With the commissioning of 400kV KSTPS-Raipur-Bhilai lines, 400kV Vindhyachal-Jabalpur-Itarsi-Dhule-Bableshwar, 500kV Chandrapur-Padhe HVDC bipole, 400kV Gandhar-Padghe S/C line and 400kV Vindhyachal-Satna-Bina D/C line have completely changed the scenario. In the post 97 occurrence, total splitting of the Eastern and Western part has rarely occurred. This highlights the importance of transmission adequacy. But still some transmission bottlenecks persist along the 400kV Itarsi-Indore, 400kV Satpura-Indore and 400kV Bhilai-Koradi and 400kV Vindhyachal-Korba S/C corridors which needs to be addressed at the earliest. The slow moving oscillations were observed on 8.3.2001 and 17.5.2001 during the outage of 400kV Bhilai-Koradi S/C and 400kv Korba-Vindhyachal S/C line respectively, when the system was already under a stressed condition due to outage of number of other lines.

The present decongestion in the Itarsi-Indore corridor was removed to a certain extent with the charging of the 400kV Dhule-Kasor line on 5.9.2001. The line was made out of the already constructed and unutilized lines of the Sardar Sarovar Project (SSP).

5.5 FACTS (Flexible AC transmission system) devices

It is possible to improve the security margins with the help of FACTS devices which can help in reducing the line length, supply dynamic VAR support. In the present scenario, getting ROW (right of way) is very difficult proposition and Series Compensation may be provided on the transmission lines to improve the power transfer capability.

SVC (Static Var Compensation) may be used to provide dynamic VAR support. This would help in improving the system damping through auxiliary damping controls of SVC, PSS (power system stabilizers) may also be properly tuned and put into operation to improve the system damping and suppress low frequency oscillations. The trick however is to tune the stabilizers after studying the characteristic modes of the system.

Generating units at Koyna Stage-IV (4x250 MW) hydro power station which is a peaking power station have the flexibility to run as synchronous condensers. These units may be run as synchronous condensers to provide VAR compensation during the off peak hours.

5.6 PROTECTION AND STABILITY

Stability of the grid depends upon faster clearance of faults and localization of faults. Provision of bus-bar protection schemes and local breaker back-up (LBB) schemes at all the generating stations, 220kV and 400kV sub-stations is essential. Auto reclose facilities should be implemented on all 400kV lines and carrier based protections provided on important 220kV lines.

The zone III settings should be reviewed in the context of tripping of lines on load encroachment, particularly under low voltage conditions. In case of provision of LBB and bus-bar protections, zone-III need not cover the entire adjacent section and beyond. The zone III could be restricted to 150% of the protected line section. Lenticular type of characteristics should be selected to overcome the load encroachment problem.

The manual load shedding (due to capacity shortages) is carried out strategically in the low voltage pockets to prevent voltage instability. However, this should be backed up by provision of under voltage load shedding (automatically through u/v relays).

Simple automations like load shedding through inter-trip for transformer overloads are required at various locations. At some places, these have already been implemented.

HVDC controls could be utilized to improve the stability and to damp out power swing by fast ramping of power to the deficit area.

5.7 DECISION SUPPORT SYSTEMS

The EMS (Energy Management system) enable load dispatchers to identify the constraints and plan appropriate corrective action, to plan outages, generation scheduling etc. The current augmentation scheme of the SCADA in the Western region includes Network Analysis functions in the study mode. In the proposed Unified Load Despatch Scheme for the Western region to be implemented in near future, full range of EMS functions are planned.

6.0 CONCLUSION

The statistical analysis of grid disturbances over the period 1988-2001 reveal the impact of pre-fault conditions, initiating events and compounding factors on grid occurrences. To safeguard the grid from credible contingencies, it is required to put in place appropriate commercial mechanism (ABT), free governor operation on generating units and properly designed and implemented AUFLS. More efforts can be made to decongest the over loaded corridors. The upcoming 1980 MW (3x 660 MW) Sipat generating power station is also planned in the Eastern part of the grid and this would pose more challenges to grid operation. It is also required to cut down the restoration time by providing more black start sources and islanding schemes and avoid disturbances during restoration by following the well documented restoration procedures developed by WRLDC and available at all the control centers in the region.

ACKNOWLEDGEMENT

The authors acknowledge with thanks the guidance and support given by the management of POWERGRID and for permitting the publication of this paper. The views expressed in this paper are of the authors in their individual capacity and not necessarily that of Power Grid Corporation of India Ltd.

Table-1

SYSTEM OCCURRENCES DURING 1988-2001

YEAR	CATEGORY-A	CATEGORY-B
1988	2	1
1989	2	2
1990	2	4
1991	2	5
1992	3	2
1993	1	-
1994	-	3
1995	5	4
1996	1	-
1997	3	2
1998	1	1
1999	-	-
2000	1	4
2001	4	

Table-2

LIST OF MAJOR OCCURRENCES (CATEGORY-A) DYURING 1988-2001

SL.NO	DATE	TIME	COLLAPSED PARTS
1.	11.10.88	0923	Western MP
2.	28.12.88	1034	Western Maharashtra, part of Gujarat
3.	14.8.89	1526	Eastern MP
4.	17.8.89	1635	Western Maharashtra including Bombay
5.	31.7.90	1124	MP
6.	24.11.90	0837	Western Maharashtra and Bombay
7.	16.3.91	1243	Western Maharashtra
8.	25.10.91	1051	Bombay + Western Maharashtra + Gujarat + Western MP
9.	12.2.92	1612	South Bombay + parts of Western Maharashtra
10.	31.3.92	1503	Western Maharashtra + Bombay
11.	15.6.92	1925	Western MP, Gujarat, Maharashtra and North Bombay
12.	28.5.93	2145	Western Maharashtra, parts of Goa
13.	19.4.95	1802	Western Mah, Gujarat, North MP and parts of Goa
14.	1.5.95	1546	Western Mah, Bombay, North MP and parts of Goa
15.	10.11.95	1108	Entire grid except Bombay, parts of Eastern MP excluding KSTPS, VSTPS and few Gujarat excluding few islands
16.	14.11.95	0840	Maharashtra system excluding Bombay
17.	9.12.95	0736	Entire grid except few islands – Bombay collapsed
18.	11.12.96	1602	Western Maharashtra
19.	28.2.97	2051	Western Maharashtra & TEC
20.	23.10.97	0813	Eastern MP including KSTPS & VSTPS
21.	26.10.97	2355	Maharashtra, TEC islanded & survived.
22.	16.12.98	1055	Maharashtra & MP system
23.	14.10.00	0441	MP system collapsed except Indore area.

Table-3

LIST OF CATEGORY – B OCCURRENCES DURING 1988-2001

SL. NO.	DATE	TIME	COLLAPSED PARTS	LOSS OF GENERATION*	ISLANDS FORMED
1.	28.6.89	1947		Units tripped in Eastern MP (900 MW)	MP split into two parts
2.	28.6.89	2050	Eastern MP	Eastern MP (1400 MW) and VSTPS	Eastern MP and KSTPS
3.	1.9.89	0012		@	
4.	17.8.90	0706		Korba STPS (1200 MW)	
5.	2.8.90	0934		Korba STPS (1260 MW)	
6	9.10.90	0925		@	VSTPS units transferred on HVDC
7	23.11.91	2107		Maharashtra (1000 MW)	Western Mah + Bombay + Guj + Eastern Mah.
8	14.4.91	1907		Korba STPS (1700 MW)	
9	8.6.91	0735	Vindhyachal STPS	Total tripping of VSTPS	VSTPS
10	13.9.91	1235		VSTPS (600 MW)	
11	23.9.91	1395		VSTPS (600 MW)	
12	28.11.91	1736		KSTPS (1200 MW)	
13	6.6.92	1530	All units of VSTPS	VSTPS (650 MW)	
14	6.7.92	1505	All units of VSTPS	VSTPS (600 MW)	
15	30.5.94	1736	None	NTPC (1700 MW) and Eastern MP	Eastern MP separated
16	1.6.94	0340	None	NTPC (1050 MW), Eastern MP (1375 MW) and BCPP	Eastern MP islanded
17	1.6.94	1512	None	NTPC (900 MW), Eastern MP and BCCP (535 MW)	Eastern MP islanded
18	2.3.95	2013	None	Eastern MP (1100 MW) and NTPC (500 MW)	Eastern MP islanded
19	12.7.95	1641	North Guj, Saurashtra, Central Guj	3000 MW	Parts of Gujarat
20	31.7.95	1541	Bombay, Parts of Western Mah.	1500 MW	Gujarat, parts of Western Mah and Bombay
21	30.11.95	0246	Maharashtra	Western Mah (3000 MW), Koradi, Chandrapur	Bombay islanded and survived, Western Mah islanded and collapsed.
22.	1.6.97	0550	Gujarat	-	System split with both the system surviving (GEB + TAPS+ BSES separating from the grid)
23.	7.6.97	1750	Maharashtra	1500 MW at Chandrapur	System split into three parts and all the parts survived. TEC system islanded and survived.
24.	8.6.98	1523	Gujarat	2330 MW	South Gujarat
25.	27.3.00	0920	All units of NTPC, VSTPS	1550 MW	Vindhyachal Power Station
26.	31.3.00	0358	Gujarat	1000 MW	Kutch area island collapsed.
27.	31.3.00	2232	Gujarat	1000 MW	Kutch area island collapsed.
28.	2.5.00	0521	Maharashtra	1725 MW	Chandrapur PS of MSEB.
29.	29.8.00	1000	NTPC Vindhyachal	830 MW	VSPTS bus-II collapsed.
30.	12.12.00	1624	NTPC Korba	900 MW	KSTPS bus-II collapsed
31.	26.1.01	0846	Gujarat	2600 MW	Load throw of 3500 MW in Northern Gujarat, Central Gujarat & Saurashtra
32.	16.5.01	0421	NTPC Vindhyachal	2070	NTPC, Vindhyachal

* Tripping of transmission elements not shown in the table

@Only transmission lines tripped

Table-4

SUMMARY OF EVENTS RELATED TO MAJOR OCCURRENCES DURING 1988-01

SL. NO	DYNAMICS	A	B
	PRE-FAULT		
1.	Low frequency	4	5
2.	Low voltage	6	2
3.	Transmission inadequacy	9	8
4.	Transformation capacity inadequacy	3	1
5.	Low generation / overdrawals	3	1
6	High voltage	-	2
	INITIATING EVENT		
1	Equipment failure	3	5
2	Mal-operation of protection scheme	2	3
3	Overload tripping of lines / ICTs	5	-
4	Bus faults	6	6
5	Tripping of ICT's or lines on faults	2	7
6.	Natural disasters	1	1
7.	Voltage collapse	1	-
8.	Sudden bulk load shedding	1	-
9.	Others	3	1
10.	Unknown	1	-
	COMPOUNDING FACTORS		
1.	Operation of RPUF / inter-trip of tie lines	8	1
2	Maloperation of protection schemes	6	3
3	Trippings on overload	10	7
4	Tripping on power swing	13	6
5	Simultaneous faults	3	1
6	Over voltage	-	2
	SYSTEM OPERATION		
1.	System splitting	17	10
2.	Collapse of part systems	17	7
3.	Islanding of Bombay	11	5
4.	Survival of Bombay island	5	1

WRLDC/OS/1532/01 6th September, 2001

To

Shri S.P.Kaushih,
Secretary,
Central Board of Irrigation & Power,
Malcha Marg,
Chanakyapuri,
New Delhi 110 021.

Sub: International Conference on Bulk Power Transmission System Integration in Developing Countries.

Sir,

We are enclosing a paper titled "AN OVERVIEW OF SYSTEM DISTURBANCES IN WESTERN REGION DURING THE PERIOD 1988-2001" for inclusion in the above Conference. This paper may be included in the session on "Bulk Power Marketing in Developing Countries".

We hope you will find the above paper suitable for inclusion in the above conference.

Thanking you,

Yours faithfully,

(Anjan Roy)
Addl. General Manager

Encl: As above