Black StartDrill in Eastern Regional Power System-Case studies

P.Pentayya *   U.K Verma **   GopalMitra*** M.Thakur****S.Sahay *****

Abstract:**The phenomenal increase in complexity of integrated power system operation demands more reliability in supplying of bulk power. The forced outages of power system elements due to faults in a grid are practically unavoidable. Widespread propagation of such disturbances in a system may affect the healthy part of the grid eventually leading to a partial or a total collapse of a system. As mandated in Indian Electricity Grid code(IEGC)[1] , the restoration plans for all the regional grids are in place. Such restoration plans are being finalized and reviewed with due discussions with all the state as well as central utilities system. However, once a restoration plan is developed it requires a periodic drill to evaluate the plan that provides a measure for an utilities ability to respond to a real time situation besides validation of its plan[2]. Eastern Regional Load Despatchcentre in coordination with utilities have conducted such drills at different hydro stations of having black start capabilities. This paper discusses the experience gained for such exercises carried out.**

Keywords: **- restoration, Indian Electricity Grid code, black start, HEP, voltage, frequency.**

I.INTRODUCTION

BLACK Start is the procedure to recover from a total or partial collapse of the transmission system which has caused an extensive loss of supplies. In the event of a partial or total collapse of the transmission system, the general principle of recovery includes re-establishment of isolated power stations through black start to provide ‘power islands’. These are then integrated into larger sub-systems eventually allowing the re instatement of the whole regional or national grid system. By having this capability at a number of strategically located sites, electrical supplies can be rapidly restored. In general, all power stations need an electrical supply to start up. Under normal operation this supply would come from the transmission or distribution system while under emergency conditions Black Start stations (Generally Hydro) through itsself-start facilities provide this electrical supply.Normally these auxiliary supplies are provided by a small hydro plant, gas turbine or a diesel plant, the minimum size of which is dependent on the size of the main Generating units, which in turn is started from a battery or some other form of energy storage device.

II. RESTORATION IN EASTERN REGION

The restoration procedures prepared [3] and made available atState Load Despatch Centre (SLDCs) and Regional LoadDespatch Centre (RLDC) define restoration paths forextending start up power to each power station clearly alongwith alternative paths and priorities of paths. The priorities aregenerally decided based on usage of short line sections andlower voltage lines.Geographically the Hydro power stations of Eastern Region having Blackstart facilities are mainly located at the North East corner and at the southern part of the region. This renders a major challenge of extending start up power to the large thermal power stations which are geographically located in the Central zone. The Fig 1 shows the locations of the hydro power stations of Eastern Region having black start facilities and major thermal stations Black start facilities are available in Power station as shown in Table 1.

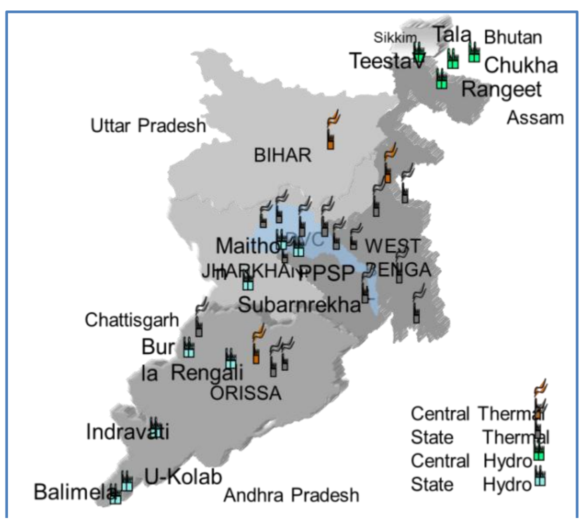

Figure:1   Location of major power plants in eastern region

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TABLE:1 GENERATING STATIONS IN EASTERN REGION HAVING BLACK- START FACILITY

Power stations	**Capacity MW**	**Unit type**	**Start up**
Subarnrekha (Stage I) Jharkhand SEB	2X65	Hydro	Diesel sets 2x250KW
Maithon (Damodar Valley Corporation)	3x20	Hydro	Battery
Rengali (OHPC)	5x50	Hydro	Diesel sets 400KW & 500KW
Indravati (OHPC)	4x150MW	Hydro	Diesel sets 2x500kVA
Jaldhaka (WBSEDCL)	3x9+4x2	Hydro	Diesel sets 200KVA & 230kVA
Rammam (WBSEDCL)	4x12.5	Hydro	Diesel sets 2x310kW
TCF (WBSEDCL)	9x7.5	Hydro	Diesel sets 750kVA
Purulia (WBSEDCL)	4x225	Pumped storage hydro	Diesel sets
Rangit (NHPC)	3x20	Hydro	Diesel 312.5 kVA
Teesta V NHPC)	3x170	Hydro	Diesel sets 2x500kVA

III DRILL STRATEGIES

Strategic choice for SystemRestoration in the event of a major failure could be'build up strategy' or a 'build down strategy' [6]. In the 'Build up' strategy the black start facilities are used to extend supply to the rest of the system whereas 'Build down' strategy suggeststo avail supply from the healthy neighboring system for restoration. While planning the various mock drill exercises of the Eastern Regional Grid both such strategies were attempted. The various drills defined their respective content and objectives. While the primary objective was to evaluate theexisting emergency restoration plan the drills to start with aimed at building confidence amongst power plant operators. The other objective was to assess there readiness and response of the operators involved during the exercises.

The mock Black Start drillsconducted in Eastern Region during the year 2010, 2011& 2012 is shown in Table 2.While all the exercises was to build an island using black start facility, operate it stably and finally synchronizing with rest of the grid using build up strategies, the start up exercise carried out for Indravati HEP on 24.3.11 used the build down strategy when power was extended from Southern Regional grid using HVDC AC bypass at Gazuwaka.In this paper three such mock drill exercises at Tessta V, Indravatiwithstart up using black start facility and AC bypass at HVDC Gazuwaka have been discussed

TABLE: 2 MOCK BLACKSTART DRILLS

Sl No	Generating station	Date of drill
1	Teesta V	22.04. 2010
2	Maithon HEP	02.07.2010 & 14.10.2011
3	Rengali HEP	09.03.2011
4	Indravati HEP	10.2.2012
5	Subarnrekha HEP	19.11.2011
6	Indravati HEP through Gazuwaka HVDC by pass	24.3.2011

IV. CASE STUDIES ON MOCK BLACK START DRILL

A) Black Start of Teesta-V on 24th April 2010.

Teesta–V is a run of river type hydro generating stationbuilt on snow fed river Teesta. The power station is connected to the grid through 400 kV twin moose D/C line of115km length at Binaguri substation of Powergrid.The 400kV and adjoining 220kV network around Teesta V and Binaguri S/S is shown at Fig: 2

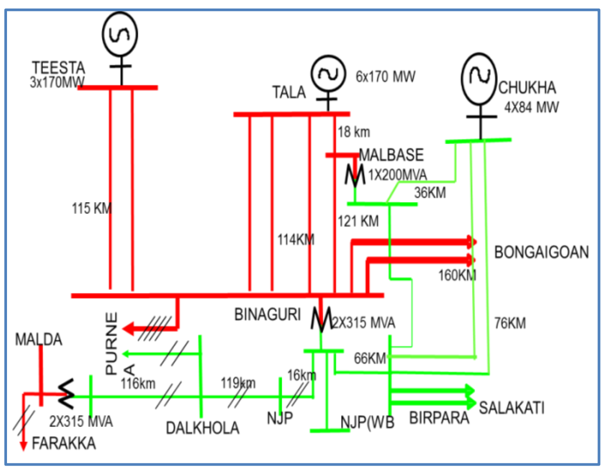

Figure 2: Network around Binaguri s/s

Teesta V is having an installed capacity of 3 X 170 MW with a GIS based switchyard with one and half breaker scheme. The station strategically located with its 400kV connectivity at Binaguri S/S of POWERGRID that feeds around 200MW of load of West Bengal. The restoration Mock drill thus envisaged curbing out a portion of the West Bengal system Load to form an island. However, because of certain problems envisaged byWBSETCL,the formation of the island not was considered.The mock drill was thus revised to attempt blackstart of one unit at Teesta V to extend power at Binaguri, Necessary bus splitting arrangement as envisaged is shown at Fig 3

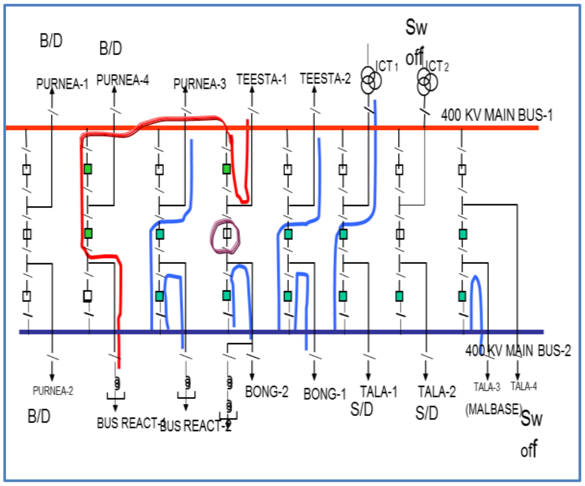

Figure 3: Switching arrangement at Binaguri 400 kV S/S

Similarly bus splitting arrangement at Teesta V was also planned with an objective to keep one running machine on bar and to continue feeding power at 400kV Bus II of Binagurithrough the 2nd feeder of Binaguri. In order to contain the voltage, it was decided to preclose the 63MVAR bus reactor with Teesta I feeder. The system synchronization was planned at Binaguri by way of closing the tie breaker of Teesta I and Bongaigaon II. At 12:01 Hrs the exercise commenced with desynchronisation of Unit 3 (to be taken into service through black start) and making the Bus 1 of Teesta dead by opening of Binaguri feeder1. However, while attempting to do so an induced EMF of 40-45 kV was observed. While detailed feed back from the station is still awaited it is expected that a 10% induce voltage could be a common phenomenon in a GIS substation. Eventually, the entire drill plan was revised and was decided to make the station completely dead. At 13:27Hrs the unit 3 of Teesta was black started and power was extended to Bus 1 of Binaguri. The excitation was well controlled and the post charging voltage at Bus 1 at Binaguri was observed as 371 kV(vide FIG 4). The voltage was raised gradually to 392kV at 13:52 Hrs and at 13:54 Hrs the tie breaker between Teesta 1 and Bongaigaon 2 at Binaguri was closed for synchronization(vide FIG 5). The MW and MVAR plots for Teesta Generators are shown at Fig: 6

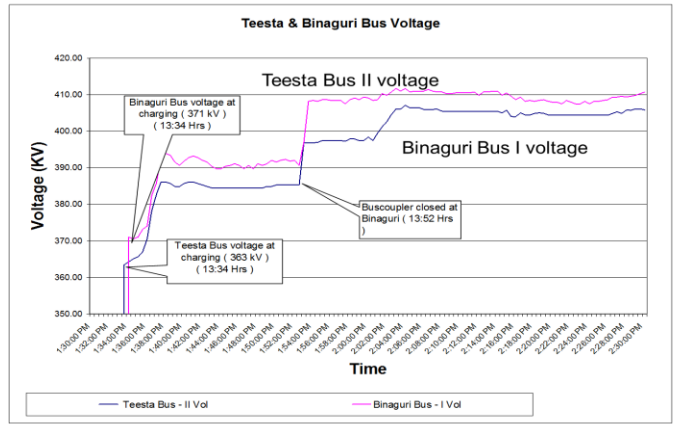

Fig:4Binaguri Bus II and Teesta Bus I Voltage

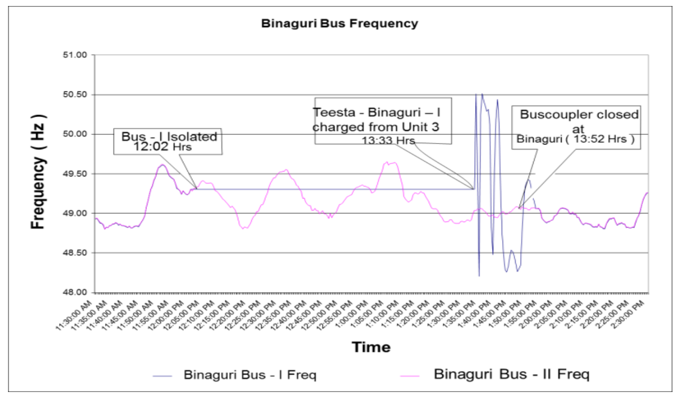

Figure: 5 Island Synchronization of two systems

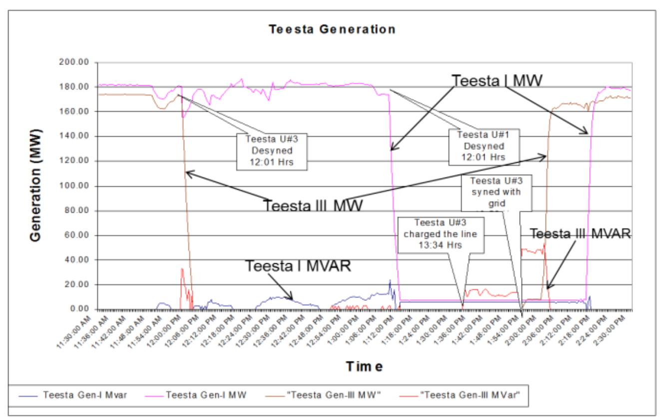

Figure 6: Mw and Mvar plots for Teesta generation

B) Extending start-up power to Indravati HEP from SR grid through AC bypass at HVDC Gazuwaka on 24th March 2011.

Indravati hydro Power station in South Orissa has installed capacity of 150X4 MW and it has connectivity with Theruvali by four ckts of 220KV and with 400KV Indravati Power grid sub-station circuit diagram shown in Fig.7

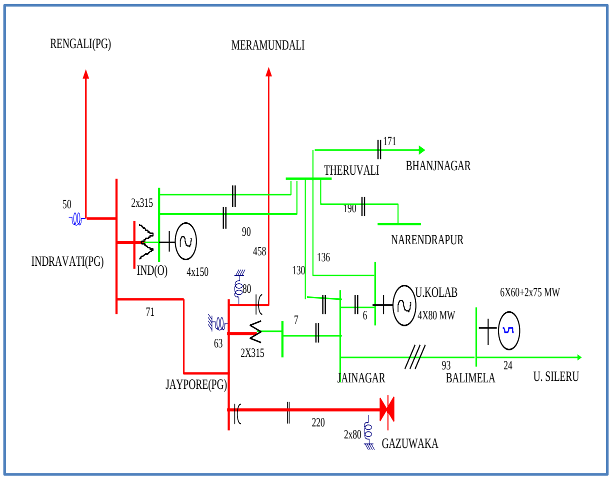

Figure:7 Schematic SLD for Indravati HEP & adjoining Substations

One of the major challenges for extending start up power to Indravati through AC bypass link involved huge number of switching operations. The mock drill commenced from 09:45 Hrs

The basic plan for the drill was envisaged in consultation with Indravati HEP, Jeypore S/S,OPTCL SLDC. Jeypore-Gajuwaka-I was to be charged from Gajuwakaend , after obtaining final clearance from Jeypore(PG). As estimated by SRLDC, the short-circuit capacity of Gajuwaka(South) bus being of the order of 10,000 MVA, thus the voltage rise at Gajuwaka was expected to be around 2 kV , while the rise along the line of the order of 5kV. As an alternate measure it was also planned that the line CB of 400kV Jeypore-Gajuwaka-II at Jeypore and main CB of the 63 MVAR bus reactor at Jeypore to be kept pre-closed, thereby ensuring that the reactor acts as a line reactor for the line, thus help controlling overvoltage issue. The study further suggested that Jeypore voltage after charging from Gazuwaka shall have to be maintained within 415kV. The voltage of Jeypore bus was expected to rise further by around 9 kV, while the rise along the line will be of the order of 1.5 kV with charging of 400kV Jeypore-Indravati(PG) section.

a) Bus Switching operation at Jeypore sub-station.

400 kV Jeypore is having one and half breaker bus scheme. First both the 400 kV JeyporeGazuwaka lines were switched off after making the power orderof HVDC Gazuwaka B/B to zero. Subsequently 400 kV Jeypore-Indravati(PG), Indravati(PG)-Rengali and Indravati HEP was switched off. This results in a complete blackout of 400 kV Indravati (PG) substation. Bus-II at Jeypore was made off by switching off the bus coupler and connecting 400 kV Jeypore –Meramandali, 2x 315 MVA ICT to bus I. The bus reactor was kept pre-closed to dead bus to control charging over voltage.

b) Switching operation at UIHEP switchyard

400 kV side of Indravati HEP has one and half breaker bus scheme while 220 kV side is having two main and one transfer bus scheme. Unit 2 was identified as the machine to be black started. By around 10:56 Hrs, 400kV IndravatiHEP – Indravati (PG) S/C line, 400/220kV ICT-II (ICT I was already under shutdown) were switched out and 220 kV transfer bus was disconnected from main 1 and main 2with desynchonisation of Indravati Unit 2. 220 kV Theruvali circuits and other units at UIHEP (1, 3 & 4) remain connected to 220kV mainBus I & II. With the aforesaid switching operations, the system was ready for availing start up power through AC Bypass at Gazuwaka to be extended up to Indravati HEP 220kV Transfer bus.

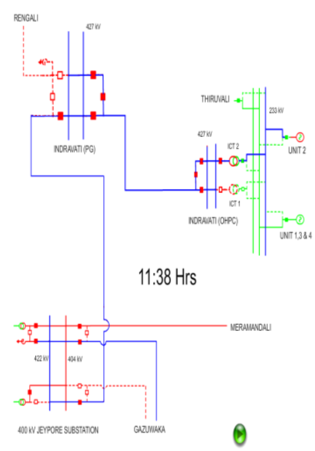

Figure 8: Start up route of Indravatihep via HVDCgazuwaka bypass

c) Extension of Startup power.

Gazuwaka East Bus was charged by bypassing B/B HVDC at Gazuwaka at 11:02 Hrs. Power was extendeduptoJeypore by charging 400 kV Gazuwaka-Jeypore–II from Gazuwaka end. This energized Bus-II at Jeyporealongwith the bus reactor when voltage at Jeypore could be contained at 404kV. The 400 kV Bus II was thus got connected with Southern Grid while Bus I remained synchronized with NEWGrid.Power was then extended upto 400 kV IndravatiHEP via 400 kV Jeypore(from Bus-II)-Indravati-Indravati(OHPC) section. Post charging voltage after charging of the entire section was observed at 427kV at Indravati. 315MVA ICT-2 at

Indravati HEP was then charged to extend power at 220 kV transfer bus. And finally to Unit 2 for its start up. The entire exercise could be completed successfully within 1 Hr and 50 minutes that involved over 25 numbers of switching operations .

The generation of Unit # 2 of UIHEP was raised to 50 MW and it was operated for about 9 minutes in synchronization with SR grid. No major voltage problems were encountered during charging of lines while extending start up power to Indravati (vide FIG 8).

C. Black start of Indravati HEP and its operation in islanded mode on 10th Feb'2012

The mock drill for Black start for Indravati station was attempted again on 10th Februray'2012. The exercise aimed at black start of one of its unit(Unit 3) at Indravati , extending power at Therubali 220kV station and forming an island of around 70MW of load at 132kv by way of having bus section arrangement at 132kv Therubali. The schematic arrangement is shown at Figure 9.

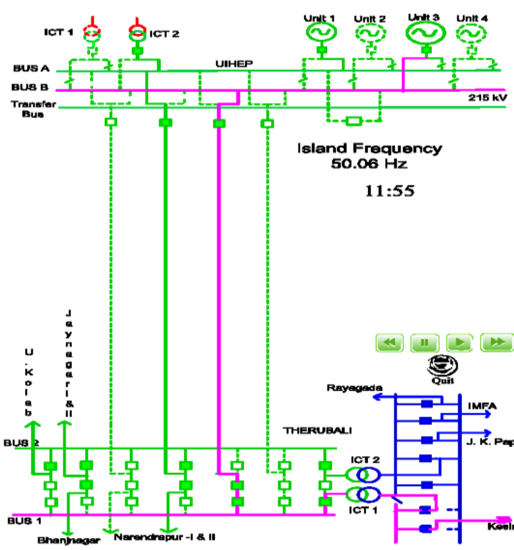

Figure 9: The schematic black start arrangement for Indravati HEP alongwith island formed

The Indravati –Therubali 220kv line being of around 90km no major voltage problems could be observed. However, the island formed with around 60-70MW of load of Kesinja could be operated stabily and the sub-system was synchronized with rest of the grid at Therubali 220kv through main bus breaker of Indravati-Therubali 220kV ckt 2. The entire drill time took around 1 Hr and 32 minutes

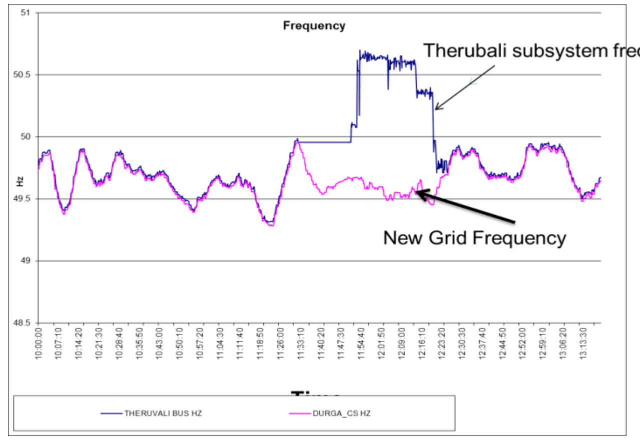

Figure: 10 Island synchronisation of two systems

V. Future Plans

The mock black start drill for othersmaller power stations such asMaithon(DVC), Rengali(OHPC), Subrnrekha(JSEB) could also be successfully carried out in Eastern Region. Besides the experience, the drills have brought in awareness and their importance amongst the operators. It has also revealed many a weakness and deficiencies in various stations. These are being attended to for a detailed drill to be carried out as a part of routine practice to fulfill the objective of disaster management such as quick restoration of the grid in the event of a major blackout. As has been stated, most of the hydro power stations in Eastern Region being located at the farthest corners of the region, it is of utmost importance to attempt the black start of units at Purulia Pumped storage plant of West Bengal. The plant is centrally located in the region with its proximity of major thermal plants such DPL, Bakreswar, Waria , Mejia and Chandrapura besides the major load centre at Bidhnnagar.

V. Conclusion

Since blackouts occur rarely, it would be difficult totrain the system operators on system restoration in real time. With significant loss to economy and great inconvenience to consumers, faster and efficient restoration is of utmost importance. This would require well documented detailed restoration plans tested through system studies, dispatcher training simulator, mock drills and creation of awareness, confidence and familiarity not onlyto grid operators but also to operating personnel at generating stations and sub-stations.

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