Report of the Group on

Incidents Rihand Station Outage and tripping of Rihand-Dadri Pole on 18 & 19 June 2013

1. A group of engineers from NRPC, NLDC, NRLDC, POWERGRID and NTPC was constituted by Member Secretary, NRPC vide letter No. NRPC/OPR/105/10/41823 dated 19.06.2013 (copy enclosed as Annex) to investigate the incidents of complete outage of Rihand STPS Stage-I, II and III and tripping of Rihand-Dadri Pole 2 which occurred on 18-19 June 2013. The group met at NRPC office on 21.06.2013 and discussed the incident in detail. The findings of the group and suggestions for improvement for future are discussed in the succeeding paragraphs.

2. Brief description of the event:

2.1.1 Rihand STPS was operating at about its full capacity (2500MW) with one 400/132kV Inter Bus Transformer (IBT) feeding the Station supply (through four 132/11kV Station Transformers) to the Stage-1 (2 x 500MW) and Stage-2 (2 x 500MW) units. The commissioned unit (#5, 500MW) has 400/11kV Station Transformer feeding its Station supply. The 132 kV line from Singrauli/Vindhyachal providing alternate source of auxiliary supply is already not usable since long due to right of way encroachments. Around 21.14hrs the Red Phase Current Transformer (CT) of 132kV Bus Coupler (B/C) blasted and resulted in a minor fire in the 132kV switchyard. At this time there was heavy rains and thunder storm in the area.

2.1.2 On failure of the B/C CT, bus bar differential protection of 132kV Bus-2 operated (correct operation) and tripped all circuit breakers switched to 132kV Bus-2, including the IBT#2. This resulted in the interruption of Stations Supply to Stage-1 and Stage-2 units. All the five units in operation were either directly or indirectly dependent on Station supply and tripped one after the other. The first unit to trip was Unit#4 almost immediately and the last unit to trip was Unit#5 at 21.40hrs after about 25minutes. There was total AC power interruption in Stage-1 and Stage-2 units.

2.1.3 The second source of aux power to HVDC from Unit#5 continued to be available, supply changeover happened successfully at HVDC station and Rihand – Dadri HVDC link continued to be in service.

2.1.4 The auxiliary power to HVDC is supplied from IBT & station transformer at Rihand. On loss of auxiliary power from IBT, the successful changeover at 415V bus took place on 11kV station transformer supply resulting in No interruption of Power from HVDC at the time of incident as successful changeover has taken place in Aux. Power at HVDC leading to uninterrupted operation of Pole-1 & Pole-2. Later on at 03:30 Hrs, the auxiliary power from IBT was restored by NTPC resulting in restoration of second 11kV Incomer supply to HVDC from NTPC. After restoration of 11 KV incomer from IBT , the auto changeover in 415V Scheme in Pole 1 & 2 took place to restore back the 415 V aux. power scheme to Two Incomer close and B/C open to energize both Buses at 415 V from different 11KV incomers. The changeover

wherein Bus Coupler opens and Incomer breaker closes to energize both 415 V buses from separate 11 KV incomers through 11KV/415 V transformers took place successfully in Pole-1, However, one no. closing coil in 415V Incomer CB of pole-2 burnt during closing, leading to loss of auxiliary power to 415 V Bus-A which resulted in Chang over of Fine water Pump to only available aux. Power from 415 V Bus-B. During pump changeover from Supply A to Supply B, the Power contactor in MCC for Supply-B burnt leading to loss of Power to Both the pumps in Pole-2 which resulted in tripping of Pole-2 on loss of power after 10Sec due to Low Flow in Fine water system in Valve Hall. Though, the changeover scheme is completely foolproof, the failure has taken place due to the double contingency took place at the time of restoration of second 11KV power supply from IBT to HVDC. However, no Power flow interrupted from HVDC on tripping of Pole-2 as HVDC was run at 600 MW and all power was taken over by Pole-1 in operation.

3. Outage of 132kV Supply

3.1 The 132 kV Intermediate Voltage Switchyard is designed with Two Main Bus scheme, with a Bus Coupler between the two Bus Bars. A single line diagram of the Switchyard is enclosed as Exhibit-1. The 132kV system catering to Stage-1 & Stage-2 had been provided with 2 x 400/132kV IBTs of 200MVA each. The 132kV bus in turn feeds the four Station Transformers catering to the four units of Stage-I and Stage-II.

3.2 IBT#1 had failed (irreparable) in April 2010 and the Station has since been operating with only one IBT. A replacement transformer is under order and is expected to be delivered soon. In the mean while a third IBT had been procured and has been delivered and is currently getting ready for commissioning. This Transformer is being commissioned at the location of IBT#1 and will be energized in this month. For the security of Auxiliary power to HVDC, a 11kV feeder has been made available from Stage-3.

3.3 On 18.06.2013 at 21.14hrs, while the area was experiencing thunder storm and rain, the 132kV CT of the B/C bay failed, resulting in a bus fault and 132kV Bus#2 tripped appropriately on Bus Bar Differential Protection. IBT#2 was thus removed from service and the only 132kV source was lost, resulting in loss of Station Auxiliary Supply in stage-1 and Stage-2. The Fault as recorded in PMUs available at NRLDC is as enclosed at Exhibit-2.

4. Tripping of Generating Units at a glance:

Parameter	Unit1	Unit 2	Unit 3	Unit 4	Unit 5
Load (MW)	449	520	510	515	500
MD BFP	Motor driven Boiler Feed Pump (MDBFP) 1A & 1C	Motor driven Boiler Feed Pump (MDBFP) 2A, 2B	Turbine driven Boiler Feed Pump (TDBFP) 3A &3B	Turbine driven Boiler Feed Pump (TDBFP) 4A & MDBFP 4C (Station Supply)	No Supply failure
CW pumps in service	1A, 1B,1C, 2A,2B (1C supply from station board)		3B,3C,4A,4B (3C supply from station Board)		No Supply Failure
Instrument	Stage-1		Stage-2		**Stage-2**

Air Source					
Trip Time (Respective Unit Time)	**21.21.48**	**21.21.53**	21.16.38	21.14.09	21.40.19
Trip time as per NRLDC SOE	21:26:51:719	21:26:59:625	21:16:41:348	Not reported to NRLDC SOE	21:41:28:005
Trip Trigger	Condenser Vacuum Low	Manually tripped on Condenser Vacuum Low	Condenser Vacuum Low	Drum Level low	Manually tripped on Condenser Vacuum Low

The outage of different units has also been recorded in frequency plot of the PMUs while no fault is seen during these unit outages. The frequency plot of PMU is attached as Exhibit-3.

5. Analysis of Tripping of Generating Units:

5.1 The tripping root cause for each unit of the Station during this incident is discussed below in the chronological order of tripping. The schematic of auxiliary cooling water system is enclosed as Exhibit-4.

1. **Unit # 4 (21:14:09):** Runback operated and unit load reduced to 357 MW. One TDBFP could not meet the requirement of feed water pumping and drum level started falling. Unit tripped on drum level low. TDBFP 4B was out of service for a bearing replacement.
2. **Unit # 3 (21:16:42:323):** Unit # 3 & 4 were operating with CW system interconnected, with four CW pumps in operation. Two pumps of Unit # 4 (4A & 4B) were fed from Unit supply and two pumps of Unit # 3 (3B & 3C) were fed, one pump each, from Unit and Station supply respectively. On tripping of IBT # 2. Pump 3C tripped and pumps 4A and 4B tripped when Unit # 4 tripped. Pump 3A took auto start and two pumps were feeding the condensers of operating Unit#3 & Tripped Unit#4. With the 2 CW pumps in service and both unit 3 & 4 condensers in charged condition, condenser vacuum started falling and Unit#3 tripped on Condenser Vacuum Low Protection.
3. **Unit # 1(21:26:51:719):** CW pump 1C, fed from Station supply, tripped on failure of 132KV supply. Unit Supply fed running CW pumps tripped later on cooling water flow low protection as CW cooling water overhead tank level became low. The over head tank supplies water for bearing lube-water and lube oil coolers. Make up for over head tank was being supplied from RW water pump fed from Station Supply and the pumps tripped on Station Auxiliary Supply failure. Alternate source from CW discharge water to overhead tank came into service but debris which came through this line choked the ACW filters and finally water did not reach to overhead tank. Scheme of ACW system is enclosed as Exhibit-2. It may be pointed out that CW of Rihand Station gets lot of debris during rains. The power supply to the filter flushing system from Station supply was not available. Condenser vacuum started falling and load was reduced to 300MW from 449MW by cutting one mill. Unit 1 tripped on condenser vacuum low

4. **Unit # 2(21:26:59:625):** Unit 2 load was also reduced by cutting 2 no of mills to around 300MW load. In the mean time all CW pumps got tripped (see 3 above) and unit was tripped by manually pressing EPB.
5. **Unit # 5 (21.40.19):** Unit was running on full load. SACW system (cooling water to air compressors) of Stage-3 was under permit from morning for giving connection to Unit # 6, which is currently under erection/ commissioning. Instrument Air Compressors (IACs) of Unit # 5 were out of service on this account. Instrument Air of Unit # 5 was hence charged from Stage-2. On tripping of Unit 3 & 4, with no power supply in Stage-2, all the IACs of Stage-2 tripped and instrument air supply to Unit 5was interrupted. Due to loss of air pressure,Condenser Vacuum pump suction line valve got closed and vacuum started falling (became 183mmhg before tripping). SH spray valve got closed and steam temperature increased. Make-up also stopped as makeup is taken from Stage 2 and Condenser Hot-Well level started dropping. Operator stopped the unit at 21:40:19 hrs.

5.2 The plots based on SCADA data as available at NRLDC for various units, bus voltage and lines flows at Rihand is as attached at Exhibit-5. It needs to be seen that values for unit # 3 got frozen after the tripping:

6. Post tripping Survival

In Stage-3, Unit # 5, Power Supply was available normally and there was no ac power failure. In Stage-1 and Stage-2 there was complete ac powerfailure and the survival power supply system took over normally. DG sets started on auto and ac survival power supply was restored in all the units. All turbines came on Turning except Unit # 1. In Unit # 1, the turbine turning failed and it was suspected to be a case of temporary seizure, which would become free as the turbine cools down. However, NTPC engineers indicated that there was some disturbance in the lubrication system during the event and the coasting down of the turbine was faster than normal. Since the turbine is not free even after cooling down to 275ºC, the bearings will have to be inspected for any damage. No bearing metal debris could be detected in the lubrication oil. The inspection of the bearings will be taken up only after the machine cools down sufficiently. This is yet to happen at the time of writing this report.

7. Tripping of Rihand- Dadri Pole-2

7.1 The auxiliary power to HVDC is supplied from IBT & station transformer at Rihand On loss of auxiliary power from IBT, the successful changeover at 415V bus took place on 11kV station transformer supply resulting in uninterrupted operation of Rihand-Dadri HVDC system at 1450MW. The system remains connected at Rihand on tripping of all five units is as follows:

1. + 500kV Rihand-Dadri HVDC at 1450MW
2. 400kV D/C Rihand-Singrauli Line
3. 400kV D/C Rihand-Allahabad Line

7.2 Later on at 03:30 Hrs, the auxiliary power from IBT was restored by NTPC resulting in restoration of 11kV Incomer supply to HVDC. After restoration, the changeover in 415V Scheme in Pole 1 & 2 took place. However one no. closing coil in 415V Incomer CB of pole-2 burnt during closing, leading to loss of auxiliary power to fine water pump which leads to tripping of pole-2 during restoration of second auxiliary supply to HVDC at 03:59 Hrs. The changeover in pole-1 took place successfully & pole kept on running without interruption. Subsequently the burnt closing coil of 415V Incomer CB and burnt Power Contactor to Fine water pump replaced & auxiliary power to fine water pump restored & pole has been energized at 06:05 Hrs.

8. Restoration

IBT # 2 was energized and the 132kV system restored at 02.49 hrs of 19.06.2013 after due isolation and confirmation that there is no consequential damage to other equipment. Action to replace the damaged CT has been initiated. After the Station supply was normalized the units were restored progressively as tabulated below, in chronological order.

Unit No	Date	Time (hrs)
5	19.06.2013	09.07
3	19.06.2013	11.55
2	19.06.2013	12.28
4	19.06.2013	16.36

Unit # 1 is expected to take some time for restoration, which will depend on the findings in the inspection.

9. Findings of the group and Suggestions for improvement

9.1 The group recognized a series of unfortunately coinciding situations, which played a role in thisevent leading to the Station outage. These could be summarized as follows:

i. The failure of only 2 sets of CTs in the entire 132kV system viz. B/C bay and IBT#2 bay could have brought about the event, yet it happened.
ii. IBT#2 was bussed on 132kV Bus-2. Had it been bussed on Bus-1, it might have survived along with 132kV Bus-1 and the total Station supply failure would have been avoided.
iii. TDBFP 4B was incidentally out of service and MDBFP in service. Had the TDBFP been in service, Unit # 4 would not have tripped. Had Unit # 4 not tripped, neither would Unit # 3 (partial CW system loss) nor Unit # 5 (loss of instrument air) would trip.
iv. Had the ACW strainer not been choked by the debris in the CW, the CW Pump lube water system would not have been disturbed and Unit #1 and Unit # 2 would not have tripped as a consequence of CW Pump tripping.

9.2 However, the group feels the need to look for improvement options and find the 132kV Intermediate Voltage system vulnerable to failure. In this connection, the following are

suggested for making the 132kV system more secure and at the same time making the unit survival independent of the Station Supply.

i. IBT#1 to be commissioned as early as possible and IBT#3 to be expedited.
ii. NTPC may examine the possibility of providing a double Breaker connection option for the third IBT, to either Bus Bar. In the event of tripping of any one IBT or any one 132kV Bus Bar, two IBTs will still be available in service.
iii. NTPC may examine the possibility of providing two Circuit Breakers and two sets of CTs in the B/C bay. This option will eliminate the possibility of a single fault causing tripping of both 132kV Bus Bars.
iv. To take care of the possibility of failure of Bus Bar differential protection the option of applying a single zone non-directional impedance protection on the bus coupler may be considered. POWERGRID representative informed that they have applied such an arrangement in many of their 220kV switchyards.
v. Need for sectionalizing the intermediate voltage bus may be examined for increased reliability. .
vi. Feasibility of revival of 132 kV connections between Rihand/Singrauli/Vindhyachal may be examined. However, representative of NTPC was of the view that it is not possible to revive these lines.
vii. Till either suggestion iii or iv stated above is realized, 132kV B/C may be normally kept open and isolated, with each bus being fed separately by one IBT.
viii. Unitization of power supplies may be explored for CW Pump House LT auxiliaries as well.

Annex

भारत सरकार
उत्तर क्षेत्रीय विद्युत समिति
18-ए, शहीद जीत सिंह मार्ग, कटवारिया सराय नई दिल्ली - 110016
Government of India
Northern Regional Power Committee
18-A, Shaheed Jeet Singh Marg, Katwaria Sarai, New Delhi-110016

N0.NRPC.OPR/ 105 /10/418-23 Dated 19-6-2013

Subject: Constitution of Team to investigate and suggest corrective action on tripping of all five units of Rihand I, II and III and tripping of one pole of Rihand- Dadri HVDC.

NRLDC has reported that all the five running units of Rihand I, II and III tripped at 9:14 PM on 18th June, 2013. The total loss generation was about 2402 MW. Also one pole of HVDC Rihand – Dadri tripped at 3:00 AM on 19th June,2013.

The following team is constituted to investigate the reasons for the above trippings and suggest corrective actions .

1. Shri G. Pillai, Executive Engineer, NRPC
2. Shri P.P. Francis GM, NTPC
3. Shri A.K. Arora, General Manager, PowerGrid.
4. Shri Rajeev Porwal, Chief Manager NRLDC
5. Shri V.K. Gupta, DGM, NLDC.

CEA has desired that report of investigation and corrective action should be submitted in the shortest time to enable the concerned utilities to take corrective action with in 24 hours.

PKPahwa 19/6/2013
(P.K. Pahwa)
Member Secretary

To:

1. Shri G. Pillai, Executive Engineer, NRPC
2. Shri P.P. Francis GM, NTPC
3. Shri A.K. Arora, General Manager, PowerGrid.
4. Shri Rajeev Porwal, Chief Manager NRLDC
5. Shri V.K. Gupta, DGM, NLDC.

Copy for information to Member (GO&D), CEA.

Exhibit-1

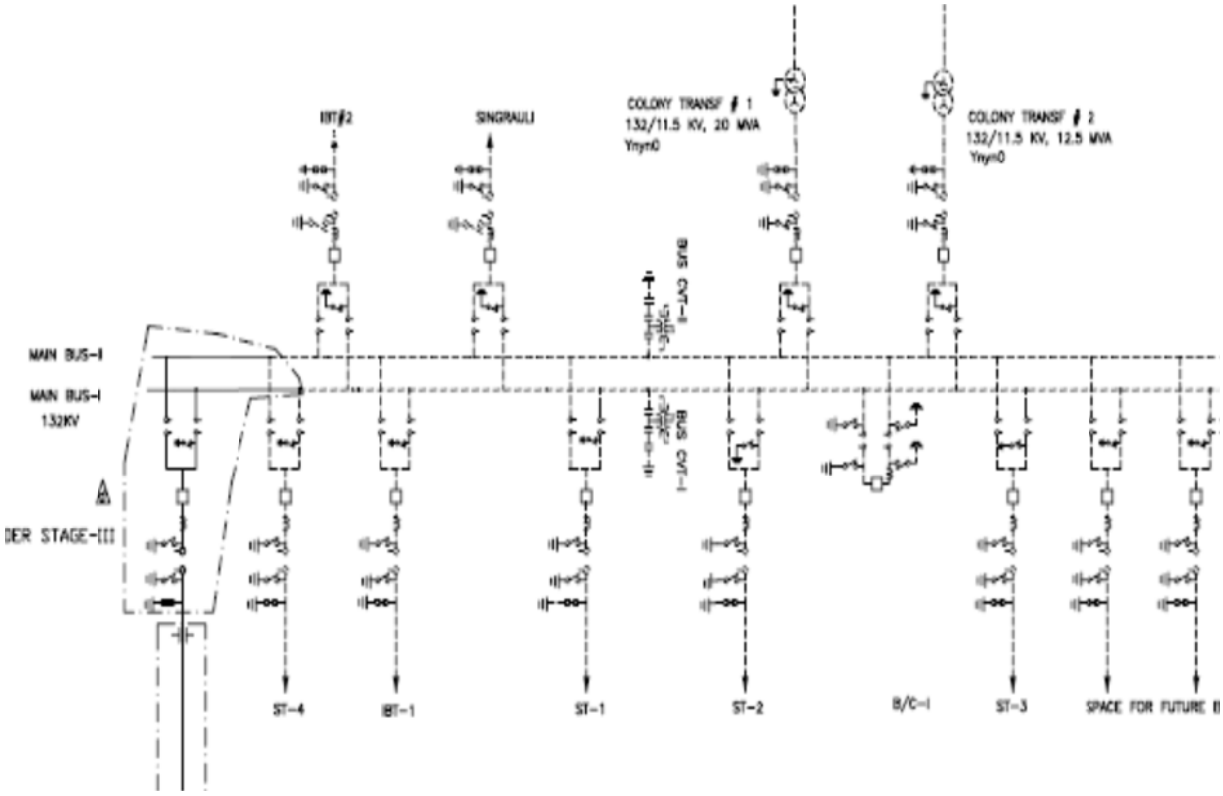
IBT#2
SINGRAULI
COLONY TRANSF # 1
132/11.5 KV, 20 MVA
Ynyn0
COLONY TRANSF # 2
132/11.5 KV, 12.5 MVA
Ynyn0
BUS CPT-I
BUS CPT-II
MAIN BUS-I
MAIN BUS-II
132KV
DER STAGE-III
ST-4
IBT-1
ST-1
ST-2
B/C-I
ST-3
SPACE FOR FUTURE

Exhibit-2

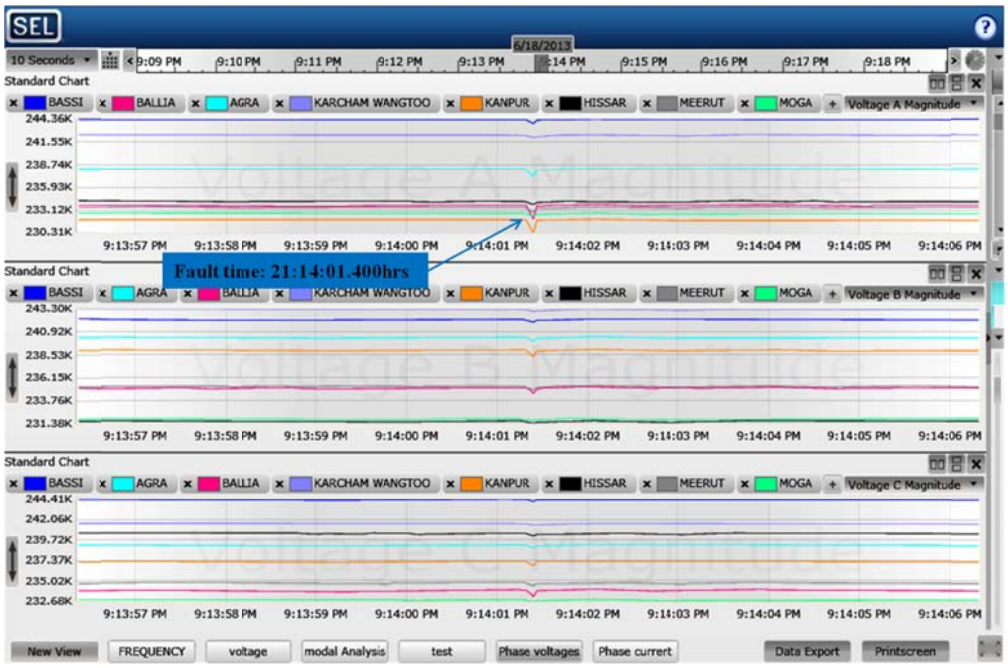

Fig: PMU plots of phase voltage at different stations

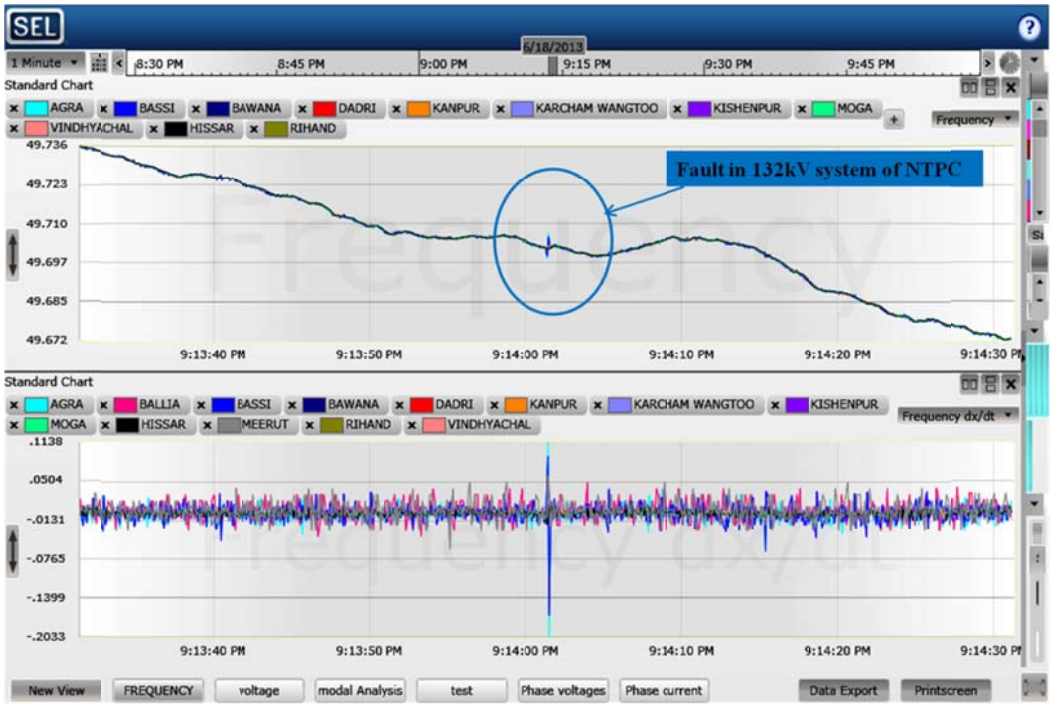

Fig: Frequency and df/dt plot of different stations

Exhibit-3

Fig: Frequency plot at different PMU locations during the Rihand incident

Exhibit-4

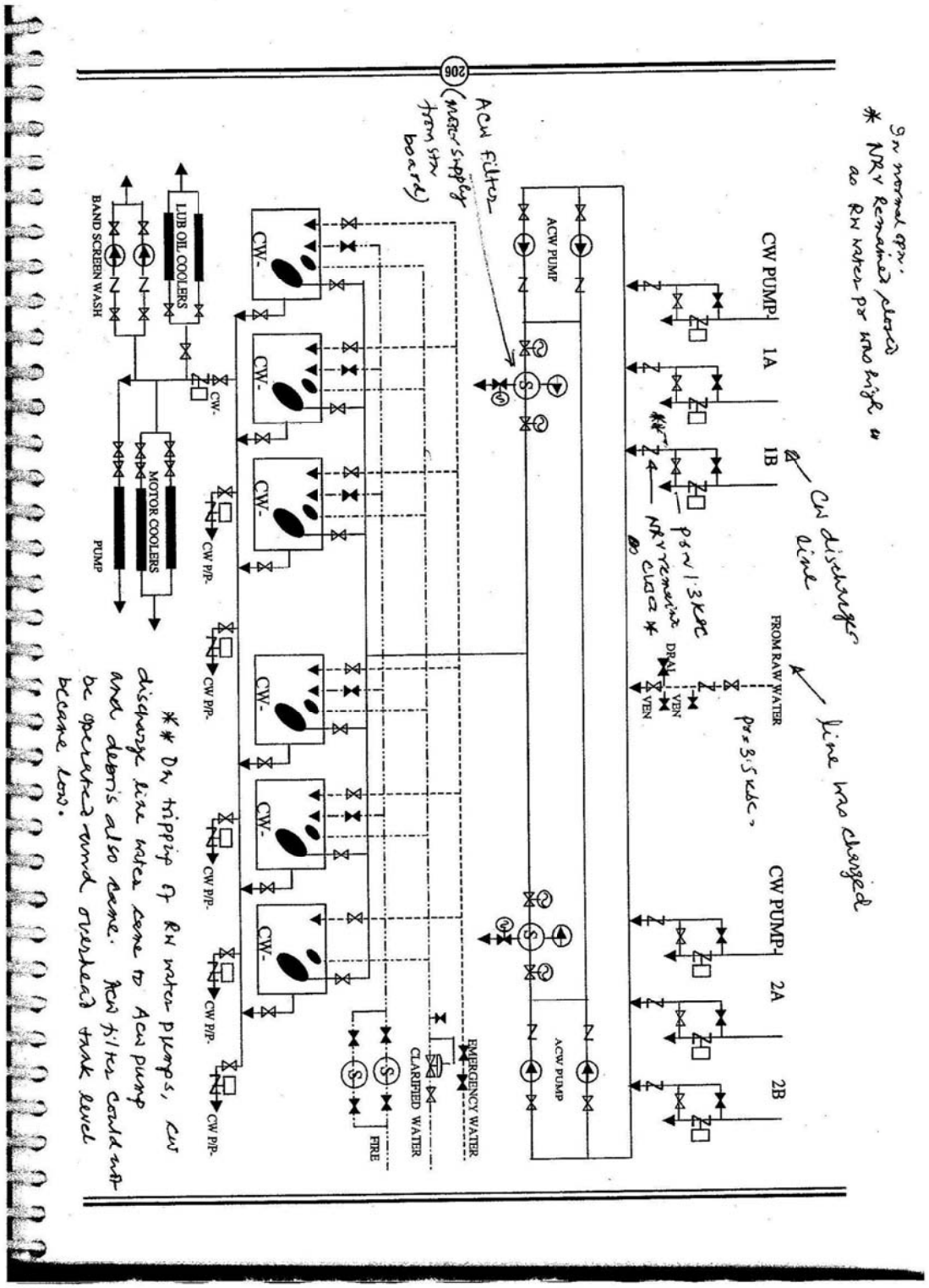
In normal op:
* NRV Remain closed
as RW water pr was high
CW discharge line
line was changed
CW PUMP 1A
1B
2A
2B
ACW PUMP
FROM RAW WATER
Pr 3.5 kgc
Pr 1.3 kgc
NRV remain closed
DRAIN
VEN
VEN
206
ACW filter
(water supply from stn board)
CW-
CW P/P-
LUB OIL COOLERS
MOTOR COOLERS
BAND SCREEN WASH
PUMP
EMERGENCY WATER
CLARIFIED WATER
FIRE
** On tripping of RW water pumps, CW discharge line valve come to ACW pump and debris also come. How filter could not be operated and overhead tank level became low.

Exhibit-5

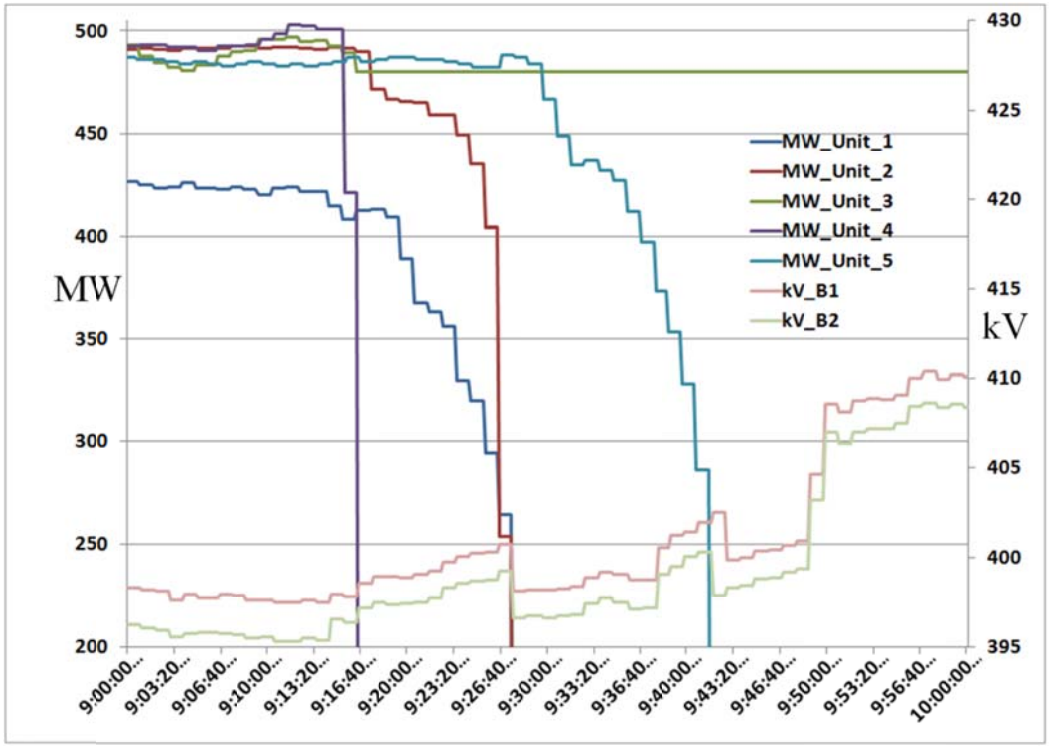

Fig: SCADA plots for Rihand bus voltage and rihand units power output.

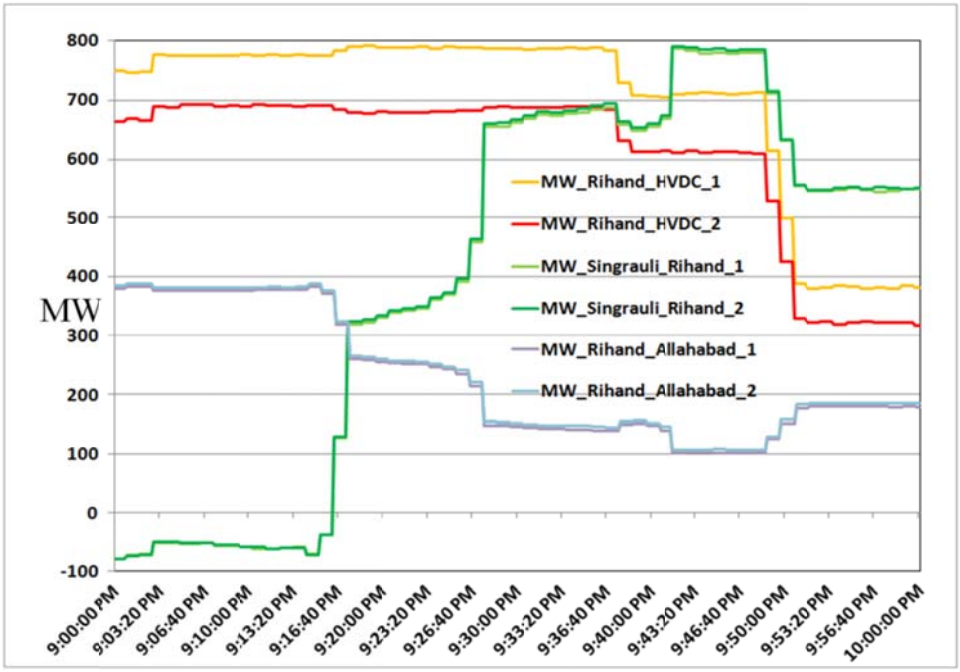

Fig: Power flow on different lines from Rihand STPS