# Eastern Regional Power Committee

**Minutes of the Meeting on "Total Power Failure in NALCO from 30.09.2021 to 02.10.2021" held on 15th February 2021 (Monday) through online MS Teams platform**

A total power failure occurred in the Smelter and Power (S & P) complex of NALCO from 30.09.2021 to 02.10.2021. In this context, A committee was constituted by the Member Secretary, ERPC to identify and analyse the cause of total power failure in NALCO smelter and power (S & P) complex and to recommend preventive measures and course of action to avoid occurrence of such type of disturbance in future.

The Constituted Committee is as follows.

1. Sh Shyam Kejriwal, Superintending Engineer, ERPC -Chairman
2. Sh Lenin B, Executive Engineer, ERPC - Member
3. Sh Sourav Sahay, Chief Manager (SO & SS) ERLDC -Member
4. Sh Md Ziaul Huda, GM(El), OPTCL -Member
5. Sh Anuj Panda, CGM (Electrical), NALCO -Member

Subsequently, the first meeting of the constituted committee was convened on 15.02.2021.

Chairman of the Constituted Committee welcomed the participants from NALCO, OPTCL & ERLDC. Further, he requested the NALCO representative to explain in detail the disturbances which occurred on 30th September 2020 to 2nd October 2020.Thereafter, NALCO representative explained the issues one by one in detail and the presentation of the same is enclosed at **Annexure-A.**

All the three events of disturbance discussed and analysed one by one with the probable causes and the necessary preventive measures has been suggested. The disturbances occurred as follows.

**Event 1**: Disturbance Occurred on 30th September 2020, Time - 22:36 hrs.
**Event 2**: Disturbance Occurred on 1st October 2020, Time - 04:07 hrs.
**Event 3**: Disturbance Occurred on 2nd October 2020, Time - 03:15 hrs.

**Event 1: Disturbance Occurred on 30th September 2020, Time - 22:36 hrs.**

NALCO representative informed during the disturbance on 30.09.2020, CPP was generating 874 MW with 8 units were in operation. Smelter plant was drawing 740 MW power & export to the grid was 45 MW.

At 22:36 hrs, 220 KV line isolator of unit-4 got opened due to malfunction causing fault in the 220 KV main bus. This caused severe disturbance in the power system leading to tripping of all the other running units. Subsequently, tripping of both the GRIDCO feeder lines connecting CPP with Meramundali substation resulting in total power failure. Prior to occurrence of this incident, all the GTs and smelter load feeders are connected with the Main Bus-II and Gridco feeder -III & IV present on Main Bus-I.

Further, it was informed that physical inspection was carried out in the 220 KV switchyard and it was observed that the line isolator 89C of unit-4 was in open condition. As per the interlock logic provided, the isolator should not open even with a command as long as the GCB is closed. Hence, it was confirmed the failure was due to malfunctioning of control circuit of isolator 89C. Further, it was noticed the moisture ingress in the control panel following heavy rain which occurred prior to the incidence. The presence of moisture in the panel could have short circuited the control and interlock circuit thereby energising the contactor responsible for opening of the isolator. Therefore, all the interlock circuits and etc were being redundant in that condition.

Subsequently, GRIDCO feeder-3 was tripped at 300 msec on "Transformer Buchholz" and it may be due to malfunctioning of Buchholz relay following high current disturbance in transformer. Regarding the operation of Buchholz for the Isolation transformer, NALCO mentioned that it might have operated because of sudden increase in current further updated as per the BDV & DGA analysis of transformer oil all the values are within the limit.

GRIDCO feeder-4 was tripped at 910 msec on overcurrent from Meramundali end, but no trip from NALCO end, therefore committee advised NALCO to ensure the proper relay coordination with in Meramundali substation in consultation OPTCL and the report in this regard is to be sent at the earliest.

Upon detailed explanation of the event-1 by the NALCO representative the following were advised:

- The 220 KV Switchyard configuration of NALCO CPP is Double Main & Transfer bus, therefore, the appropriate segregation of GT feeders and smelter load feeders among the two main buses maybe envisaged to enhance the reliability of the system.

- In response, NALCO representative informed a system study is being carried out by a consultant in this regard. Based on the study results the necessary changes will be

implemented. NALCO was advised to expedite the system study and report shall be submitted to ERPC & ERLDC by **the mid of March, 2021**.

- NALCO was advised to carry out all the necessary tests like BDV & DGA of the Transformer oil (including Isolation Transformer and GTs and other Interconnecting Transformers). Apart from this, other tests like Tan Delta and IR tests are also to be done for all the Transformers and bay (switchyard) equipment. on yearly basis as recommended. Thorough checking of marshalling boxes of CBs, Isolators, Earth Switches etc including checking of control circuits, battery etc are to be done. Relay co-ordination and protection settings are to be checked thoroughly and it shall be ensured that they are in service at all times. NALCO was advised to submit all the test reports as suggested above to ERPC & ERLDC at the earliest. Regular maintenance of bay equipment of all the generating units and smelter feeders, such as, breakers, isolators, earth switch, power & control circuits and marshalling boxes should be done as recommended.

- Committee advised NALCO to operate the isolators of all the bays in local mode until all the interlocks of all the generating units are checked.

- Ensure the redundancy of the DC Supply system for the control circuit & protection switchgear and preventive measures to be taken to avoid moisture ingress into control panels.

- Proper relay coordination is to be ensured with the GRIDCO feeders to avoid the cascading effect of the fault into the grid system and proper islanding of the system.

- Envisage the possibility of grouping the Generating units and smelter feeder loads to prevent entire loss of generation and load during this kind of disturbances.

NALCO was advised to send the detailed report of protection coordination settings to ERPC & ERLDC in consultation with OPTCL at the earliest.

**Event 2: Disturbance Occurred on 1st October 2020, Time - 04:07 hrs.**

NALCO informed that after power failure the start-up power from GRIDCO drawn for synchronization of units. Power was also supplied to smelters in phases by import from grid & own generation.

At 04:07 Hr, Voltage dip was observed and both the GRIDCO feeders and Unit -5 tripped and at the time of fault total Import through GRIDCO lines was 289 MW, 195 MVAR i.e. 348.6 MVA.

OPTCL informed that at 00:15 hrs., after the charging of 220 KV NALCO-1 circuit, NALCO requested to draw at least 100 MW in each circuit for about 40 min duration. It subsequently

increased to 162 MW in each circuit at 01:35 hrs which resulted in sparking at Meramundali end switchyard. SLDC, Odisha advised NALCO to reduce the loading of the circuit. At 04:07 hrs, due to heavy load, the line side pipe at Meramundali end of the above-mentioned circuit got broken as the pipes were 20-21 years old, and fell on the ground along with the breaker jumper causing Bus fault at 220kV Bus-1 of Meramundali S/s. All the elements connected with 220 kV bus-1 along with the bus coupler tripped.

Both GRIDCO feeders tripped at Meramandali end on Distance protection Reverse zone with a fault clearing time of 563 ms from fault initiation. And the Feeder-4 tripped at NALCO end after 623 m Sec after the fault in Distance Protection on Zone-I.

- OPTCL informed after occurrence of the above disturbance, tightening of all the nuts & bolts, jumper connections and any sort of loose connection have been taken care of all the bays of the in the switchyard of Meramundali. The committee observed it to be a clear case of lack of proper maintenance and expressed serious concern over such lapses considering the fact that the 220kV Meramundali – Nalco feeders are catering to a critical load such as smelter. OPTCL was advised to properly plan and ensure timely execution of all the maintenance activities. OPTCL representative ensured that such maintenance lapses shall not recur in future.

- OPTCL representative informed that the bus bar protection at Meramundali substation was not in service and the main controlling unit of the bus bar protection relay (siemens make) was defective for 2 months prior to the occurrence of this event. As the relays were in AMC they were sent to M/s Siemens, Goa for repair. However, it could not be repaired on time. It was observed that the bus bar protection scheme is not in service for almost 5 months due to pending repair works of Seimens make relay. The committee took serious took serious note of this and advised OPTCL to proactively co-ordinate with Seimens for repair of defective relay and ensure implementation of Bus bar protection at Meramundali **by the mid of March,2021**. OPTCL representative agreed.

- It was further informed by OPTCL that the individual earth resistance of bay equipment including LAs is more than 5 ohms. However, as per the stipulated guidelines of CEA (Measures relating to Safety and Electric Supply) Regulations,2010 and amendments thereof and IS 3043, the individual and grid earth resistance should be less than 5 ohms and 1 ohm respectively. Therefore, OPTCL was advised to take necessary corrective measures and ensure compliance with all the stipulated guidelines of CEA and IS. After compliance, OPTCL has to carry out earthing audit of the substation and submit the report to ERPC & ERLDC by the mid of March 2021. OPTCL representative agreed.

ERLDC informed that in the 96$^{th}$ PCC meeting OPTCL was advised to reduce the zone-4 timings till restoration of bus bar protection at Meramandali end.

- OPTCL informed that they have kept the time setting of zone-4 at 350 ms and intimated to ERLDC and also informed that high voltage in healthy phases were observed in the PMU plot during the fault which may be attributed to neutral shifting.
-

**Event 3: Disturbance Occurred on 2nd October 2020, Time - 03:15 hrs.**

NALCO representative informed on 02.10.2020 at 12:27 hrs Unit # 9 of NALCO CPP got tripped due to failure of DCS and the cause of failure could not be ascertained. Therefore, the generation of CPP reduced to 600 MW & import from grid increased to 190 MW and 218 MVAR. As MVAR import through GRIDCO feeder increased, voltage at CPP 220 KV bus dropped to 213.6 KV.

As the bus voltage dropped, generator current increased for the (same MVA), and MVAR generated decreased. This cumulative process continued and so the GRIDCO lines got overloaded and GRIDCO feeders tripped on overcurrent protection, thereafter, bus coupler got opened eventually NALCO system got islanded.

Further, NALCO bus voltage dropped to 117 KV after GRIDCO feeder trip and to reduced 106 KV after second GRIDCO feeder trip. Smelter load reduced drastically due to low voltage and as the load on the generators decreased, MVAR generation of units increased and NALCO bus voltage again increased.

The committee opined that the root cause of event-3 due to sudden tripping of Unit # 9 resulted in heavy VAR drawl by NALCO from grid. It might be beyond the reactive capability of the generating units.

NALCO also mentioned that they have planned to trip the smelter feeders internally by installing the directional overcurrent relay in the GRIDCO feeders rather than tripping the GRIDCO feeders.

NALCO was advised the following:

- NALCO was advised to ensure that DCS is functional at all times and regular maintenance of the same should be done so that causes of any disturbance does not get hampered.
- The committee further advised NALCO to co-ordinate with OPTCL to identify the possible worst-case scenarios (considering sudden outage of generating units, outage of OPTCL feeders or combination of both) and determine the VAR requirements during such scenarios by considering the dynamic grid conditions. and submit a report to ERPC and ERLDC at the earliest.
- NALCO was also advised to explore the possibility of reduce the load in smelter feeders during sudden outage of a Generating unit to limit the VAR drawl.

NALCO, in co-ordination with OPTCL, shall carry out the study and determine the VAR requirement as suggested above. The report shall be submitted to ERPC & ERLDC at the earliest.

NALCO & OPTCL are to carry out all the study and tests as suggested for the three events above and submit the reports to ERPC & ERLDC **by the mid of March, 2021**. Based on the outcome of submitted reports, the committed may convene 2nd meeting for further deliberation.

Finally, the committee advised NALCO to report any such incidences in near future to ERPC & ERLDC as and when the incidence happens.

The meeting ended with a vote of thanks to the chair.

*****

Annexure A

# Presentation on TOTAL POWER FAILURE at NALCO, ANGUL

(30.09.2020 02.10.2020)


**Presented By:**

**Mr. Anuj Kumar Panda,**
**D.G.M. (Electrical),**
**CPP, NALCO, ANGUL**

# Captive Power Plant– *at a glance*

- Presently the Captive Thermal Power Plant has a generation capacity of 1200 MW (10X120MW).
- It provides entire electric power requirement of Aluminium Smelter.
- it also feeds for approximately 35 MW of the power requirement to the alumina refinery through the State Grid.
- The location of captive thermal power plant at Angul is also strategic to the availability and supply of coal from nearby Talcher Coalfields. (MCL)
- The 18.5 KM captive railway system links the captive thermal power plant to the Talcher coalfields, enabling transport of the critical and bulk requirement of coal.

# Major Equipments for Generation and Distribution of Power:

- GENERATORS – 10 nos.
- GENERATOR TRANSFORMERS – 10 nos.
- UNIT AUXILIARY TRANSFORMERS – 10 nos.
- STATION TRANSFORMERS – 06 nos.
- SMELTER FEEDERS – 06 nos.
- GRIDCO FEEDERS -– 04 nos.

# SCOPE OF THE COMMITTEE:-

**Discussion on Total Power Failure at Nalco, CPP**

**On**

**Dt. 30.09.2020 (Event-1),**

**Dt. 01.10.2020 (Event-2)**

**&**

**Dt. 02.10.2020 (Event-3)**

# EVENT-01

## (Time: 22:36 Hrs, Date: 30.09.2020)

# BRIEF DESCRIPTION OF THE FAILURE:-

On Dt. 30.09.2020, CPP was generating 874 MW with 8 units in operation.
Smelter plant was drawing 740 MW & export to grid was 45 MW.

At 22.36 Hrs, 220 KV line isolator of Unit-4 got opened due to malfunction causing 220 KV Main Bus fault.

This caused severe disturbance in the power system leading to tripping of all units & trip-out of both feeder lines connecting CPP with GRIDCO Meramandali Substation.

This resulted in Total Power Failure.

# PRE-FAULT CONDITIONS:-

## BUS CONFIGURATION

| 220 kV BUS | CONNECTED BAY | REMARKS |
|---|---|---|
| Main Bus-I | GRIDCO Feeder –III & IV | 220 kV Bus Coupler was in 'Closed' Condition. |
| Main Bus-II | 1) GT-1 to 10<br>2) Smelter Feeder-I, II, III, IV, V, VI<br>3) SAT-I, II, III, IV,V & VI | |

***N.B.:- Unit -3 was under annual over hauling.***
***Unit -9 was under S/D and available.***

## LOAD CONFIGURATION

| LOAD DETAILS | MW | MVAR |
|---|---|---|
| CPP Generation (10.5 kV) | 874 | 497 |
| SMELTER Consumption (220 kV) | 740 | 389 |
| Grid Power flow (220 kV) | 45 | (-) 68 |
| Grid voltage | 223 kV | |
| Grid Frequency | 49.90 Hz | |

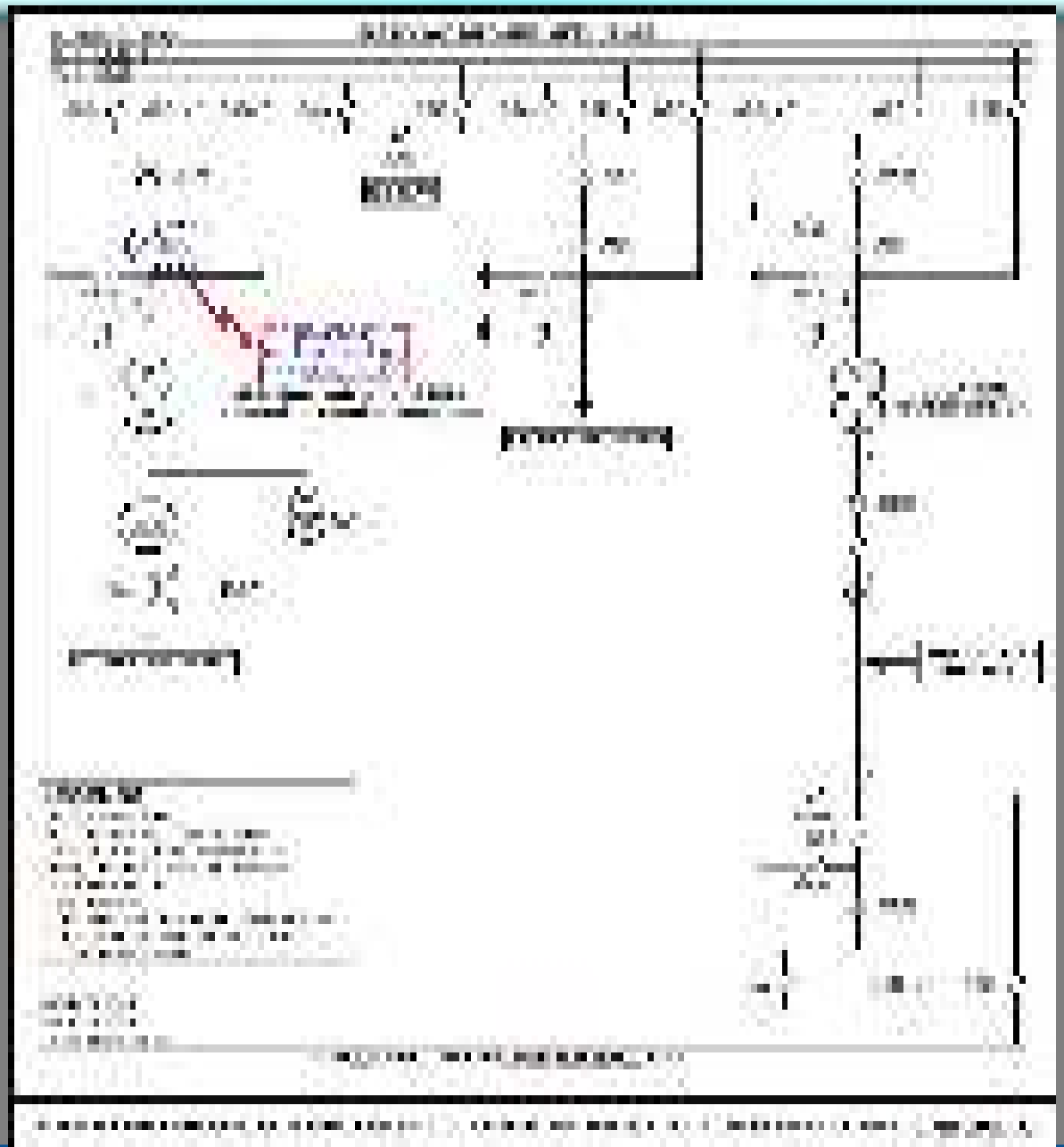
# OBSERVATION DURING THE FAULT:-

- At around, 22:36 Hr, sudden Voltage dip was observed at 220 kV switchyard system and all the running units including both the Gridco feeders tripped leading to Total Power Failure. Subsequently, Bus Coupler at 220 kV switchyard also tripped. All other outgoing feeders except Smelter Feeder-4 were in ON condition at 220 kV switchyard.

- Physical inspection was carried out in the 220 kV switchyard and it was observed that the Line Isolator 89C of Unit-4 was in Open condition.

- No abnormality was observed in any other equipment at CPP 220 kV switchyard.

# OBSERVATION DURING THE FAULT:-



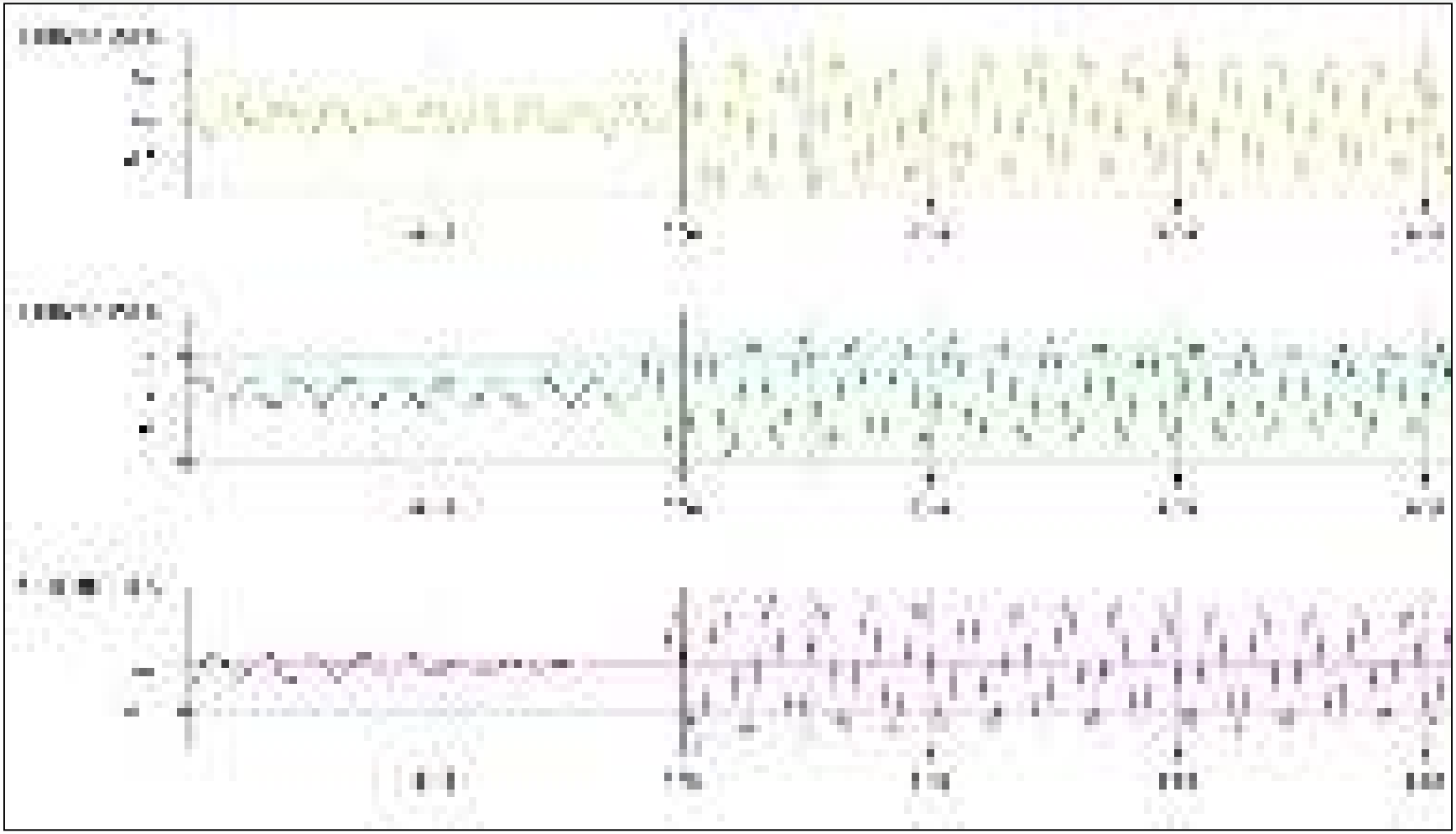
# INITIATION OF FAULT:-

- From the current waveform signature of the relays, it is seen that current in all units as well as GRIDCO feeders were normal till 22:36:46.168 Hrs., after which it has increased suddenly. For the present analysis this time is considered as time “t=0” and all timings are calculated on this base.

- Only there is abnormality in current of Unit-4 slightly prior (around 100 mSec) to this time. Hence, it was concluded that fault started in Unit-4. In fact after the incident it was found that the line isolator 89C was in open condition. There were heavy flashover marks on its moving contacts and ‘Y’-phase arcing rod. Hence, it can be concluded that opening of the isolator has initiated the problem.

- From close observation of current waveform prior to time 0, it is seen that B phase current has temporarily fallen to 0 slightly (few cycles) before increase at time 0. ‘B’-phase contact of 89C might have opened first with subsequent opening of other phase contacts. When contacts of all phases began to open on load, heavy flashover might have occurred leading to 3 phase short circuit.

# INITIATION OF FAULT:-



- Current waveform of 220 KV side of GT- 4 downloaded from Numerical Relay furnished below, which indicates a 3 phase short circuit.

# INITIATION OF FAULT:-

- Current in all source feeders, i.e., GRIDCO feeder-3 (Meramundali Circuit–2), GRIDCO feeder-4 (Meramundali Circuit–1) and all the running Units-1,2 ,4,5,6,7,8 &10 has increased.

- Current has increased (at 220 KV level) from 270–280 Amp to 1000-1200 Amp (approx) in all the running Units.

- Current has increased (at 220 KV level) from 115 Amp To 3500-4000 Amp (approx) in both the Gridco Feeders.

# ISOLATOR IMAGE TAKEN AFTER THE FAULT:-

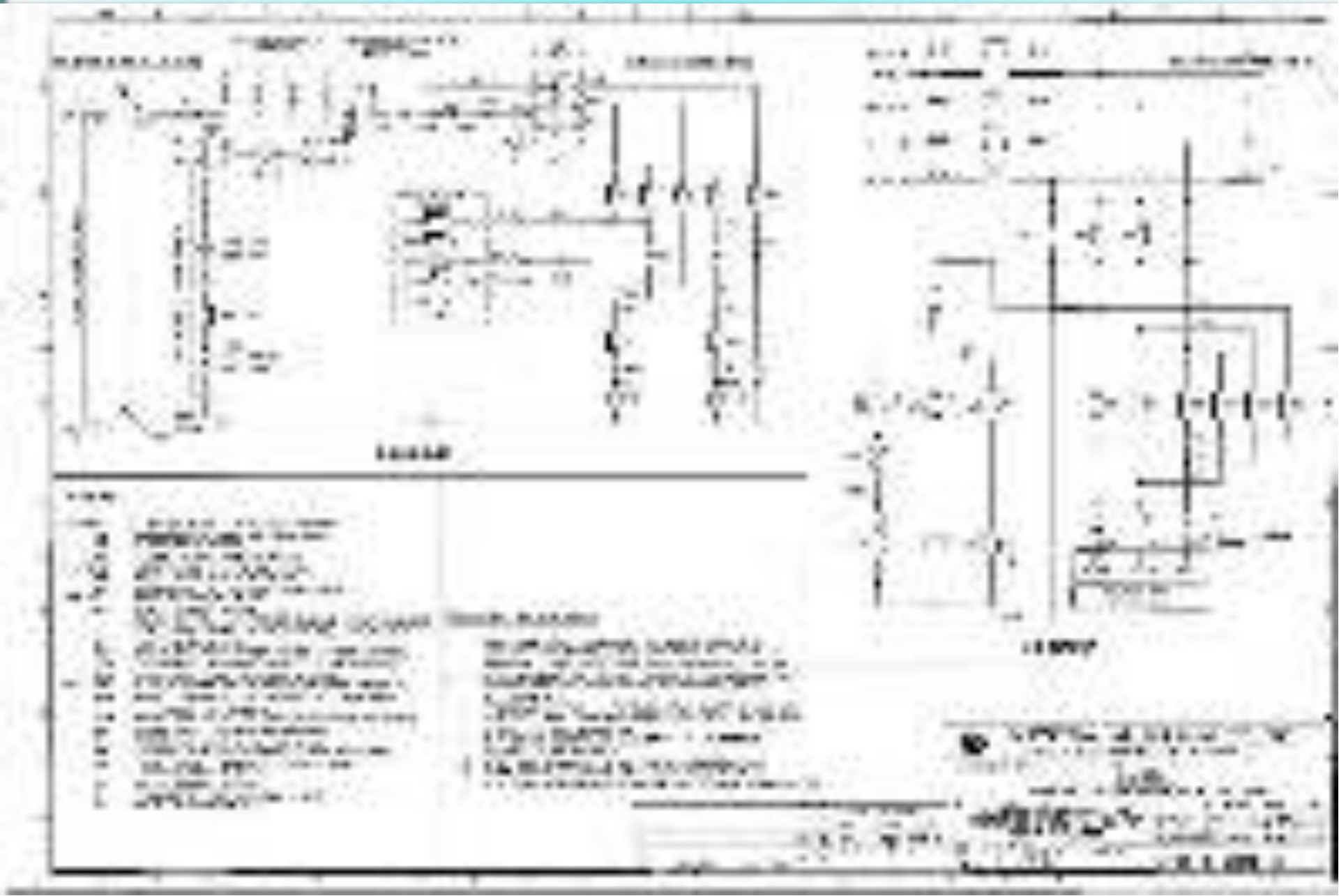
# OPENING OF ISOLATOR 89C:-

- As mentioned above the 220 KV isolator 89C of Unit-4 opened automatically. As almost full load current was flowing through it, breaking of the current resulted in heavy flashover and consequential short circuit. This seems to be the root cause of problem leading to subsequent events. As per the interlock provided, the isolator should not open even with a command as long as the GCB is closed. Hence, it was a complete malfunctioning of control circuit of isolator 89 C.

- It was seen that there was moisture ingress in the control panel following heavy rain which occurred prior to the incidence. The presence of moisture in the panel could have short circuited certain portion of control and interlock circuit thereby energising the contactor responsible for opening the isolator.

- As per the scheme, the +ve of control 220 volt DC voltage should not be available in the panel when GCB is in closed condition. Hence, the circuit was further analysed. It was seen that in the 220 volt DC system, the positive side is almost at earth potential.

# CONTROL CIRCUIT OF ISOLATOR 89C:-

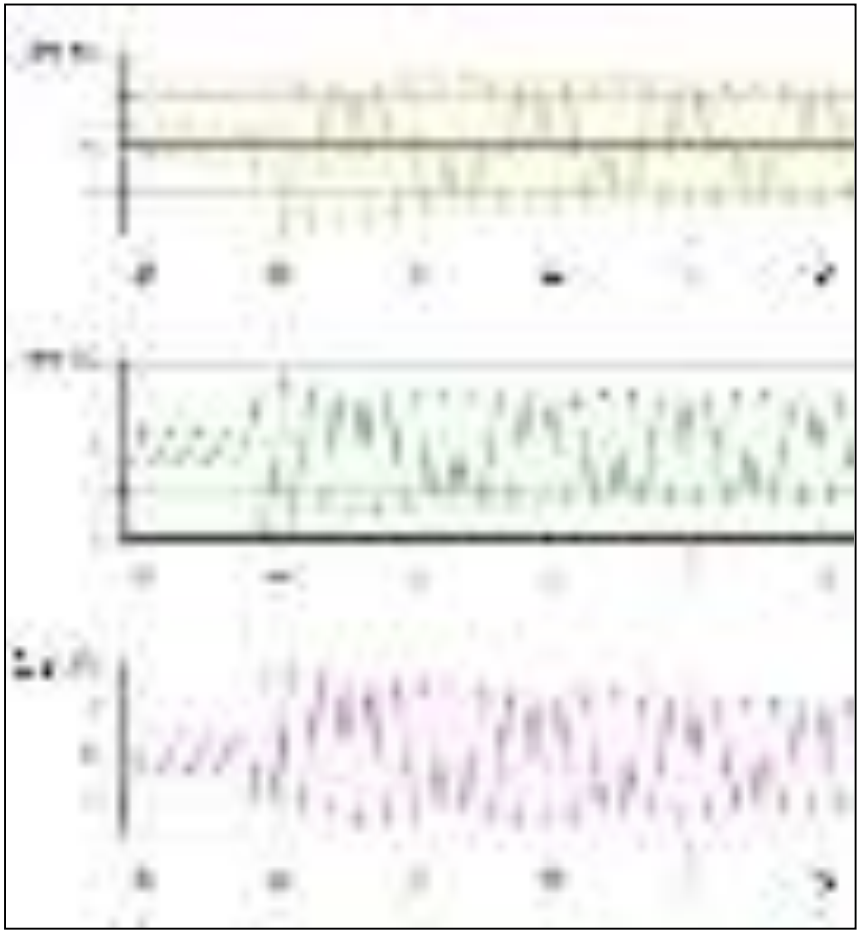


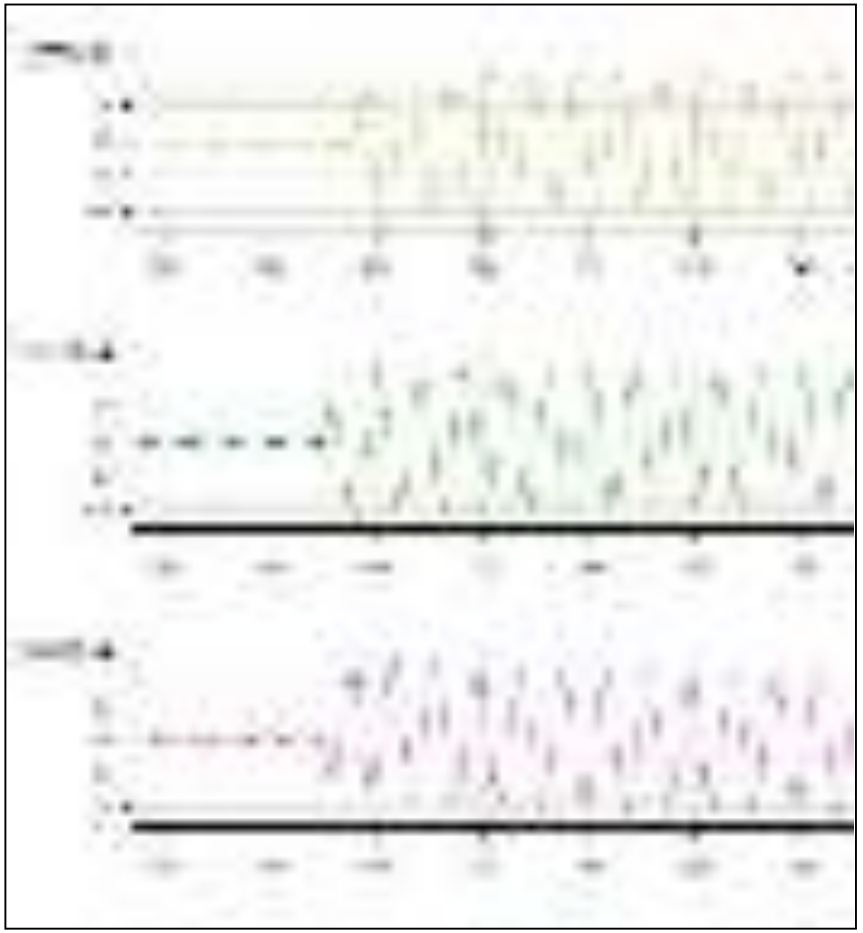
# OPENING OF ISOLATOR 89C:-

From control circuit , in case of terminals TB4-3, TB4-6 orTB4-7 or terminal of limit switch LS2 is connected to earth, the contactor might have energised with extension of 220 volt DC supply and open the isolator. Hence, the most probable cause seems to be earthling of any of the above terminals due to water ingress.

# CURRENT WAVEFORM DURING FAULT:-

| Current waveform : GT-1 | Current waveform : GRIDCO-4 |
| --- | --- |





CURRENT IN SOURCE FEEDERS

# CURRENT IN LOAD FEEDERS:-

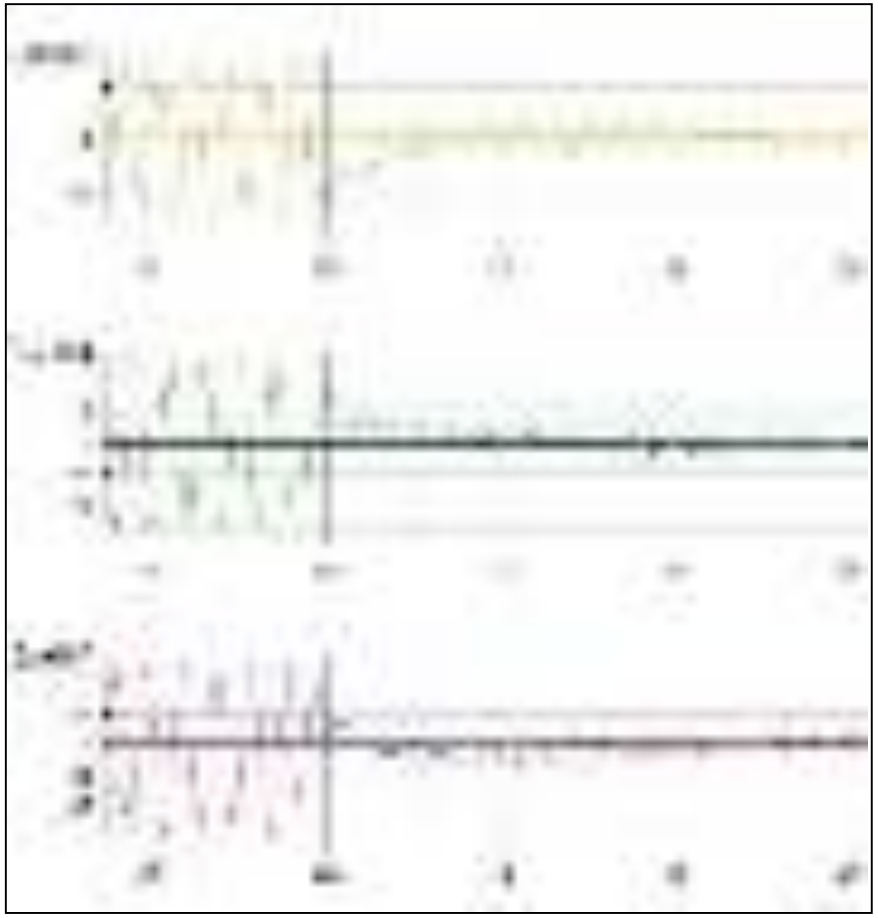
- It is seen that in all loads the current had fallen to almost zero very fast after time 0, though there was no tripping except Smelter feeder-4. This was due to voltage collapse in 220 KV Bus resulting in loss of load in outgoing feeders like Smelter feeders and Station transformer feeders. Moreover, Potline loads also became zero due to tripping of Rectifier groups at Smelter due to low voltage.

- Current waveform of one Smelter feeder and one Station Aux Transformer (as recorded in Busbar differential relay) are shown for reference.

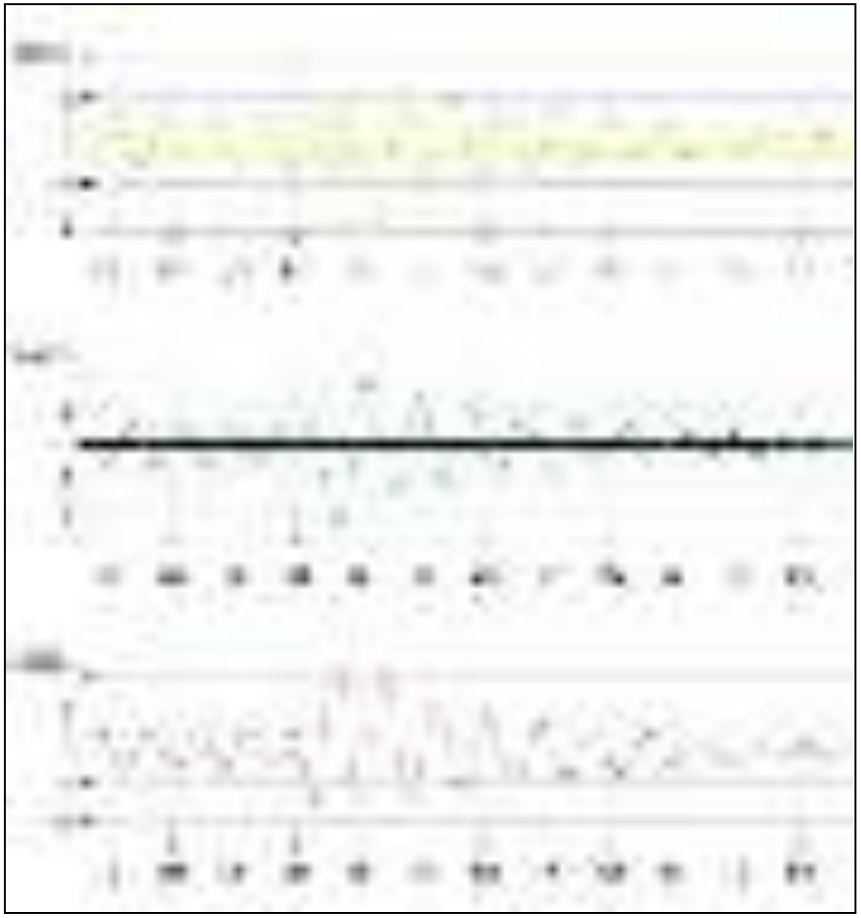
- Temporary increase of current in Station transformers before dying down to very low value is probably due to running motors feeding to fault as induction generators.

# CURRENT WAVEFORM DURING FAULT:-

**Current waveform : Smelter Feeder-4**

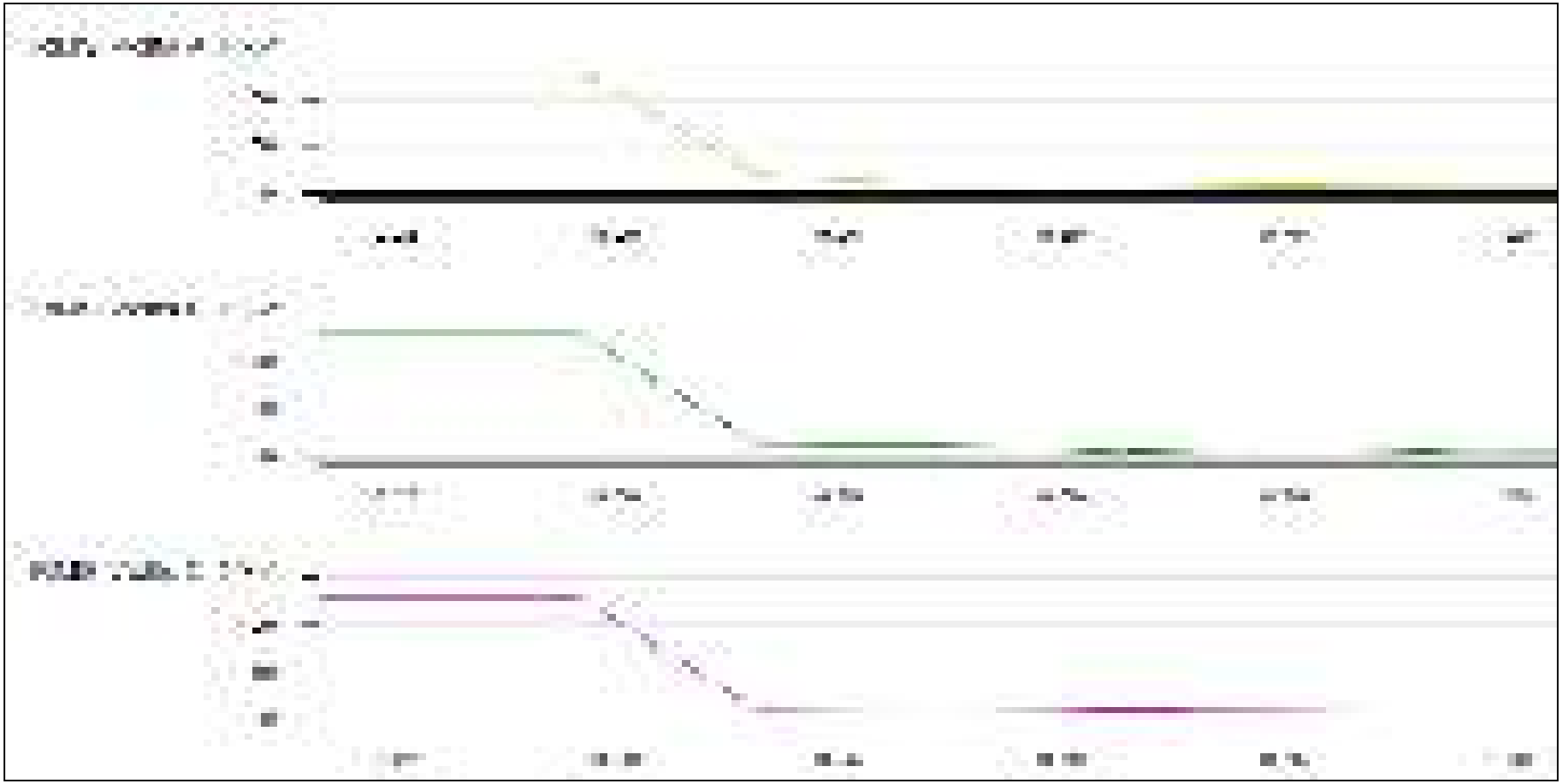


**Current waveform : Station Aux Tr-1**



**CURRENT IN LOAD FEEDERS**

# VOLTAGE WAVEFORM DURING FAULT:-



- *As observed, three phase Bus Voltage of Nalco during the fault has reduced from 223 kV to 17 kV.*

# TRIPPING OF GRIDCO FEEDERS:-

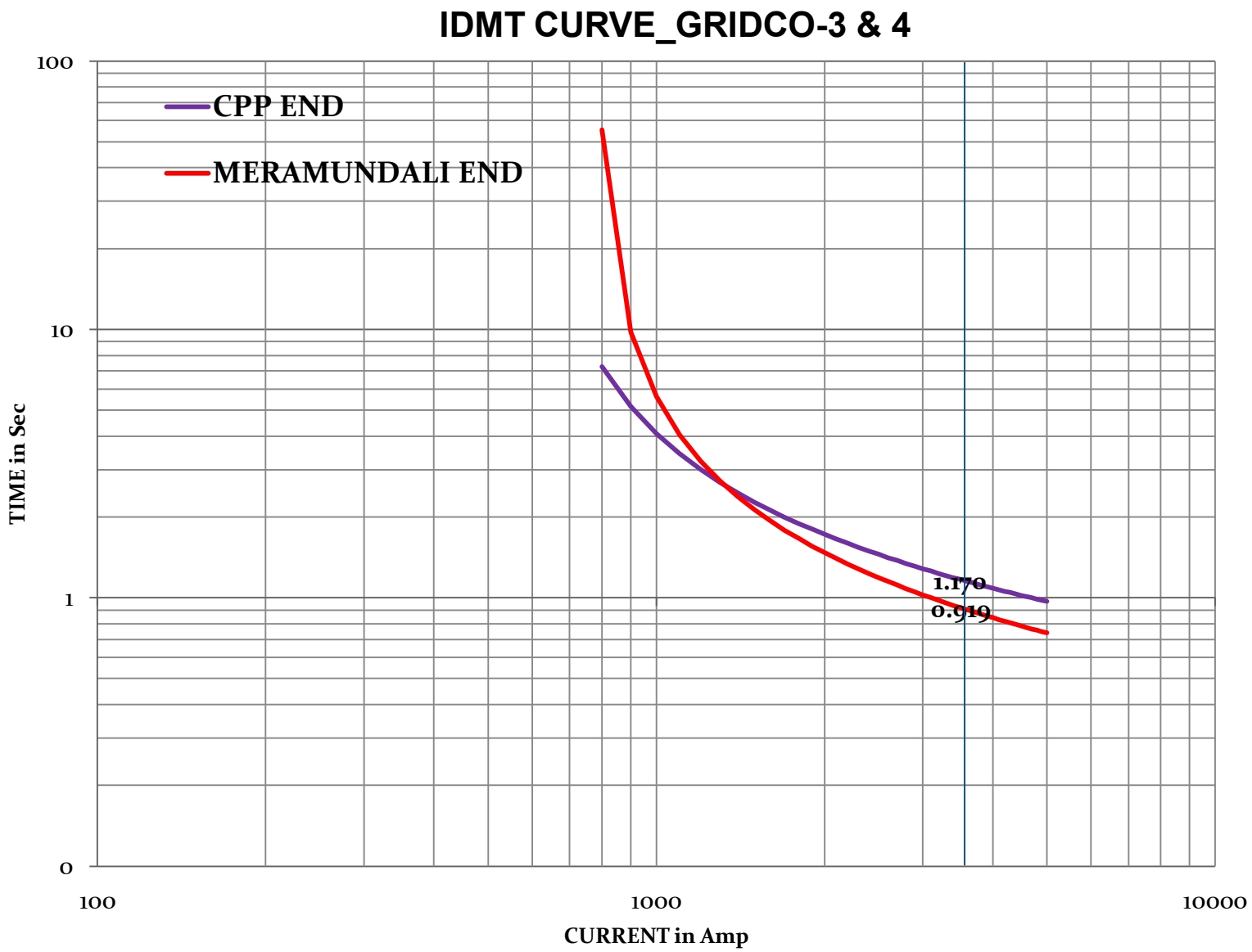
**GRIDCO feeder-3 :**

- The feeder tripped at 300 mSec on 'Transformer Buchholz'. This tripping is not very clear. It may be due to malfunctioning of Buchholz relay following high current disturbance in transformer.
- However, the feeder would otherwise have tripped on ‘over-current’ and this did not create any additional problem.
- After this, current in Bus Coupler fell to almost half as desired.

**GRIDCO feeder-4 :**

- It tripped at 910 mSec on ‘over-current’ at Meramandali end, but did not trip at NALCO end.
- Considering over-current relay settings at Meramandali and CPP, this is in order as calculated for a fault current of 3600 Amp.

# TRIPPING OF GRIDCO FEEDERS:-



# TRIPPING OF GENERATING UNITS:-

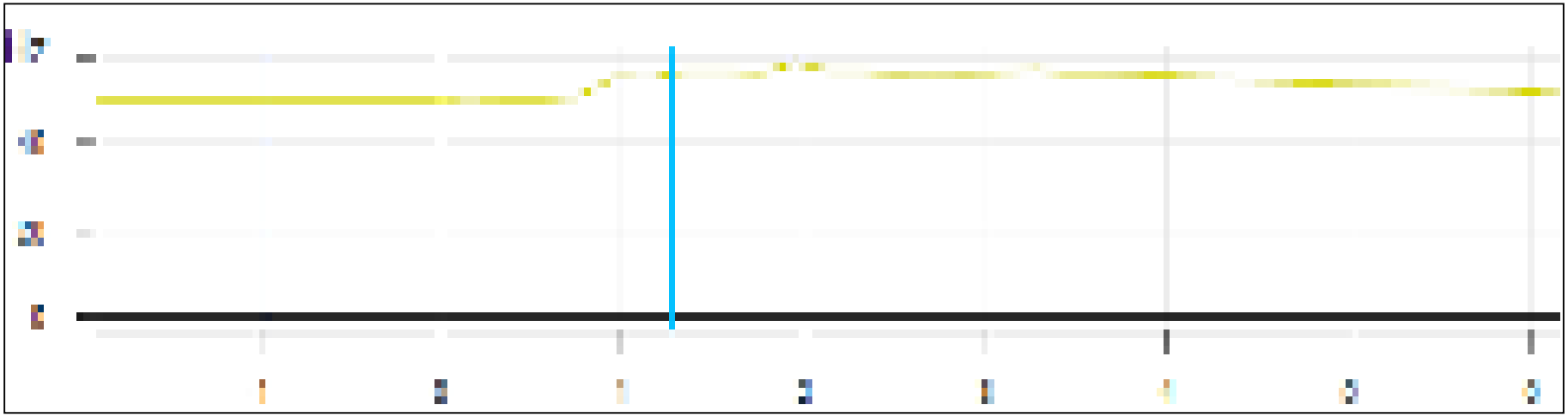
- After 910 mSec., both GRIDCO feeders had tripped and load in all outgoing load feeders (Smelter feeders and Station transformers) had fallen to almost zero due to voltage collapse.

- So, it was an island condition with the Generators in operation with negligible load. This resulted in over speeding of units. It is observed from records that speed started increasing just after tripping of GRIDCO feeders and gradually increased to 58.168 Hz.

- Subsequently, some units tripped on Electrical protection and others tripped on turbine over speed protection as mentioned below. After tripping of turbines, generator speed came down and in those units GCBs opened on under frequency.

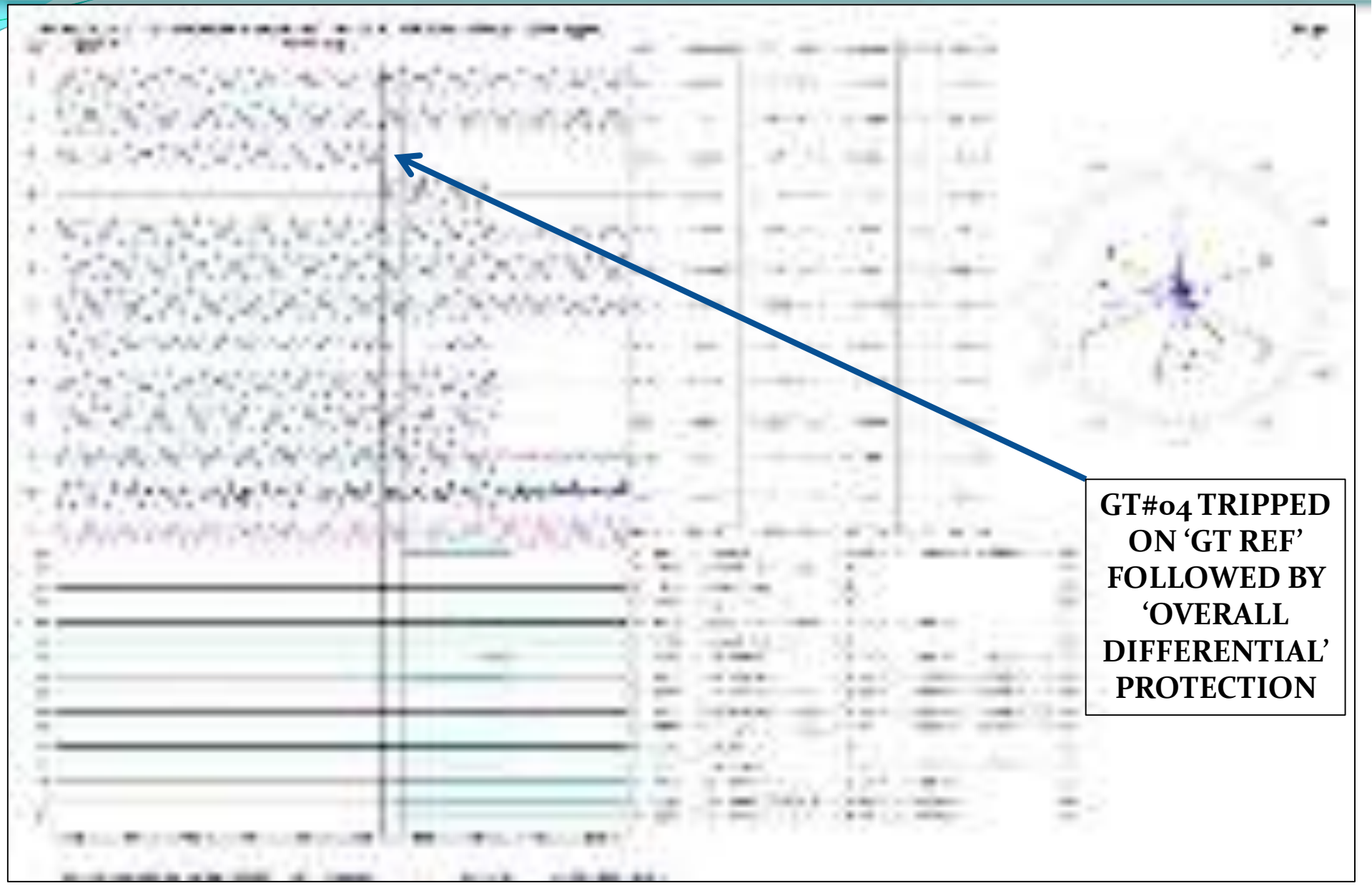
# TRIPPING OF GENERATING UNITS:-

Frequency variation showing both over-frequency and under-frequency is shown below.



- Unit-10 tripped on Generator Dead machine protection
- Unit-4 tripped on GT Restricted Earth fault.
- Unit - 7,8 tripped on voltage controlled over-current protection.
- Unit-1,2,5,6 tripped on Turbine over-speed trip and GCBs tripped subsequently.

# WAVEFORM FOR GT#04:-



# OPERATION OF PROTECTION RELAYS

# i) Bus bar Differential Protection:-

- As desired, it has operated, but did not trip the breakers as it was kept in alarm mode.

- This was not kept in ‘trip mode’ under the apprehension that mal-operation of the relay would cause a total power failure.

- However, even if the relay had been in trip mode, it would have resulted in total power failure in CPP-Smelter system as occurred, but with a smaller duration of fault current. Moreover, as Gridco Feeders were in Main Bus-1, which would not have tripped, power revival process would have been comparatively quicker.

# ii) GRIDCO feeder :-

- GRIDCO feeder-3 tripped on ‘Buchholz’ protection.

- GRIDCO feeder-4 tripped on ‘over-current’ at Meramandali end at 910 mSec, but not at NALCO end which is in order as per the setting, as shown below.

***Calculation based on a fault current of 3600 Amp.***

- **Meramandali end**: Setting – 780 Amp., TMS- 0.2
  Normal time = 0.14 /( ((3600/780)^0.02)-1) = 4.5073 Sec
  With TMS of 0.2, Tripping time is 0.2X 4.5073 = 0.90 Sec
- **NALCO end**: Setting – 600 Amp., TMS- 0.3
  Normal time = 0.14 /( ((3600/600)^0.02)-1) = 3.8372 Sec
  With TMS of 0.3, Tripping time is 0.3X 3.8372 = 1.15 Sec

- GRIDCO feeders did not trip at NALCO end on Distance protection. Though the relays have sensed the fault in Reverse zone, fault current became zero before their time setting due to tripping of feeders at Meramandali end.

# EVENT-02

## (Time: 04:07 Hrs, Date: 01.10.2020)

# BRIEF DESCRIPTION OF THE FAILURE:-

Start-up power was made available from the GRIDCO and one unit (Unit-5) was brought back with other units in line and were about to be restored one after another.

Power was also supplied to Smelter in phases by import from grid & own generation. Import from grid was 289 MW.

There was a fault in the 220 KV Nalco-Meramandali GRIDCO Feeder-4 bay at Meramandali end at 04.07 Hrs on Dt. 01.10.2020 leading to tripping of both GRIDCO feeders at Maramandali.

This resulted in disconnection of CPP from the grid leading to severe power instability & subsequent Total Power Failure.

After availability of start-up power, units were brought back one after another.

# PRE-FAULT CONDITIONS:-

## BUS CONFIGURATION

| 220 kV BUS | CONNECTED BAY | REMARKS |
|---|---|---|
| Main Bus-I | GRIDCO Feeder –III & IV | 220 kV Bus Coupler was in 'Closed' Condition. |
| Main Bus-II | 1) GEN -5<br>2) Smelter Feeder-I, II, III, IV, V, VI<br>3) SAT-I, II, III, IV,V & VI | |

***N.B.:- Unit -3 was under annual over hauling.***

.

## LOAD CONFIGURATION

| LOAD DETAILS | MW | MVAR |
|---|---|---|
| CPP Generation (10.5 kV) | 81 | 80 |
| SMELTER Consumption (220 kV) | 327 | 196 |
| Grid Power flow (220 kV) | (-) 289 | (-) 195 |
| Grid voltage | 225 kV | |
| Grid Frequency | 50.12 Hz | |

# OBSERVATIONS DURING THE FAULT:-

- At 04:07 Hr, Voltage dip was observed and both the GRIDCO feeders and Unit - 5 tripped leading to Total Power Failure.

- Both GRIDCO Breakers tripped at Meramandali end.

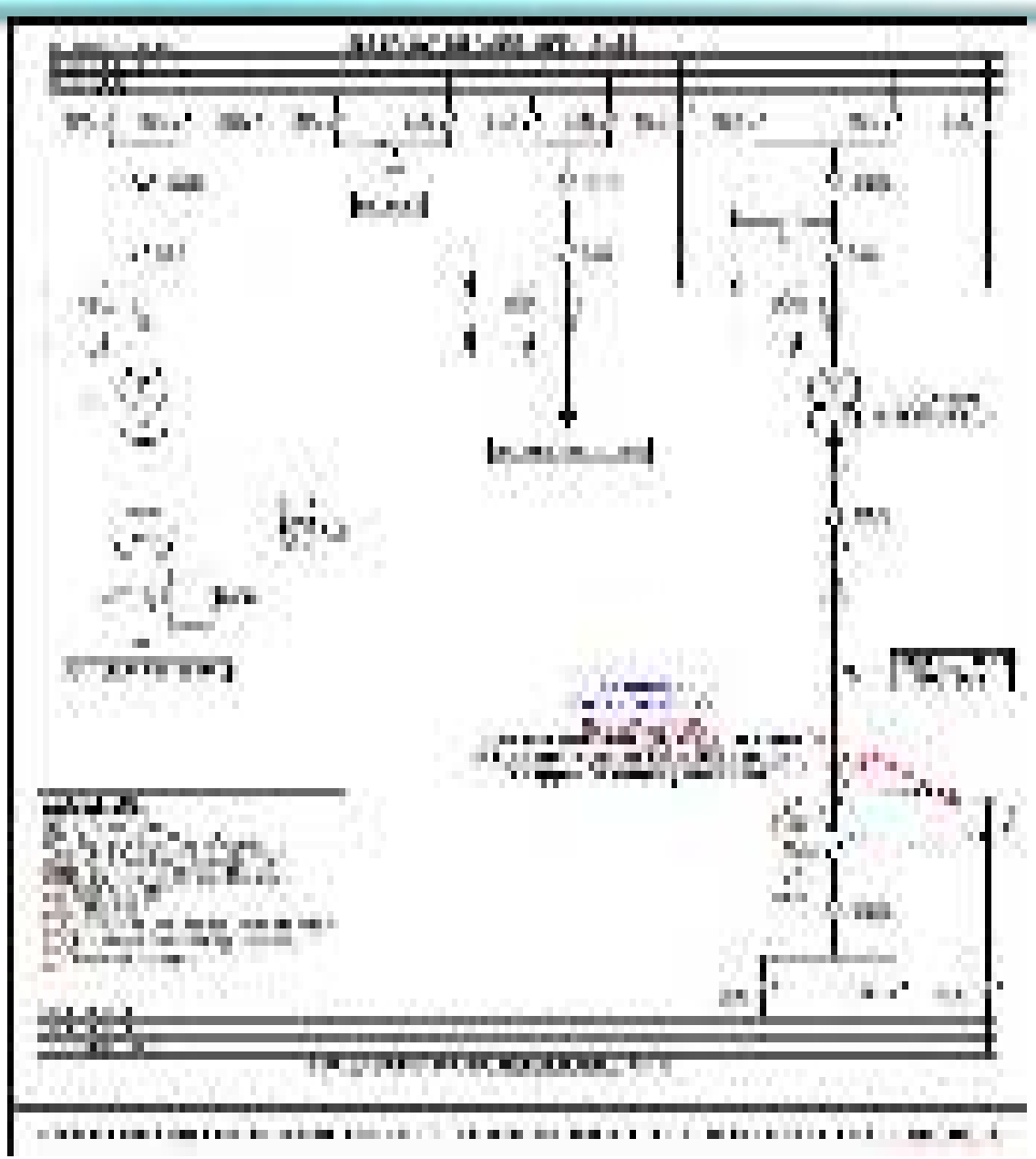
- At NALCO end GRIDCO feeder-4 tripped and GRIDCO feeder-3 breaker was in ON condition.

# INITIATION OF FAULT:-

Meramandali Switchyard was contacted immediately after the Total Power Failure followed by visit of NALCO personnel to Meramandali grid.

It was found that there was fault in GRIDCO Feeder-4 B-phase line isolator and the Pipe bus connected to it at Meramandali switchyard.

This resulted in Bus Fault at Mermandali Grid.



# VOLTAGE LOGGED DURING FAULT:-

## GRID side Voltage

| GRIDCO side Voltage | Just before the fault | During the fault |
|---|---|---|
| R-N | 130 KV | 116 KV |
| Y-N | 130 KV | 116 KV |
| B-N | 130 KV | 24 KV |

## NALCO side Voltage

| NALCO side Voltage | Just before the fault | During the fault | Just after the fault with Unit-5 operating |
|---|---|---|---|
| R-N | 122 KV | 103 KV | 95 KV |
| Y-N | 124 KV | 111 KV | 95 KV |
| B-N | 123 KV | 40 KV | 95 KV |

*The above voltage magnitudes are recorded at 220 KV Bus at CPP switchyard .*

# TRIPPING OF GRIDCO FEEDERS:-

- **Current flowing in Grid Lines just before the Fault**

  - At the time of fault total Import through GRIDCO lines was 289 MW, 195 MVAR i.e. 348.6 MVA.

  - Bus voltage was 1.732 X 130 = 225 KV.

  - So, total current was 348.6 / (1.732X 225) = 894 Amp.

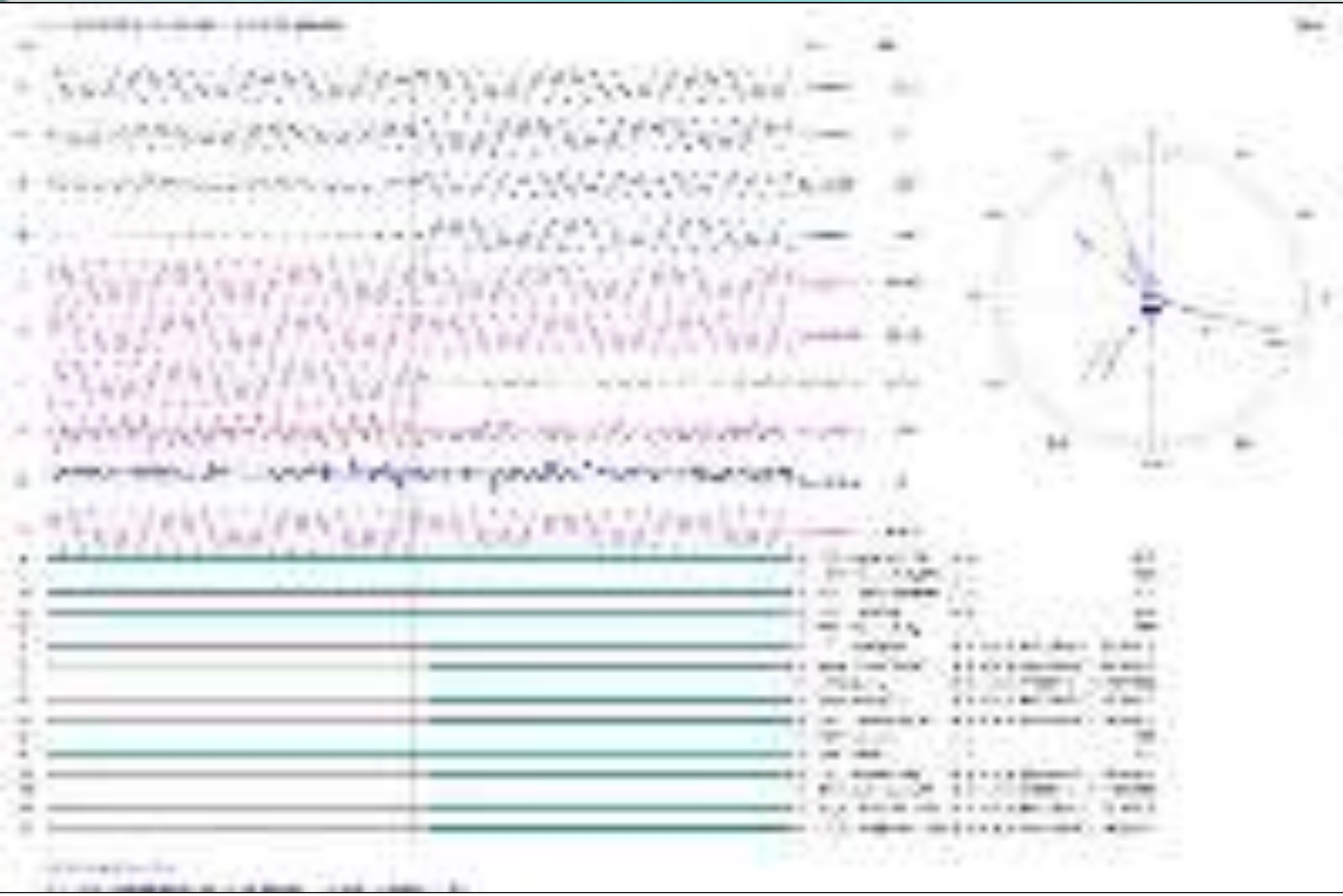
  - Current in each feeder = 894/2 = 447 Amp.

- **Tripping of Gridco feeders**

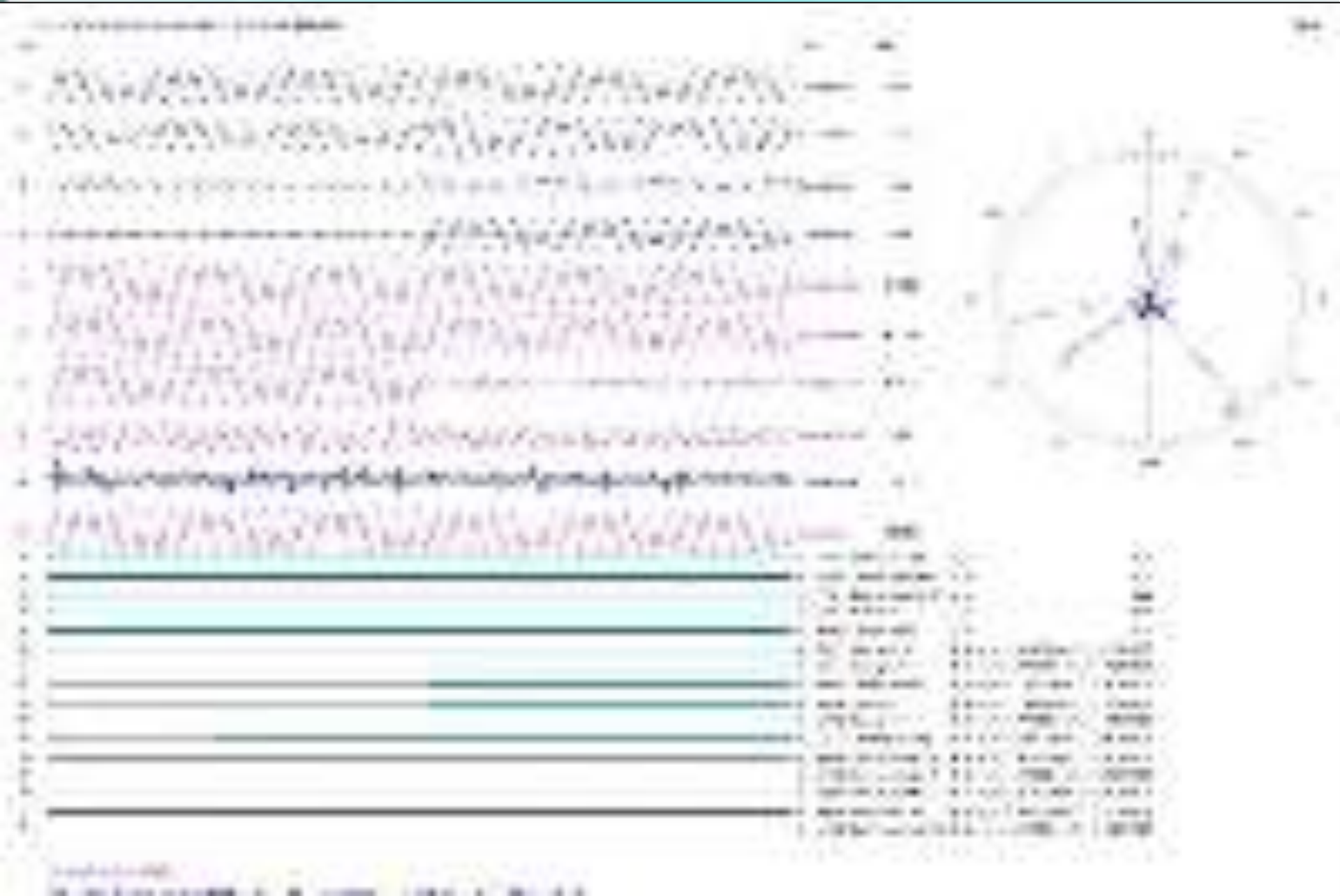
  - Both GRIDCO feeders tripped at Meramandali end on Distance protection Reverse zone with a fault clearing time of 563 mSec from fault initiation.

  - Feeder-4 tripped at NALCO end after 623 mSec after the fault in Distance Protection (on 1$^{st}$ zone)

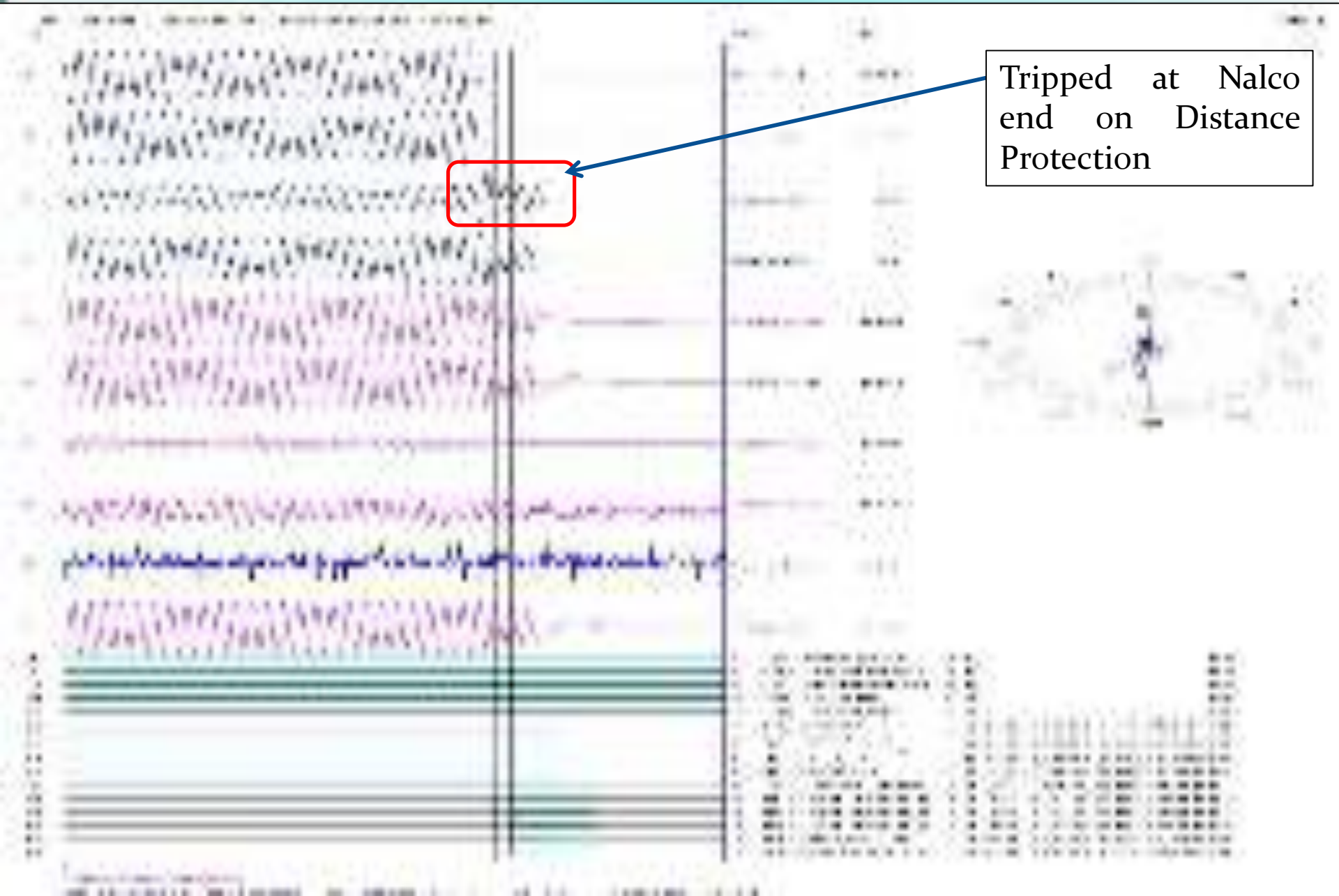
# WAVEFORM OF GRIDCO FEEDER#03:-



# WAVEFORM OF GRIDCO FEEDER#04:-



# WAVEFORM OF GRIDCO FEEDER#04:-



# TRIPPING OF GENERATOR#05:-

After tripping of both GRIDCO Feeders only Generator-5 was operating, but the load connected was very high compared to generation.

Unit Generation increased to 125 MW, 109 MVAR.

System voltage fell to around 160 KV. Generator terminal voltage was 8.22 KV.

As a consequence of MW shortfall, frequency decreased.

Bus-Coupler got opened on df/dT protection after 1576 mSec and Unit-5 tripped on under frequency after 6923 mSec.

This resulted in total power failure.

# OPERATION OF PROTECTION RELAYS:-

- Both the GRIDCO feeders tripped on Distance protection at Meramandali end on reverse zone. During the fault, before tripping of GRIDCO feeders, current to fault from CPP side were as follows taken from Distance Relays of Nalco.

- Gridco-3 - 1000 Amp. Gridco-4 - 896 Amp.

- After tripping at Meramandali end , Current feeding from Nalco end to Grid were
  - Gridco-3 : 0 Amp ( As it was not feeding to fault):
  - Gridco-4 : 2300 Amp

- At this higher current Gridco-4 Distance relay picked up and cleared fault in 1st zone. So, fault clearing time after sensing was 623-563 = 60 mSec.

# EVENT-03

## (Time: 15:40 Hrs, Date: 02.10.2020)

# PRE-FAULT CONDITIONS:-

## BUS CONFIGURATION

| 220 kV BUS | CONNECTED BAY | REMARKS |
|---|---|---|
| Main Bus-I | GRIDCO Feeder –III & IV | 220 kV Bus Coupler was in 'Closed' Condition. |
| Main Bus-II | 1) GT-1, 2, 4, 5, 6 & 9<br>2) Smelter Feeder-I, II, III, IV, V, VI<br>3) SAT-I, II, III, IV,V & VI | |

***N.B.:- Unit -3 was under annual over hauling.***
***Unit -7, 8 & 10 were under S/D.***

## LOAD CONFIGURATION (At 12:25 Hrs)

| LOAD DETAILS | MW | MVAR |
|---|---|---|
| CPP Generation (10.5 kV) | 699 | 403 |
| SMELTER Consumption (220 kV) | 725 | 400 |
| Grid Power flow (220 kV) | (-) 101 | (-) 160 |
| Grid voltage | 227 kV | |
| Nalco Bus voltage | 218 kV | |

# DESCRIPTION OF THE FAILURE:-

**At about 12:27 Hrs**

Unit-9 got Tripped. After Unit -9 tripping, CPP Generation reduced to 600 MW. (as recorded at around 13: 00 Hrs.)

Import from Grid increased to 190 MW (from 101 MW) and 218 MVAR (from 160 MVAR).

Power import from the grid was continued to cater Smelter Power requirement as reduction of Pot Line current was not possible considering the healthiness of pots .

As MVAR import through GRIDCO feeder increased, voltage at CPP 220 KV Bus dropped to 213.6 KV. Light Up activities of Unit -9 was in progress.

# DESCRIPTION OF THE FAILURE:-

**At about 15:30 Hrs**

Five Unit operations at CPP with power import from the Grid continued and Unit -9 is in the process of Synchronization.

At 15:30 Hrs, CPP generation was 590 MW and Import from Grid was 193 MW and 274 MVAR.

With MVAR import of 274 MVAR, i.e. 137 MVAR in each line, CPP Bus voltage was 207 KV, around 18 KV less than Grid voltage of 225 KV. Pot Line Load was maintained at the same level.

As Bus voltage dropped, Generator current increased (for same MVA), and MVAR generation of Unit decreased. Above Phenomena happened in all the five running Unit s.

# DESCRIPTION OF THE FAILURE:-

**At about 15:42 Hrs**

At 15: 42 Hrs., suddenly , Grid voltage dropped by 4 KV to 219 KV resulting further decrease of generator MVAR and increase in MVAR import from the Grid .

Import from Grid was 257 MVAR in each feeder resulting increase of Line Current of each Grid feeders . Line current of each feeder increased to 686 Amp.

Grid Lines got overloaded and both feeders tripped on O/C protection at Nalco ,CPP end .

GRIDCO-4 (Circuit -1) tripped at : 15.42:02.921 Hrs.

GRIDCO-3 (Circuit -2) tripped at : 15:42:03.111 Hrs.

# DESCRIPTION OF THE FAILURE:-

**At about 15:42 Hrs**

Subsequently, with opening of Grid Line Breaker, Bus-coupler got opened at 15:42:03.202 Hrs and CPP system got Islanding Command with opening of B/C.

NALCO system operated in island. NALCO Bus voltage dropped to 117 KV after GRIDCO feeder trip and to 106 KV after second GRIDCO feeder trip.

Smelter load reduced drastically due to low voltage. This sudden load reduction resulted in over frequency.

Increase in frequency resulted in tripping of units in turbine over speed protection. But the Generators were not tripped.

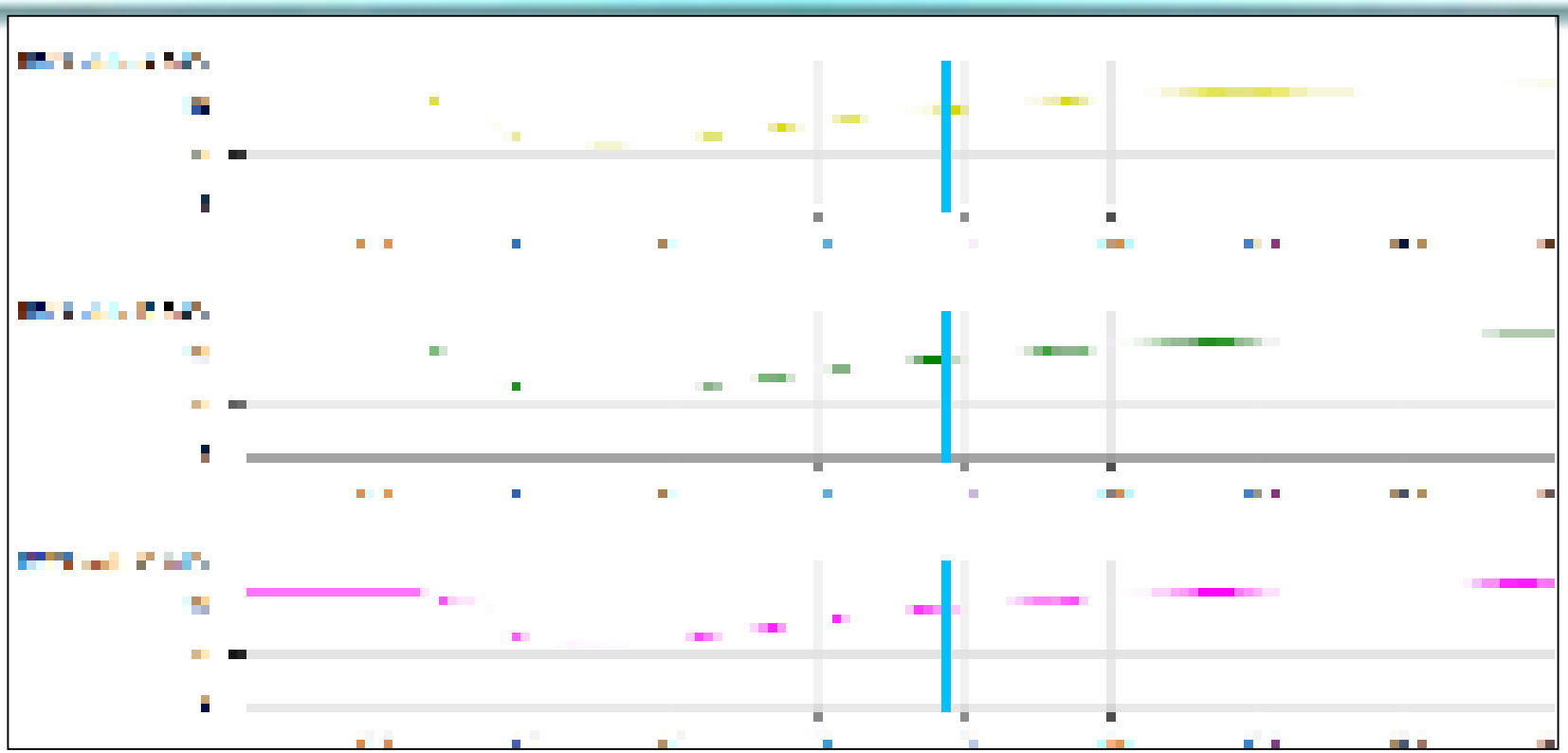
As the load on generators decreased, MVAR generation increased and NALCO Bus voltage again improved. After tripping of turbines, speed decreased and Generators tripped on under frequency protection.

# TRIPPING OF UNITS:-

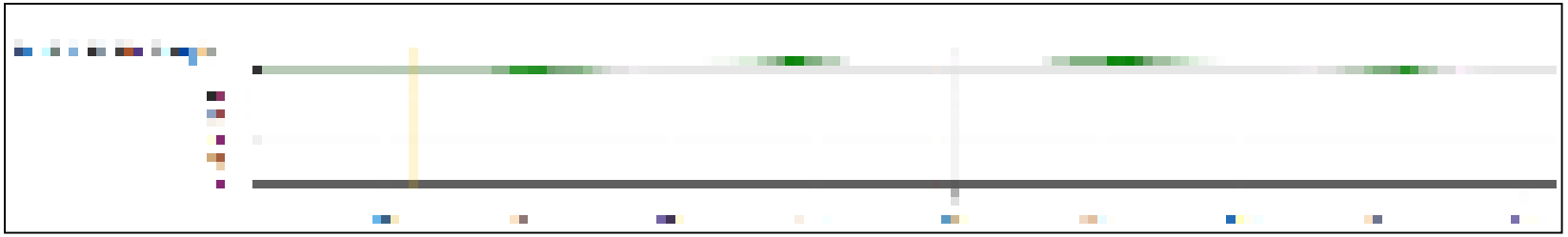
| Unit | Turbine Trip Time | Generator Trip Time |
|---|---|---|
| 2 | 15.42:04.018 Hrs | 15:42:06.854 Hrs |
| 5 | 15.42:04.024 Hrs | 15:42:06.854 Hrs |
| 6 | 15.42:04.116 Hrs | 15:42:06.877 Hrs |
| 4 | 15.42:04.131 Hrs | 15:42:06.889 Hrs |

- Unit-1 Boiler tripped at 15:42:22.700 Hrs. on ‘Master Fuel Trip’ and Generator tripped on ‘Under-frequency’ protection .

# VOLTAGE & FREQUENCY WAVEFORM:-



VOLTAGE VARIATION



FREQUENCY VARIATION

# OPERATION OF PROTECTION RELAYS:-

**GRIDCO feeders:**

- When the GRIDCO feeders got overloaded, both feeders tripped at CPP end on ‘Over-current’, but did not trip at Meramandali end.
- Current through each feeder : 686 Amp.
- Over-current setting at CPP end : 600 Amp.
- Over-current setting at Meramandali end : 780 Amp.
- So, the tripping is in order as per the settings.

# ANALYSIS OF CAUSE OF TRIPPING:-

- After tripping of Unit-9, MVAR import from Grid increased. This caused higher voltage drop in 200 MVA transformer thereby reducing CPP Bus voltage.

- At 15:30 Hrs. when MVAR import was 137 MVAR in each line. CPP Bus voltage was 208 KV, around 17 KV less than Grid voltage of 225 KV.

- This drop also matches with an approximate calculation shown below.

  - At 137 MVAR, drop in 200 MVA Isolation Transformer with 10.43 % impedance, drop will be nearly 10.43 X 137/200 = 7.144 %.

  -This is equal to 7.144X225/100 = 16.07 KV.

  - If the effect of MW and transformer resistance are considered, the value will change only slightly.)

# ANALYSIS OF CAUSE OF TRIPPING:-

- With decrease in CPP Bus voltage, Generator capability to generate MVAR (With rated MW) decreases due to stator current limit. This further increases MVAR import thereby further reducing Bus voltage. This is a cascading process.

- At 15:42 Hrs., when Grid voltage fell by 4 KV to 219 KV, this process led to reduction of MVAR generation in the units to almost zero and GRIDCO feeders got overloaded due to higher import.

- As soon as GRIDCO feeders tripped, MVAR import was stopped and there was acute shortage of MVAR in NALCO system, which was operating in islanded condition. It resulted in sudden drop in BUS voltage from 186 KV to 106 KV.

- Smelter Pot line load is mostly a resistive load and hence very much dependant on voltage (almost proportional to square of voltage ,not considering back emf of Pots). Hence, Smelter load suddenly decreased appreciably. Subsequently, Smelter Pot line loads tripped due to low voltage.

# ANALYSIS OF CAUSE OF TRIPPING:-

- This was a peculiar situation, when CPP system under islanding was operating with more MW generation than consumption and less MVAR generation than requirement . This resulted in high frequency and low voltage.

- As the generated MW was higher than load, frequency started increasing as shown in the graph above. It reached a value of 55.6 Hz after 1.5 Secs of 2nd GRIDCO feeder trip.

- Increase in frequency resulted in tripping of units in turbine over speed. But the Generators were not tripped condition .

- As the load on generators decreased, more MVAR generated and hence NALCO Bus voltage again increased. But in the meantime turbines tripped on over speed. After tripping of turbines, their speed decreased and Generators tripped on under frequency.

# Initiatives Taken for Improvement in System Reliability

# INITIATIVES TAKEN FOR IMPROVEMENT OF SYSTEM RELIABILITY

1

- Thorough inspection of all the local panels at 220 KV switchyard has been carried out. The panels are designed against water ingress with required IP protection. However, the cable entry points are sealed with proper sealing material in order to avoid ingress of water in to local panels.

2

- The operation of isolator is not very frequent. The power fuse & control fuse of all the Isolators at 220 KV switchyard have been removed from local control panel. A SOP has been prepared for operation of Isolators.

3

- Earth Fault detection and rectification is being carried out during S/D of each feeder. DC earth fault at new switchyard has been checked and possible location of earth fault has been identified. The same shall be attended during S/D of the particular Bay .

# INITIATIVES TAKEN FOR IMPROVEMENT OF SYSTEM RELIABILITY

**4**

- Bus differential Protection was kept in alarm mode but not in Tripping Mode under the apprehension of any mal operation would cause total power failure. Recently, Bus bar differential protection Tripping scheme has been taken in to service after through checking of the Scheme.

i) Presently, all the Generating and outgoing feeders (excluding two of the Gridco feeders) are connected to one of the Main Bus (Nalco Bus) and both the Gridco feeders are connected to other Main Bus (Grid Bus) and the Bus Coupler is in closed condition at our 220 kV switchyard.

ii) With present Bus configuration of 220 KV Switchyard, in case of Bus fault in any of the feeders of Nalco Bus, all the running feeders connected to that bus will trip leading to Total Power Failure of the station.

iii) The above problem can be avoided with 'Split Bus arrangement' having distribution of generating, outgoing and Gridco feeders in each of the two main buses with Bus coupler (BC) in closed condition. The suggested scheme is highly complex in nature and detail System study is required for the same with the help of external agency. The approval for carrying out the system study with the help of external agency has been approved and the same shall be carried out on priority basis .

# INITIATIVES TAKEN FOR IMPROVEMENT OF SYSTEM RELIABILITY

5

- Healthiness of all equipment / installation at Meramandali Substation, which are related to power supply to CPP is being monitored on monthly basis in close co-ordination with grid with Regular inspection / thermography of all the Bay equipments.

6

- Proper SOP has been prepared for maintaining Bus Voltage at 220 KV Nalco Bus. The Bus Voltage is being Monitored at 220 KV switchyard and suitable annunciation scheme shall be implemented in case of Bus Under Voltage .

7

- Directional over current relay shall be installed in each GRIDCO line which will be set in a direction to operate in case of Import of power from grid. In case of overloading of the feeder during import condition, trip command shall be extended to selected Smelter feeder (feeding to a Potline) to trip before the tripping of GRIDCO feeder. The procurement action for the same has been initiated. .

# INITIATIVES TAKEN FOR IMPROVEMENT OF SYSTEM RELIABILITY

| | |
|---|---|
| 8 | • Directional over current relay shall be installed in each GRIDCO line which will be set in a direction to operate in case of export of power to grid. Before overloading of the feeder during export condition, trip command shall be issued to selected Generating Units to trip before the tripping of GRIDCO feeder. |
| 9 | • Auto tripping of Smelter Feeders in case of Import of power through Manual Selection scheme has been implemented at 220 KV CPP switchyard in order to avoid the tripping of Grid lines in case of Over Loading of the lines. |
| 10 | • Buchholz Relay of 200 MVA isolation transformer of GRIDCO feeder – 3 has been checked and no abnormality was observed. DGA analysis of Transformer oil has been carried out on 21.11.2020 and test results are within the permissible limits.. |
| 11 | • Old static type Distance relays installed in Smelter feeders shall be replaced with advance Numerical Protection relay for enhancing the reliability and the replacement job is in progress. |

# INITIATIVES TAKEN FOR IMPROVEMENT OF SYSTEM RELIABILITY



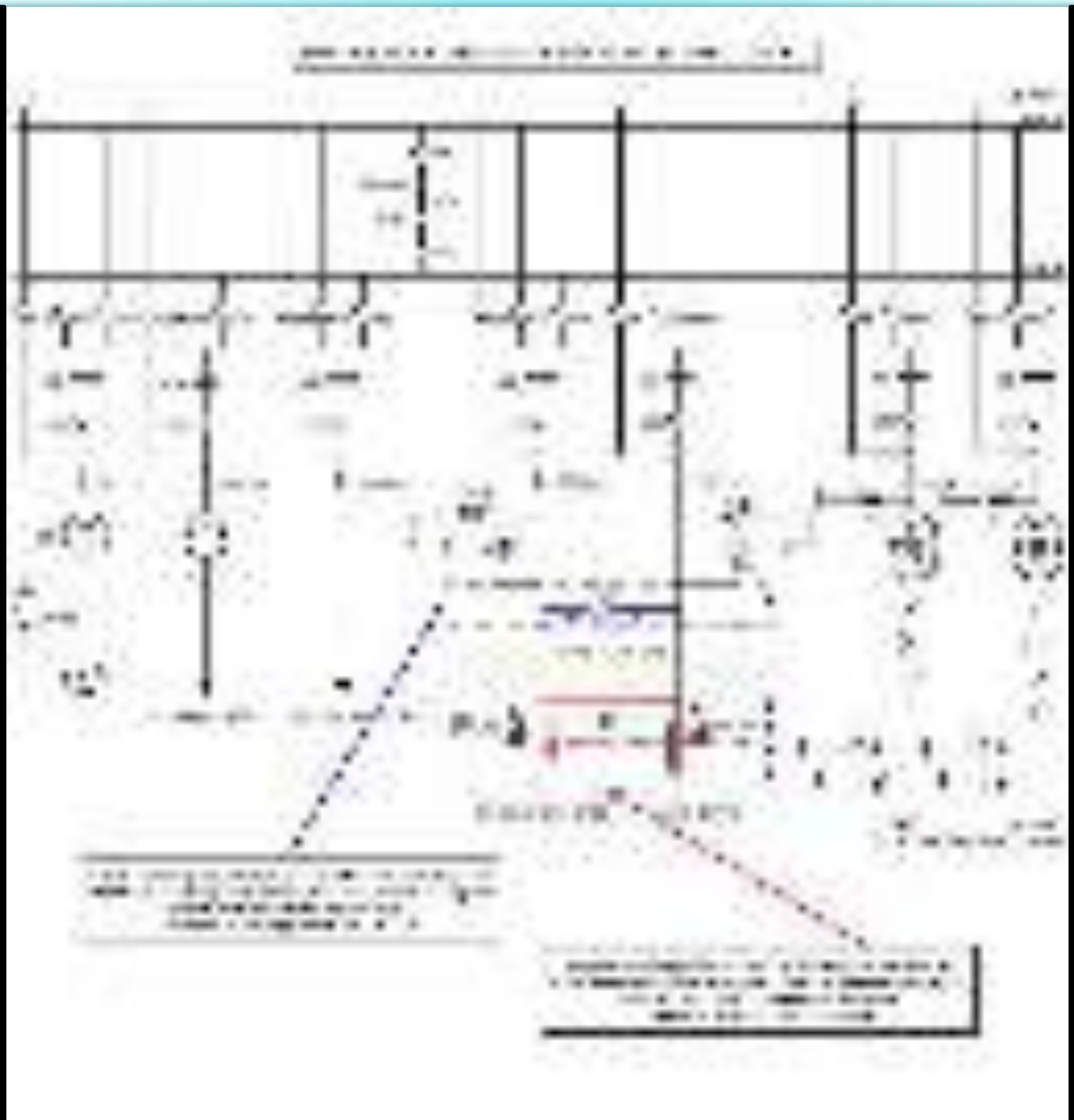
- Presently, Nalco CPP system is connected with Grid through Two Numbers of 220 KV feeders connected to Meramandali grid. The Rengali – Nalco & TTPS –Nalco has been made direct just beyond the Nalco CPP 220 KV Switchyard.

i) Any Prolonged outage of Nalco – Meramandali Lines due to problem in tower , bay equipments ( both at Nalco & Meramandali end ) will force Nalco Power System to operate in Islanding Mode which is highly unstable. In an islanded system, any minor disturbance may lead to Total Power Failure condition .

ii) In case of Total Power Failure condition and other Emergency situation at CPP, there is need to get Start Up power within 30 Minutes to save the Smelter plant . To mitigate the above risk , Nalco has proposed to OPTCL to pass the Rengali –TTPS line through an Off Load Isolator installed in CPP switchyard.

iii) There shall be no power drawl from those lines during normal conditions. In case of plant Emergency, with due permission from SLDC & OPTCL , power can be drawn from the LILO lines. The matter has been taken up with OPTCL for suitable consideration of the case .

# PROPOSED DIAGRAM FOR LILO CONNECTIVITY




नालको NALCO

*Ordinary People Extra ordinary Attitude*

# SEQUENCE OF EVENTS (TOTAL POWER FAILURE)

***Note:***

*As different devices from which data was collected are not perfectly time synchronized, there is small difference in timings. Though it has been tried to adjust the mismatches to the extent possible based on logging time of some common events, there may still be small amount of mismatches in timing.*

# SEQUENCE OF EVENTS (Event-1) on 30.09.2020

## TPF SOE_30.09.2020

| RELAY TIME | LOCATION | EVENTS |
|---|---|---|
| **22:36:46.168 PM** | **220 kV SWYD** | **Fault occurred in GT#04 89C isolator** |
| **22:36:46.258 PM** | **220 kV SWYD** | **SF-4 BKR TRIP at CPP end on 'Distance' maloperation** |
| **22:36:46.486 PM** | **220 kV SWYD** | **GRIDCO-3 BKR TRIP at CPP end on 'Bucholz'** |
| **22:36:47.062 PM** | **220 kV SWYD** | **GRIDCO-4 BKR TRIP at Meramundali end on O/C** |
| | | |
| **SOE TIME** | **LOCATION** | **EVENTS** |
| **22:36:47.228 PM** | **UNIT#10** | **GEN DEAD MACHINE PROTECTION TRIP** |
| 22:36:49.729 PM | UNIT#08 | GEN B/U IMPEDANCE (2 TRIP |
| 22:36:49.771 PM | UNIT#06 | OVER SPEED TRIP-1 UL TRIPPED |
| 22:36:49.775 PM | UNIT#06 | OVER SPEED TRIP-2 UR OPTD |
| **22:36:49.917 PM** | **UNIT#05** | **TURBINE TRIP CH-2 OPRTD** |
| 22:36:49.922 PM | UNIT#05 | TURBINE TRIP CH-1 OPRTD |
| 22:36:49.987 PM | UNIT#02 | OVER SPEED TRIP-2 UR OPTD |
| 22:36:49.993 PM | UNIT#02 | OVER SPEED TRIP DEVICE-2 TR |
| 22:36:50.016 PM | UNIT#02 | OVER SPEED TRIP DEVICE-1 TR |
| **22:36:50.037 PM** | **UNIT#02** | **TURBINE TRIP CH-2 OPRTD** |
| 22:36:50.039 PM | UNIT#02 | TURBINE TRIP CH-1 OPRTD |

# SEQUENCE OF EVENTS (Event-1) on 30.09.2020 – Contd

| | | |
|---|---|---|
| 22:36:50.078 PM | UNIT#06 | TURBINE TRIP CH-1 OPRTD |
| 22:36:50.078 PM | UNIT#06 | TURBINE TRIP CH-2 OPRTD |
| 22:36:50.126 PM | UNIT#04 | OVER SPEED TRIP DEVICE-2 TRIPPED |
| 22:36:50.133 PM | UNIT#04 | TURBINE TRIP CH-2 OPRTD |
| **22:36:50.134 PM** | **UNIT#04** | **TURBINE TRIP CH-1 OPRTD** |
| 22:36:50.154 PM | UNIT#05 | OVER SPEED TRIP DEVICE-1 TRIPPED |
| 22:36:50.160 PM | UNIT#05 | OVER SPEED TRIP-1 UL TRIPPED |
| 22:36:50.264 PM | UNIT#05 | OVER SPEED TRIP DEVICE-2 TRIPPED |
| 22:36:50.267 PM | UNIT#05 | OVER SPEED TRIP-2 UR OPTD |
| 22:36:50.889 PM | UNIT#01 | OVER SPEED TRIP-1 UL TRIPPED |
| 22:36:50.889 PM | UNIT#01 | OVER SPEED TRIP-2 UR OPTD |
| **22:36:51.083 PM** | **UNIT#05** | **GEN BACKUP IMP TRIP** |
| 22:36:51.094 PM | UNIT#05 | GENERATOR PROTECTION OPERATED |
| **22:36:51.105 PM** | **UNIT#05** | **CLASS A TRIP** |
| 22:36:51.125 PM | UNIT#01 | OVERSPEED TURB TRIP ELECTRICAL |
| 22:36:51.175 PM | UNIT#05 | GENERATOR BKR OPEN |
| 22:36:51.553 PM | UNIT#07 | DP ACR HPT LOW ALARM FINAL TRP ALM |
| 22:36:51.936 PM | UNIT#08 | DP ACR HPT LOW ALARM FINAL TRP ALM |
| 22:36:57.797 PM | UNIT#05 | BUS COUPLER OPEN (GRID CONNECTION BKR)/ISLANDING |
| **22:36:52.024 PM** | **UNIT#04** | **GEN REF TRIP** |
| 22:36:52.035 PM | UNIT#04 | OVERALL DIFF TEMP |
| 22:36:52.037 PM | UNIT#04 | GENERATOR PROT OPTD |
| **22:36:52.048 PM** | **UNIT#04** | **CLASS A TRIP** |
| 22:36:52.131 PM | UNIT#04 | GENERATOR BKR OPEN |
| 22:36:52.149 PM | UNIT#04 | OVERALL DIFF TEMP |
| 22:36:52.160 PM | UNIT#04 | GEN BACKUP IMP TRIP |

# SEQUENCE OF EVENTS (Event-1) on 30.09.2020 -contd

| | | |
|---|---|---|
| **22:36:52.463 PM** | **UNIT#07** | **GEN VOLT/CONTROL O/C TRIP** |
| **22:36:52.468 PM** | **UNIT#08** | **GEN VOLT/CONTROL O/C TRIP** |
| 22:36:52.471 PM | UNIT#07 | GEN PROT-2 LEVEL HIGH |
| 22:36:52.473 PM | UNIT#07 | GEN PROT-1 LEVEL HIGH |
| **22:36:52.474 PM** | **UNIT#07** | **TRIP RELAY '86A' OPERATED** |
| **22:36:52.484 PM** | **UNIT#08** | **TRIP RELAY '86A' OPERATED** |
| 22:36:52.544 PM | UNIT#07 | GCB OFF LEVEL HIGH |
| 22:36:52.554 PM | UNIT#07 | GEN PROT OPTD TRIP FINAL TRP ALM |
| 22:36:52.563 PM | UNIT#07 | GEN PROT OPTD TRIP FINAL TRP ALM |
| 22:36:52.594 PM | UNIT#07 | TURBINE TRIP CH A TUR TRP CH A |
| 22:36:52.599 PM | UNIT#08 | GEN PROT OPTD TRIP FINAL TRP ALM |
| 22:36:52.599 PM | UNIT#08 | GCB OFF LEVEL HIGH |
| 22:36:52.639 PM | UNIT#08 | TURBINE TRIP CH A TUR TRP CH A |
| **22:36:52.753 PM** | **UNIT#01** | **TURBINE TRIP CH-1 OPRTD** |
| **22:36:57.797 PM** | **UNIT#02** | **BUS COUPLER OPEN (GRID CONN** |
| **22:36:57.797 PM** | **UNIT#04** | **BUS COUPLER OPEN (GRID CONNECTION BKR)** |
| **22:36:57.797 PM** | **UNIT#06** | **BUS COUPLER OPEN (GRID CONNECTION BKR)/ISLANDING** |
| **22:36:57.798 PM** | **UNIT#01** | **BUS COUPLER OPEN (GRID CONNECTIO** |
| 22:36:58.344 PM | UNIT#01 | GEN UNDER FREQ |
| **22:36:58.367 PM** | **UNIT#01** | **CLASS C TRIP** |
| 22:36:58.381 PM | UNIT#02 | GEN UNDER FREQ |
| 22:36:58.381 PM | UNIT#06 | GEN UNDER FREQ |
| **22:36:58.400 PM** | **UNIT#06** | **CLASS C TRIP** |
| **22:36:58.408 PM** | **UNIT#02** | **CLASS C TRIP** |
| 22:36:58.437 PM | UNIT#01 | GENERATOR BKR OPEN |
| 22:36:58.486 PM | UNIT#02 | GENERATOR BKR OPEN |
| 22:37:02.466 PM | UNIT#01 | LOW FORWARD POWER RELAY OPTD |
| 22:37:02.535 PM | UNIT#02 | LOW FORWARD POWER RELAY OPT |
| 22:37:10.787 PM | UNIT#06 | LOW FORWARD POWER RELAY OPTD |

# SEQUENCE OF EVENTS (Event-3) on 02.10.2020

TPF SOE_02.10.2020

| RELAY TIME | LOCATION | EVENTS |
|---|---|---|
| **15:42:02.921 PM** | **220 kV SWYD** | **GRIDCO-4 BKR TRIP** |
| **15:42:03.111 PM** | **220 kV SWYD** | **GRIDCO-3 BKR TRIP** |
| **15:42:03.202 PM** | **220 kV SWYD** | **BUS COUPLER BKR TRIP** |

| SOE TIME | LOCATION | EVENTS |
|---|---|---|
| 15:42:03.063 PM | 220 kV SWYD | BUS COUPLER OPEN (GRID CONNECTION BKR)/ISLANDING |
| 15:42:03.772 PM | UNIT#06 | OVER SPEED TRIP-1 UL TRIPPED |
| 15:42:03.797 PM | UNIT#06 | OVER SPEED TRIP-2 UR OPTD |
| 15:42:04.000 PM | UNIT#02 | OVER SPEED TRIP DEVICE-1 TR |
| 15:42:04.011 PM | UNIT#02 | OVER SPEED TRIP-1 UL TRIPPED |
| 15:42:04.018 PM | UNIT#02 | TURBINE TRIP CH-2 OPRTD |
| 15:42:04.021 PM | UNIT#02 | TURBINE TRIP CH-1 OPRTD |
| 15:42:04.024 PM | UNIT#05 | TURBINE TRIP CH-2 OPRTD |
| 15:42:04.028 PM | UNIT#05 | TURBINE TRIP CH-1 OPRTD |
| 15:42:04.110 PM | UNIT#04 | OVER SPEED TRIP DEVICE-2 TRIPPED |
| 15:42:04.116 PM | UNIT#06 | TURBINE TRIP CH-1 OPRTD |
| 15:42:04.118 PM | UNIT#06 | TURBINE TRIP CH-2 OPRTD |
| 15:42:04.131 PM | UNIT#04 | TURBINE TRIP CH-2 OPRTD |
| 15:42:04.132 PM | UNIT#04 | TURBINE TRIP CH-1 OPRTD |
| 15:42:04.347 PM | UNIT#01 | OVERSPEED TURB TRIP ELECTRICAL |

# SEQUENCE OF EVENTS (Event-3) on 02.10.2020

| | | |
|---|---|---|
| 15:42:06.828 PM | UNIT#02 | GEN UNDER FREQ |
| 15:42:06.853 PM | UNIT#04 | GEN UNDER FREQ |
| *15:42:06.854 PM* | *UNIT#02* | *CLASS C TRIP* |
| 15:42:06.860 PM | UNIT#06 | GEN UNDER FREQ |
| *15:42:06.877 PM* | *UNIT#06* | *CLASS C TRIP* |
| *15:42:06.889 PM* | *UNIT#04* | *CLASS C TRIP* |
| 15:42:06.930 PM | UNIT#02 | GENERATOR BKR OPEN |
| 15:42:06.966 PM | UNIT#04 | GENERATOR BKR OPEN |
| 15:42:10.991 PM | UNIT#05 | LOW FORWARD POWER RELAY OPTD |
| 15:42:11.017 PM | UNIT#06 | LOW FORWARD POWER RELAY OPTD |
| 15:42:19.078 PM | UNIT#04 | LOW FORWARD POWER RELAY OPTD |
| 15:42:23.063 PM | UNIT#01 | TURBINE TRIP CH-1 OPRTD |
| 15:42:24.424 PM | UNIT#01 | GEN UNDER FREQ |
| *15:42:24.445 PM* | *UNIT#01* | *CLASS C TRIP* |
| 15:42:24.512 PM | UNIT#01 | GENERATOR BKR OPEN |
| 15:42:27.115 PM | UNIT#01 | SPRAYWATERV/V-3 OPEN |
| 15:42:28.540 PM | UNIT#01 | LOW FORWARD POWER RELAY OPTD |