



REPORT OF THE SUB-GROUP
ON THE INCIDENT OF 19TH MAY, 2009
ON TRIPPING OF EVACUATION LINES
LEADING TO
LOSS OF GENERATION OF ABOUT 1700 MW
AT
NATHPA JHAKRI HYDRO POWER STATION
(NJHPS)
AND
BASPA HYDRO POWER STATION (BHPS)
IN
HIMACHAL PRADESH
NRPC
New Delhi
SEPTEMBER, 2009

Acknowledgement

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The Sub-Group places on record its appreciation of the assistance provided by Shri Balwant S Negi, Dy. Manager SJVNL, Shri Rajeev Porwal, Chief manager, NRLDC, Shri Rajesh Kumar, Manager, NRLDC, Sh Ramprakash, Power Controller, HPSEB and Shri Vikram Singh, EE of NRPC in analysing the causes of the incident and preparation of the report.

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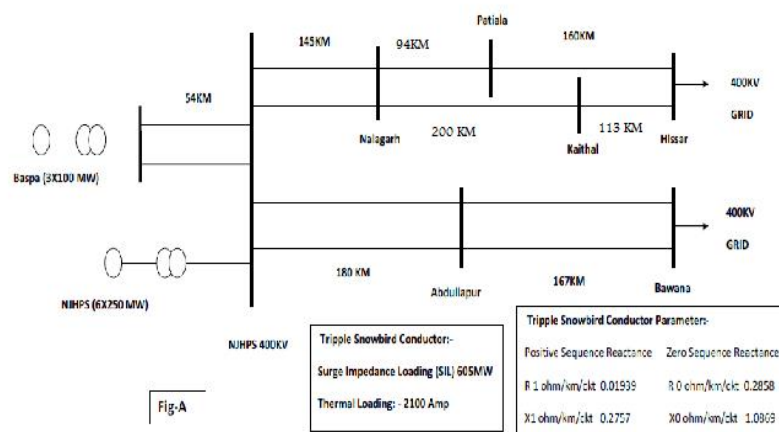
**NORTHERN REGIONAL POWER COMMITTEE
NEW DELHI**

Report of the Sub-group on the incident of 19th May, 2009 on tripping of evacuation lines leading to loss of generation of about 1700 MW at Nathpa Jhakri Hydro Power Station (NJHPS) and Baspa Hydro Power Station (BHPS) in Himachal Pradesh.

1.0 Introduction

An incident of tripping of all the generating units and outgoing circuits at Jhakri and Baspa occurred at around 16:37 hours on 19th May, 2009. About 1700 MW generation loss occurred during this incident. Water spillage to the extent of loss of energy of 1.55 MUs occurred at Jhakri and 0.35 MUs at Baspa. The system was normalized and full generation at Jhakri/Baspa hydro stations restored by 18:00 hours on 19-05-2009.

Nathpa Jhakri Hydro Power Station (NJHPS) has 400 kV double busbar Gas Insulated Switchgear (GIS) System which transmits 1500 MW power from NJHPS and 300 MW from Baspa HPS (BHPS) through four outgoing 400 kV circuits i.e. Nalagarh-I&II and Abdullapur-I& II to the Northern Grid. The 400 kV circuits i.e. Baspa-I&II are also terminating at 400 kV GIS of NJHPS (network shown in Figure-A).



1.1 On 19.05.2009, 250 MW Generating Units No. 1,3 & 5 of NJHPS along with 400 kV circuits Abdullapur-I, Nalagarh-I & Baspa-I were connected with the busbar-I and 250 MW Generating Units No. 2,4 & 6 of NJHPS along with 400 kV circuits Abdullapur-II, Nalagarh-II & Baspa-II were connected with the busbar-II of the GIS System at NJHPS.

1.2 The tripping incident was discussed in detail during the 39th OCC meeting of NRPC held at Delhi on 15.6.2009. SJVNL representatives presented the analysis of incident in the 39th OCC meeting. NRLDC had also prepared a preliminary report and was also deliberated during the meeting. During 39th OCC meeting a sub-committee comprising of members from HPSEB, SJVNL, NRLDC, PGCIL and NRPC was formed to analyse the incidents in details and to submit the report to OCC.

1.3 In order to look into the incident of tripping of power evacuation circuits from Jhakri and Baspa Hydro Stations, a sub-committee was constituted with its composition as under:

1. Sh Suneel Grover Director (PR &CERC), HPSEB, Shimla;
2. Sh Anoop Singh, Chief Manager, POWERGRID, NR-II, Jammu;
3. Sh R. K. Agarwal, GM (C & SO), NJPS/SJVNL;
4. Sh V. K. Agrawal, General Manager, NRLDC or his representative, New Delhi; (Shri S. R. Narasimhan, Chief Manager(SO-II))
5. Sh A. K. Rajput, SE (O), NRPC, New Delhi, Convener.

1.4 The sub-committee had its meetings as under:

First meeting	10-07-2009.
Second meeting	20-08-2009.
Third Meeting	11-09-2009.

2.0 Antecedent system conditions at 16:00 hours of 19th May 2009:

Stormy weather conditions were reported from Jhakri at that point of time. The antecedent grid conditions were as under:

- a) System frequency: 49.51 Hz

- b) Northern Region system size: 27918 MW
- c) Net Inter-regional import by NR: 1317 MW (schedule of 1214 MW)
- d) Voltage profile:

Station	Voltage(kV)	Station	Voltage (kV)
Kanpur	401	Agra(PG)	394
Gorakhpur(PG)	423	Dadri	390
Abdullapur(PG)	392	Nalagarh	397
Kishenpur	396		

- e) Line flows at Jhakri: (all metered at receiving ends)

Sl No.	Line Name	Flow in MW
1	400 kV Jhakri-Nalagarh-1	447
2	400 kV Jhakri-Nalagarh-2	447
3	400 kV Jhakri-Abdullapur-1	463
4	400 kV Jhakri-Abdullapur-2	486
	Total	1843 MW

3.0 The incident

At about 16:37 hrs, tripping of all the four circuits of 400 kV power evacuation circuits and generating units at Nathpa Jhakri Hydro Power Station (NJHPS) & Baspa occurred on 19th May, 2009. Approximately 1700 MW generation was lost during this incident. (NJHPS 1400 MW and Baspa 300 MW). Water spillage to the extent of 1550 MWh occurred at NJHPS and 350 MWh at Baspa. The incident is summarized as under:

There are four evacuation circuits from Jhakri i.e. Jhakri-Nalagarh D/C and Jhakri-Abdullapur D/C. The incident started with tripping of 400 kV Nathpa Jhakri-Nalagarh ckt-II (NJ-NLG-II) at 16:29:15:865 (as per Jhakri end MICOM distance relay timings) hrs on Y phase to ground fault from both ends on persistence of this fault. The generation was evacuated with other three circuits without any problem for about seven (7) minutes.

There was an R phase to Ground fault in Nathpa Jhakri-Abdullapur ckt-I, and this fault was fed from Jhakri end. At about 16:36:53:245 hrs (Jhakri timings) Nathpa Jhakri-Abdullapur ckt-I (NJ-ABD-I) tripped from Jhakri end in Zone-III. Abdullapur end of this line auto-reclosed through the tie breaker at Abdullapur end. The main CB of NJ-ABD-I had problem in R phase and it did not auto-

reclose, later on main circuit breaker (CB) tripped on pole discrepancy. At this stage the Jhakri/Baspa complex was left with only two 400 kV lines, one each to Nalagarh and Abdullapur for evacuating 1700 MW generation.

Soon thereafter, 400 kV Jhakri-Abdullapur-II tripped at Abdullapur end on operation of Main-I distance protection leaving only one line for evacuation from Jhakri/Baspa complex. (Nalagarh-I). The Nathpa Jhakri-Nalagarh ckt-I, tripped due to load encroachment and the Jhakri units tripped on under voltage (U/V) and Baspa units on over voltage (O/V) due to non-availability of evacuation path.

3.1 Time Line of Events

Tripping times of circuits and generators on 19.5.2009.

- Nathpa Jhakri-Nalagarh ckt-II (NJ-NLG-II) at 16:15:35 hrs. B-Phase to ground fault and and line auto-reclosed successfully.
- Nathpa Jhakri-Nalagarh ckt-II (NJ-NLG-II) at 16:29:15:865 hrs.(Jhakri timing)
- Nathpa Jhakri-Abdullapur ckt-I (NJ-ABD-I) at 16:36:53:245 hrs. at Jhakri end (Jhakri timing)
- Nathpa Jhakri-Abdullapur ckt-II (NJ-ABD-II) at 16:36:59:602 hrs. at Abdullapur end (Abdullapur end timing)
- Nathpa Jhakri-Nalagarh ckt-I (NJ-NLG-I) at 16:37:00:034 hrs. at Jhakri end
- All Generators at Jhakri and Baspa tripped around 16:37:00 hrs after tripping of Nathpa Jhakri-Nalagarh ckt-I.
- Nathpa Jhakri-Abdullapur ckt-II (NJ-ABD-II)/Nathpa Jhakri-Baspa-I/ Nathpa Jhakri-Baspa-II at 16:37:03:874 hrs.

3.2 Operational Status of N-E-W Grid

In rest of the system the frequency declined to 48.85 Hz from a level of 49.60 Hz during the incident of 19-05-2009. The frequency plot for the NEW grid based on the Historical Data records (HDR) at NRLDC is illustrated below in Fig 1. The loss in generation in Northern region resulted in a 700 MW increase in inter-regional imports from 1300 MW to 2000 MW. However as the line loadings were satisfactory, the situation remained under control.

**Frequency profile of NEW grid during tripping on
19th May 2009 at Jhakri HEP**

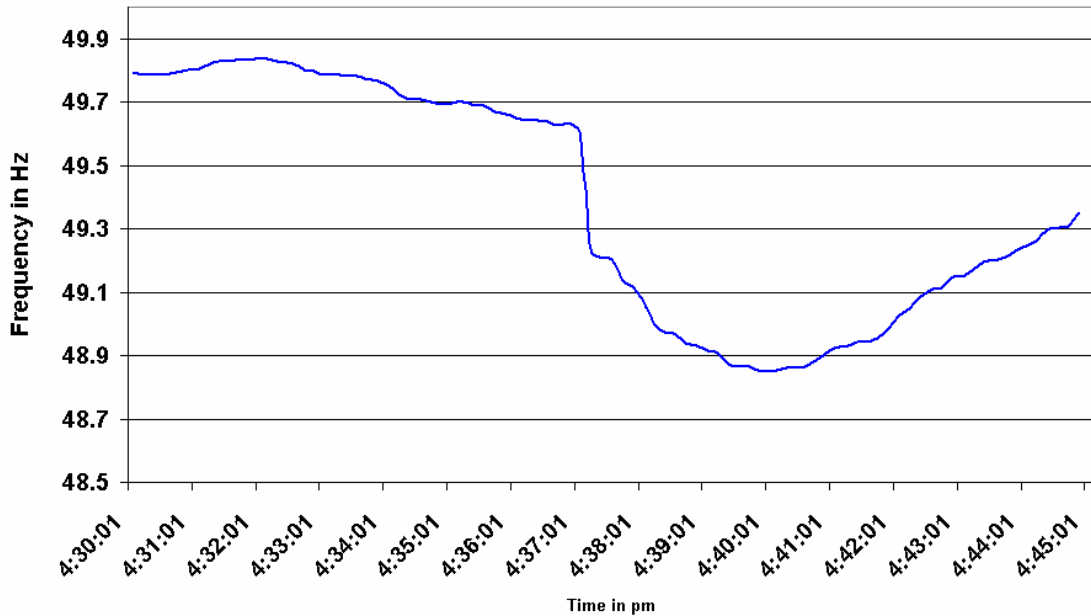


Figure 1: Frequency Profile during the incident of 19th May, 2009

The computation of df/dt from frequency data at 100 msec interval (illustrated graphically in Fig 2 below) indicates that the chances of any df/dt relay set at 0.1 Hz/sec operating during the incident is quite remote.

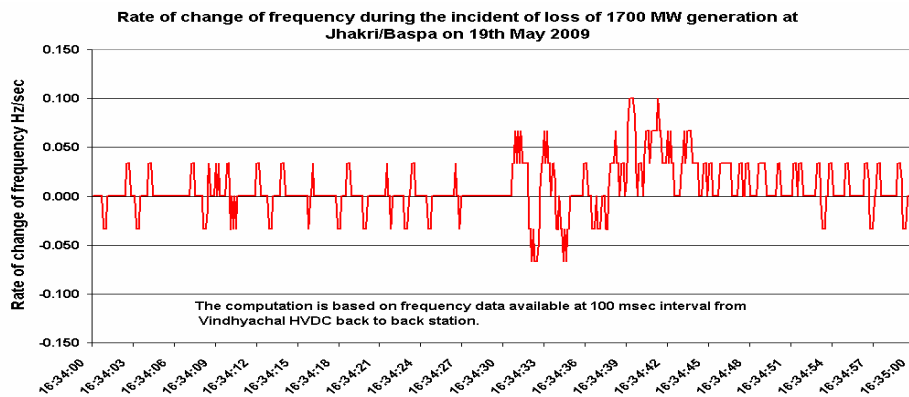


Figure 2: Rate of change of frequency during the incident of 19th May 2009

4.0 The restoration was done promptly and the Sequence of Restoration of the System is as under:

Sl. No.	Time (hhmn) on 19 th May 2009	Element restored

1	1706	400 kV Jhakri-Nalagarh-2
2	1715	400 kV Jhakri-Abdullapur-2
3	1716	400 kV Jhakri-Baspa-1
4	1722	Unit-2 at Jhakri
5	1727	Unit-3 at Jhakri
6	1733	Unit-4 at Jhakri
7	1736	Unit-5 at Jhakri
8	1739	400 kV Jhakri-Nalagarh-1
9	1742	Unit-6 at Jhakri
10	1747	Unit-1 at Jhakri
11	1759	400 kV Jhakri-Baspa-2
12	1908	400 kV Jhakri-Abdullapur-1

5.0 Analysis of the incident

5.1 Inputs received for analysis of the incident

M/s SJVNL submitted the detailed report of the incident along with the disturbance and event records (DR and ER).

POWERGRID, NR-II submitted the DRs and ELs of Nalagarh sub-stations. DR for Abdullapur- Jhakri –I/II were also made available from Abdullapur. ELs from Abdullapur s/stn were not available. POWERGRID informed that Event Logger (EL) panel at 400 kV Abdullapur had hung during that period and the same had to be reset by removing and resetting DC supply. Since then it had been functioning normally. Power flow simulation studies, Sequence of Events and data from Historical Data Recording (HDR) from NRLDC were also made available.

The inputs received for analysis of the incident are enclosed at the end of the report. (All timings as per the local DR or EL).

RYB phase convention has been used throughout the report.

5.2 Tripping of 400 kV Jhakri-Nalagarh ckt-II (B phase)

The first event recorded was a B-phase to ground fault on 400 kV Jhakri-Nalagarh ckt-II at 16:15:35 hours as per the EL and numerical relay output at Nalagarh sub-station. (Both these timings match). The fault is cleared by the

distance protection from both ends successfully in 40 msec as per the relay output at Nalagarh. The line successfully auto-reclosed (single phase auto-reclosure) from both ends after the auto-reclosure dead time of 1 second. All the four circuits remained intact.

The outputs at Nalagarh also indicate that the main breaker has auto-reclosed first, followed by the tie breaker 1.062 seconds later. POWERGRID confirmed that this was as per the design of their scheme (ABB) where the tie breaker closes 1 second after successful autoreclosure of the main breaker.

The frequency at this stage was 49.71 Hz and the total receipt of power at Abdullapur/Nalagarh was 1667 MW.

5.3 Tripping of 400 kV Jhakri-Nalagarh ckt-II (Y phase)

The next event recorded was a Y phase to ground fault on 400 kV Jhakri-Nalagarh ckt-II at 16:29:14:643 hrs (Jhakri end timing). The fault was detected by distance relay as Zone-I fault and opened the Y-phase at 16:29:14:700 hrs. The Relay tried an auto-reclose at 16:29:15:700 hrs but the fault was still persisting on the line. It then gave three-pole tripping on auto-reclose lock out. The Circuit breaker finally opened at 16:29:15:865 hrs as shown in **figure-3**. Due to persistent Y-phase fault, three phase trip of Jhakri-Nalagarh ckt-II occurred at both ends.

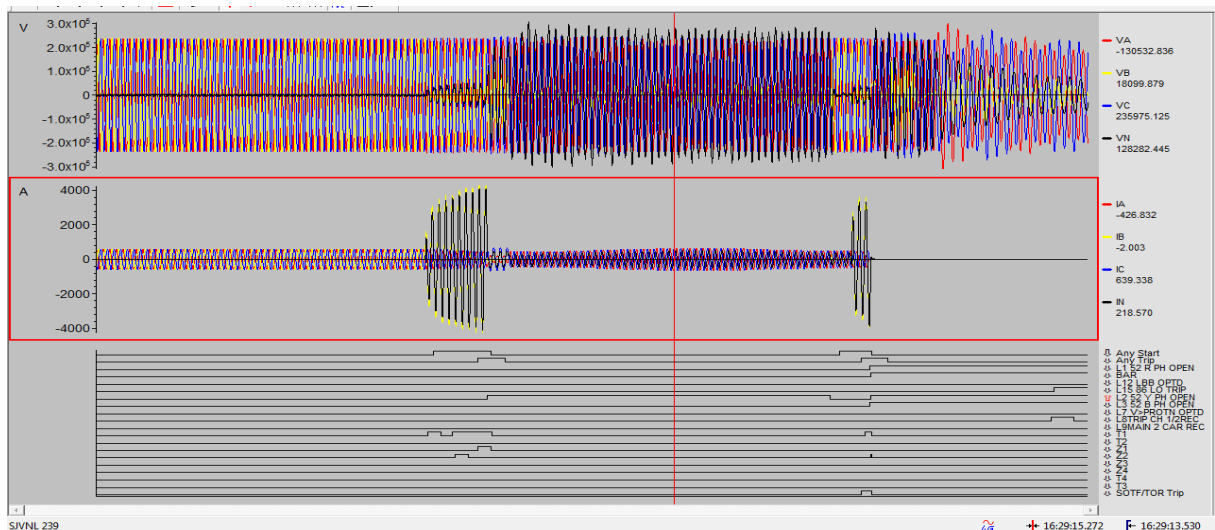


Figure-3: First incident Fault on Jhakri-Nalagarh-II as recorded at Jhakri

Fault current is 2.3 kA rms at Nalagarh end. At Jhakri end, the fault current increased gradually from 1.8 kA peak to 4.0 kA peak.

With the opening of Jhakri-Nalagarh ckt-II, Jhakri power station was left with only three 400 kV outgoing circuits for NJHPS and BHPS power evacuation and power flow on these three lines {As per NRLDC historical data recording (HDR)} before and after tripping of Jhakri-Nalagarh ckt-II was under:

	Before tripping	After tripping
400 kV Jhakri-Nalagarh ckt-I	400 MW	649 MW
400 kV Jhakri-Nalagarh ckt-II	399 MW	0 MW
400 kV Jhakri-Abdullapur ckt-I	421 MW	495 MW
400 kV Jhakri-Abdullapur ckt-II	443 MW	521 MW
Total	1663 MW	1665 MW

The system therefore continued to run normally with three circuits evacuating power from the Jhakri/Baspa complex with loadings as shown above.

5.4 Tripping of 400 kV Jhakri-Abdullapur ckt-I (R phase)

After tripping of Jhakri-Nalagarh ckt-II, 1665 MW of power got redistributed in the remaining three circuits as mentioned above. These loadings were well within the stability/thermal limits of the 400 kV lines involved although any further single element contingency could result in a cascade tripping or necessitate rescheduling of generation.

After a lapse of about seven (7) minutes of the tripping of Jhakri-Nalagarh ckt-II, i.e. at 16:36:51:865 hrs. (Jhakri end timings), an earth fault in R-phase was developed on Jhakri-Abdullapur ckt-I. The fault was of high impedance in nature with gradual increase in magnitude of current (Refer **figure-4**). Jhakri end relay has seen this fault as Zone-III fault. This fault is always associated with three pole tripping. The Zone-III has trip delay time of one second at Jhakri. The Jhakri-Abdullapur ckt-I tripped at Jhakri end at 16:36:53:245 hrs.

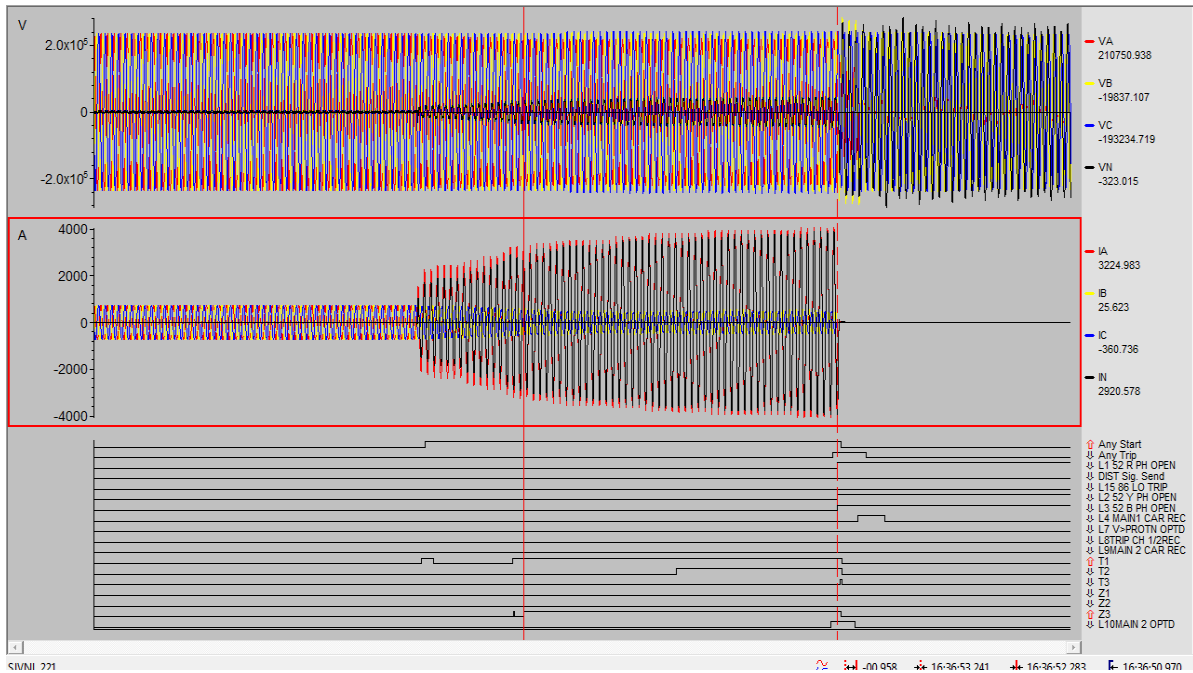


Figure-4: R phase to ground fault on Jhakri-Abdullapur ckt-I

After opening of circuit breaker at Jhakri end the fault on the line (Jhakri-Abdullapur ckt-I) was still persisting and fed from Abdullapur end only and fault got deteriorated which in turn converted in Zone-I (Z1, R-N) fault. Abdullapur relay has given the single pole tripping followed by successful auto reclosing after dead time of one second. Abdullapur line remained live upto Jhakri on successful auto reclosure at Abdullapur end. However, Jhakri end CB was opened due to Zone-III (Z-3) distance protection tripping.

Zone-III is basically back up protection of the next line at the remote sub-station. Still the distance relay at Jhakri end of 400 kV Jhakri-Abdullapur ckt-I has seen Zone-III fault for the actual fault in principal line or protected line. Abdullapur and Nalagarh lines are routed through topographically hilly areas for the majority of the length.

In the past also it has been observed that during the stormy or bad weather conditions a high impedance fault is developed in the principal line (protected line). In this particular case also a high impedance earth fault was developed in R-phase of 400 kV Jhakri-Abdullapur ckt-I.

Jhakri being the strong source to fault majority of current contribution to fault is fed by Jhakri generators and the contribution from Abdullapur end was very small. Due to this the relay at Jhakri end has seen the Zone-III fault and Abdullapur has not seen the fault. As fault continued to be of high impedance for one second, hence it got three pole tripping at Jhakri. After three pole tripping at Jhakri end fault was still persisting on the line. Abdullapur being now the lone contributor to fault and at the same time the fault getting deteriorated, Abdullapur detected the same in Zone-I, leading to single pole tripping with subsequent successful auto-reclosure from Abdullapur end. Thus Jhakri-Abdullapur ckt-I was live upto Jhakri.

The above phenomenon resulted into independent tripping of protected line.

With the tripping of Jhakri-Abdullapur ckt-I from Jhakri end at 16:36:53:245 hrs (and the circuit remaining charged from Abdullapur end), the remaining two circuits were evacuating power of NJHPS and BHPS. The power flow on the remaining circuits as per the power flow simulation by NRLDC is estimated as under:

	Before tripping	After tripping
400 kV Jhakri-Nalagarh ckt-I	649 MW	822 MW
400 kV Jhakri-Nalagarh ckt-II	0 MW	0 MW
400 kV Jhakri-Abdullapur ckt-I	495 MW	0 MW
400 kV Jhakri-Abdullapur ckt-II	521 MW	843 MW
Total	1665 MW	1665 MW

The heavy power flow on the remaining two circuits created a condition of 'emergency state' but with system intact.

5.5 Here the following observations are pertinent:

- (a) Single pole tripping and autoreclose of the tie breaker has been reported on 400 kV Jhakri-Abdullapur ckt-I at Abdullapur end. The main breaker could not autoreclose.
- (b) The fault locations are not available for this circuit or the 400 kV Jhakri-Nalagarh-II which had tripped earlier.

5.6 Tripping of 400 kV Jhakri-Abdullapur-II from Abdullapur end followed by tripping of 400 kV Jhakri-Nalagarh-I from Jhakri end:

After tripping of Jhakri-Abdullapur ckt-I at 16:36:53:245 hrs (CB opening at Jhakri but the circuit remaining live upto Jhakri from Abdullapur end) at 16:36:59:602 hrs (Abdullapur end timing) i.e. around 06 seconds later 400 kV Jhakri-Abdullapur-II tripped at Abdullapur end on operation of Main-I distance protection. This line tripped only at Abdullapur end and not at Jhakri end at this instant. Jhakri end has not tripped at this stage. It is not clear from the Abdullapur end relay output as to how long the voltage dip shown has been persisting as pre-fault voltage and currents are available only for three (3) cycles. The reasons for this line tripping at Abdullapur end is not clear as there is no apparent line fault and Jhakri end distance protection has not sensed any fault. With this tripping Jhakri is left with only 400 kV Nalagarh-1 circuit for evacuating 1660 MW from Jhakri/Baspa complex.

Almost immediately, 400 kV **Jhakri-Nalagarh ckt-I got tripped from Jhakri end on account of operation of distance protection at Jhakri end. This appears to be a case of load encroachment considering that only one line was now available for evacuating 1660 MW from Jhakri/Baspa complex.**

5.7 Tripping of Jhakri-Abdullapur ckt-I from Abdullapur end:

400 kV NJHPS-Abdullapur ckt-I tripped from Abdullapur end on operation of Main-I distance protection at 16:37:00:643 (as per Abdullapur timings). The DR indicates increase in R-Phase current for 12 cycles followed by current in R and B phase being fed for close to 23 cycles before the distance protection has cleared the fault from Abdullapur. The timing seems to suggest that the fault is closer to Jhakri.

5.8 Tripping of all Generating Machines of Jhakri

The redistribution of power flow on the Jhakri-Nalagarh ckt-I (822 MW) and Jhakri-Abdullapur ckt-II (843 MW) was taking place. The heavy loading on lines increased the voltage drop and line losses. The reactive demand of generator transformer (GT), transmission line and ICTs caused the voltage sinking in the system. This has caused the voltage to fall drastically to a level where generator under voltage (27G) relay got activated. Generator under voltage setting at Jhakri is 90% of normal voltage ($U_n=15.75$ kV) and time delay of 02 seconds. After under voltage detection and a time lapse of 02 seconds all the generators were

electrically disconnected (ELD) from the grid at about 16:37:00 hrs after few milliseconds of tripping of Jhakri-Nalagarh ckt-I (refer **figure-5**).

7040	D:	00000	00:00:00.186	10	51.1U	UAT HV SIDE O/C INV	Start	OFF
7041		2009-05-16	19:46:38.316				GenStart	OFF
7042		2009-05-16	19:46:38.330				GenStart	ON
7043	D:	00000	00:00:00.000	10	51.1U	UAT HV SIDE O/C INV	Start	ON
7044	D:	00000	00:00:00.380	10	51.1U	UAT HV SIDE O/C INV	Start	OFF
7045		2009-05-16	19:46:38.710				GenStart	OFF
7046		2009-05-19	16:15:04.871				GenStart	ON
7047	D:	00000	00:00:00.000	12	27G	UNDERVOLTAGE ALARM	Start	ON
7048	D:	00000	00:00:00.088	12	27G	UNDERVOLTAGE ALARM	Start	OFF
7049		2009-05-19	16:15:04.960				GenStart	OFF
7050		2009-05-19	16:36:30.976				GenStart	ON
7051	D:	00000	00:00:00.000	12	27G	UNDERVOLTAGE ALARM	Start	ON
7052	D:	00000	00:00:02.006				GenTrip	ON
7053	D:	00000	00:00:02.006	12	27G	UNDERVOLTAGE ALARM	Trip	ON
7054	D:	00000	00:00:02.006	12	27G	UNDERVOLTAGE ALARM		0.810 UN
7055	D:	00000	00:00:02.035		Bin.Inp. Nr.15/11	(TCS 400kv CB)	ON
7056	D:	00000	00:00:02.088		Bin.Inp. Nr.15/ 1	(420kv CB OPEN)	ON
7057	D:	00000	00:00:02.090		9 f(60.1+CBOPEN+VALVCLOSED)	BinOutput		ON
7058	D:	00000	00:00:02.090		8 f(60.1+CBOPEN)	BinOutput		ON
7059	D:	00000	00:00:02.095	12	27G	UNDERVOLTAGE ALARM	Trip	OFF
7060	D:	00000	00:00:02.095				GenTrip	OFF
7061	D:	00000	00:00:02.095	12	27G	UNDERVOLTAGE ALARM	Start	OFF
7062		2009-05-19	16:36:33.071				GenStart	OFF
7063		2009-05-19	16:36:33.105		Bin.Inp. Nr.15/11	(TCS 400kv CB)	OFF
7064		2009-05-19	16:36:33.315		Bin.Inp. Nr.15/ 3	(420kv CB TRIP FROM CON)		ON
7065		2009-05-19	16:36:33.335		Bin.Inp. Nr.15/11	(TCS 400kv CB)	ON
7066		2009-05-19	16:36:34.341		Bin.Inp. Nr.15/ 3	(420kv CB TRIP FROM CON)		OFF
7067		2009-05-19	16:36:34.375		Bin.Inp. Nr.15/11	(TCS 400kv CB)	OFF
7068		2009-05-19	16:36:36.606				GenStart	ON
7069	D:	00000	00:00:00.000	14	97	OVEREXCITATION	Start	ON
7070	D:	00000	00:00:00.255	7	60.1	VOLTAGE BALANCE	Start	ON
7071	D:	00000	00:00:00.373	7	60.1	VOLTAGE BALANCE	Trip-Line2	ON

Figure-5: Tripping of Generator at Under Voltage

When the machine got disconnected from grid by electrical disconnection (ELD, opening of CBs) by the action of under voltage relay (27G), the over speed switch of all the machines initiated the emergency shut down (ESD). Thus all the units of Jhakri were shut down on over speed.

5.9 Tripping of Jhakri-Baspa ckts- I & II

Since there was no evacuation path available 400 kV Jhakri-Baspa ckts- I & II tripped on over voltage. However, no DR or EL or numerical relay output could be made available by Baspa HPS.

At 16:37:00:100 hrs all generators of Jhakri and Baspa got tripped and NJ-NLG-I was also tripped. At this stage the following three lines were connected to Jhakri:

- (a) Jhakri-Abdullapur ckt-II
- (b) Jhakri-Baspa ckt-I
- (c) Jhakri-Baspa ckt-II

There was no generation at Jhakri and Baspa.

6.0 Conclusion & Recommendation

Based on the information obtained from NRLDC, Jhakri and NRTS-II as described above , following observations are made by the committee:

1. It has been observed that all the four 400 kV lines emanating from Jhakri towards Abdullapur/Nalagarh side developed faults within a short span of time (half an hour from 1615 hrs. to 1645 hrs.) when the weather was stormy. Unintended operation of protective systems (at Jhakri end for 400 kV Jhakri-Abdullapur-I and at Abdullapur end for 400 kV Jhakri-Abdullapur-II) compounded the problem.
2. Lines evacuating generation from Jhakri system passes through the hilly terrain of Shivalik mountain range, where chances of reduction in adequate clearances due to overgrown trees in the right of ways of lines are most likely. It appears that faults observed during this incident were due to contacts with the trees in the bad weather prevailing at the time of disturbance.
3. It has been observed that all the disturbance recorder and event logger at Jhakri , Nallagarh and Abdullapur are not synchronized with GPS clock. In the absence of time synchronized DR/EL output it becomes very difficult to determine the exact sequence of events (SOE). Data available from SCADA system SOE helped in determining the exact SOE.
4. The committee also feels that Protective relay settings should not limit transmission loadability i.e. It should not interfere with system operators' ability to take remedial action to protect system reliability. Relays shall be set to reliably detect all fault conditions and protect the electrical network from these faults.

The action on following recommendations/remedial measures should be taken to avoid such incidences.

1. The relays and switchgear operation should be tested on regular basis and reported to Protection sub-committee of NRPC. The Committee observed that while relays are tested periodically for reach, zone timings etc. they are not tested for non-operation under different loadability conditions. In the US power system the North American Electric Reliability Corporation (NERC) has a reliability standard **Standard PRC-023-1 — Transmission Relay Loadability which requires each generator and transmission line owner to test the relays for non-operation during different conditions. A copy of the Reliability Standard as downloaded from website www.nerc.com is enclosed at Annexure -I. Protection sub committee of NRPC may consider these requirements for adopting in the testing philosophy by constituents of NR at least for the trunk 400 kV system.**
(Action : NR constituents)
2. Protection system auditing should be undertaken.
(Action: protection Sub committee of NRPC)
3. Disturbance recorder (DR) and event logger (EL) should be in healthy condition and time synchronized with GPS for recording any Grid incident to enable the analysis of such incident. Time synchronization of Relays, Disturbance Recorders (DRs) and Event Loggers (ERs) should be accomplished and certificate to be submitted every quarter to NRPC/NRLDC.
(Action: All stakeholders)
4. Patrolling of the power evacuation lines to be carried out frequently on the stretches where faults due to growth of vegetation have been reported in past or where clearances have reduced due to urbanization / overgrown trees in the near vicinity of lines 'right-of-the way'..
(Action: All stakeholders)
5. Unauthorised constructions/activities in the vicinity of line route should be monitored and in case of any such development, the matter should be reported to the concerned organizations for appropriate action.
(Action: All stakeholders)
6. System Protection Scheme (SPS) for automatic reduction of generation in case of depletion in the transmission evacuation system be explored for Jhakri and other large power stations of 1000 MW and above. The details in this regard might be worked out separately at the RPC forum in line with section 5.2 (n) of IEGC.
(Action: All constituents of NRPC)

Inputs for Analysis of the Incident

400/220 kV Nalagarh (POWERGRID) substation:

- Event Logger (EL) output (Exhibit-I)
- REL 521 relay output for Jhakri-2 line at 16:15:35 hrs. (Exhibit-II)
- REL 521 relay output for Jhakri-2 line at 16:29:14 hrs. (Exhibit-III)
- REL 521 relay output for Jhakri-1 line at 16:36:59 hrs. (Exhibit-IV)
- REL 521 relay output for Jhakri-1 line at 16:45:47 hrs. (Exhibit-V)

400/220 kV Abdullapur(PG) substation:

- REL 521 relay output for Jhakri-1 line at 16:36:52 hrs. (Exhibit-VI)
- REL 521 relay output for Jhakri-1 line at 16:36:59 hrs. (Exhibit-VII)
- REL 521 relay output for Jhakri-1 line at 17:01:36 hrs. (Exhibit-VIII)
- REL 521 relay output for Jhakri-2 line at 16:36:59 hrs. (Exhibit-IX)
- REL 521 relay output for Jhakri-2 line at 16:37:03 hrs. (Exhibit-X)

Jhakri power station:

- Nalagarh-2 MICOM relay output at 16:29:15 hrs. (Exhibit-XI)
- Nalagarh-1 MICOM relay output at 16:37:00 hrs. (Exhibit-XII)
- Abdullapur-1 MICOM relay output at 16:36:53 hrs. (Exhibit-XIII)
- Abdullapur-2 MICOM relay output at 16:37:03 hrs. (Exhibit-XIV)
- Baspa-1 MICOM relay output at 16:37:03 hrs. (Exhibit-XV)
- Baspa-2 MICOM relay output at 16:37:03 hrs. (Exhibit-XVI)
- EL output for generating units. (Exhibit-XVII)

NRLDC:

- Sequence of Events (SoE) of different control centres merged at NRLDC. (Exhibit-XVIII)
- Historical Data Recording of frequency and line flows at 10 second interval.

Vindhyachal HVDC back-to-back station:

- Frequency data for North and West bus at 100 msec interval.