



सेंद्रल ट्रांसमिशन यूटिलिटी ऑफ इंडिया लिमिटेड

(पावर ग्रिड कॉर्पोरेशन ऑफ इंडिया लिमिटेड के स्वामित्व में)

(भारत सरकार का उद्यम)

CENTRAL TRANSMISSION UTILITY OF INDIA LTD.

(A wholly owned subsidiary of Power Grid Corporation of India Limited)

(A Government of India Enterprise)

Ref. No.: C/CTU/S/00/Gazuwaka HVDC

Date: 31-08-2026

Shri Rajil Srivastava

ED (AM)

POWER GRID Corporation of India Ltd.

"Saudamini", Plot No.-2, Sector-29

Gurugram - 122001

Sub: Report on usefulness of Vizag (Gazuwaka) Back-to-Back HVDC (2X500 MW) – Reg.

Dear Sir,

This is with reference to POWERGRID letter dated 21.04.2026 vide which it has been informed that Pole#2 of Vizag HVDC (OEM: ABB, now Hitachi) has completed more than 21 years and OEM has informed that they are unable to provide spare and service support due to technology obsolesce and proposed for upgradation of Pole#2.

It has also been submitted that refurbishment of both the poles may be carried out together so that implementation may be done by same OEM avoiding challenges associated with C&P integration of the two systems. In view of the above, POWERGRID requested that studies may be conducted for refurbishment of both the poles for taking up with CERC under ADDCAP works.

In this regard, please find attached detailed report on usefulness of Vizag (Gazuwaka) Back-to-Back HVDC (2X500 MW).

Thanking You,

Yours faithfully,

(RVMM Rao)

Chief General Manager

Copy to:

Chief Engineer (PSP&A-I) Central Electricity Authority Sewa Bhawan, R.K. Puram, New Delhi-110066	Chief Engineer (PSP&A-II) Central Electricity Authority Sewa Bhawan, R.K. Puram, New Delhi-110066
Member Secretary Southern Regional Power Committee 29, Race Course Cross Road Bangalore – 560 009	Director (SO) Grid-India 9th Floor, IFCI Towers, 61, Nehru Place, New Delhi – 110 019



REPORT ON USEFULNESS OF VIZAG (GAZUWAKA) BACK-TO-BACK HVDC (2X500 MW)

Central Transmission Utility of India Ltd

August 2026

A. Objective

Pole 1 of Vizag HVDC (OEM: GE alstom, now GE Vernova) was commissioned on 01.09.1999 and has completed more than 25 years of service life. In this regard, POWERGRID vide letter dated 16.04.2025 requested to review the requirement and usefulness of Pole-1 of the Vizag Back-to-back HVDC. Refurbishment of Pole 1 of Vizag HVDC was approved in the 53rd TCC and 56th SRPC meetings held on 14.11.2025 & 15.11.2025.

POWERGRID vide letter dated 21.04.2026 has submitted that Pole#2 of Vizag HVDC (OEM: ABB, now Hitachi) has completed more than 21 years. POWERGRID has suggested that refurbishment of both the poles may be carried out together so that implementation may be done by same OEM avoiding challenges associated with C&P integration of the two systems. Accordingly, it has been requested that studies may be conducted for refurbishment of both the poles and recommended for taking up with CERC under ADDCAP works. Letter dated 21.04.26 is attached at **Annexure-I**.

In view of above, the present report is prepared to evaluate the requirement and usefulness of 1000 MW Vizag Back-to-back HVDC between ER & SR with two poles of 500MW each.

B. Background

GRID India vide letter dated 19.06.2025 submitted a detailed report on requirement and utilization of Vizag Back-to-back HVDC (1000MW) which is attached at **Annexure-II**. Major observations from the report with respect to utilization of Vizag Back-to-back HVDC were as follows:

- The BtB Gazuwaka link is a vital inter-regional transmission corridor between the Eastern Region (ER) and Southern Region (SR), playing a crucial role in facilitating power transfer from other regions to SR in SR import scenario and from SR to other regions in SR export scenario. HVDC BtB Gazuwaka link is modulated to control the loading on the parallel AC corridors
- The non-availability of HDVC G'waka (1000 MW) would lead to a reduction of ~650 MW in SR Import TTC/ATC.
- Link is also modulated to control the loading of 400 kV Angul- Bolangir during the high-demand period of Odisha in non-solar hours and the other 220 kV lines network near Jeypore.
- Constraints in the Vizag area can be controlled with the modulation of HVDC BtB Gazuwaka power order.
- HVDC BtB Gazuwaka is also utilized for voltage control in Southern Region as well as Eastern Reigion.
- HVDC BtB Gazuwaka also provides the facility to bypass the HVDC converter station and extend supply through the AC bypass. The facility can be utilised for system restoration for extending start-up power from ER to SR or vice versa, post-blackout.
- Although HVDC BtB Gazuwaka has a full capacity of 1000 MW in both directions, the HVDC cannot be utilised at its full capacity due to low voltage at Gazuwaka

East bus and Bolangir upon increase in power order beyond 650-700 MW. Similarly, in the SR to ER direction, when the HVDC link is operated beyond a power order of 650-700 MW, overloading of the certain 220 kV lines in the Odisha network are observed. Necessary system strengthening measures may be taken up in the Odisha system to ensure utilization of the HVDC at rated capacity in the SR-ER direction.

It was also submitted that bypassing HVDC Gazuwaka BtB and connecting the 400 kV Jeypore and Gazuwaka with a 400 kV AC interconnection shall impact the following :

- Transmission constraints like high loading of 400 kV Jeypore – Gazuwaka D/C lines (SR import scenarios) and downstream 220 kV AC lines in Odisha (SR Export/High Odisha demand scenario) are envisaged. Therefore, the bypassing of the HVDC link will require re-conductoring of the 400 kV Jeypore – Gazuwaka D/C to high-capacity conductors and system strengthening in the associated AC system at both ends.
- The terminal equipment at Gazuwaka station needs to be upgraded along with the refurbishment. Planning of suitable reactive power compensation devices for managing the voltage issues would also be required at both ends.
- Without the HVDC BtB configuration, the power flow will be completely governed by LGB, and the flexibility in changing the power flow across the critical corridor during contingencies and grid requirements may be limited.
- Further, considering the vulnerability of the transmission network in cyclone-prone areas of Odisha, system strengthening measures aimed at enhancing resilience may also be undertaken.
- Overall, AC interconnection would require system augmentation in ER as well as SR and it could be evaluated at the end of useful life of the BtB G'waka.

In view of the above, NLDC vide report dated 19.06.2025 recommended refurbishment of the BtB HVDC Gazuwaka and improvement in its availability. Further, it was suggested that outage of only one pole at a time (along with other operational measures) shall be taken for refurbishment purposes. Other interim measures for ensuring system reliability may be planned in consultation with the stakeholders to facilitate the long outage of the HVDC for refurbishment.

CTUIL vide letter dated 08.09.2025 submitted detailed report on requirement and usefulness of Vizag (Gazuwaka) BtB HVDC (Pole-1) wherein after detailed system studies, following was concluded :

- Gazuwaka BtB HVDC has significant role in meeting the demand of Southern Region through controlled power flow.
- Gazuwaka BtB HVDC is also instrumental in facilitating export of surplus power from Southern Region.
- Gazuwaka BtB HVDC is also utilized for voltage control in Southern Region as well as Eastern Region.
- TTC for import of power from NEW grid to SR grid is expected to be reduced by about 400-450 MW during the 2029-30 timeframe without Gazuwaka BtB HVDC (1 pole). Further, reduction of about 150-300 MW is expected in TTC for export of power from SR grid to NEW grid.

In view of the above, CTUIL recommended refurbishment of Gazuwaka BtB HVDC (Pole-1) may be carried out to avoid reduction in TTC and optimal utilisation of already available infrastructure. Further, it was also recommended that reconductoring of Jeypore – Gazuwaka 400kV D/c with HTLS conductor, along with necessary upgradation in bay equipment at both ends, if required, may be carried-out in order to utilize the full capacity of the subject HVDC terminals (1000 MW) in both the directions.

Matter regarding refurbishment of Gazuwaka BtB HVDC (1 pole) was discussed in TCC and SRPC. During the 53rd CC and 56th SRPC meetings held on 14.11.2025 & 15.11.2025, SRPC approved the refurbishment works of Gazuwaka HVDC Pole-1, as the HVDC system is essential for supplying critical loads in the Vizag area. During the meeting, POWERGRID informed that matter has already been filed before CERC for approval.

Subsequently, POWERGRID vide letter dated 21.04.2026 has submitted that Pole#2 of Vizag HVDC has completed more than 21 years. In view of the above, POWERGRID has suggested that refurbishment of both the poles may be carried out together so that implementation may be done by same OEM avoiding challenges associated with C&P integration of the two systems. Accordingly, it has been requested that studies may be conducted for refurbishment of both the poles.

C. System Studies

Southern Region has faced unsurpassed increase in demand in past few years. Already peak demand of about 70 GW has been met and about 22 GW has been imported through the existing transmission links between SR and NEW Grid. Vizag B-t-B HVDC amongst other HVDC and HVAC links has been instrumental in helping meeting this huge increase in demand in Southern Region. Further, in recent times, Southern Region has witnessed export of power to other regions in high renewable scenario from June to September when there is high wind generation in the Southern region and demand is on a lower side.

As per EPS, Southern Region has been projected to have a demand of 102 GW by 2030-31. In addition to the above, transmission system for Green Hydrogen/ Green Ammonia based loads of about 10.5 GW has been approved in Southern Region in Kakinada, Vizag and Tuticorin areas in Andhra Pradesh and Tamil Nadu. In addition to this GH/GA demand, a large load has been requisitioned by data centres around Vizag area and many applications have been received by STU & CTU. RE potential of about 135 GW has also been declared by MNRE/SECI in the Southern Region. Southern Region is expected to be surplus of about 22 GW in such a scenario. However, during the evening peak scenario when solar generation is not available, Southern Region is heavily dependent on the conventional generation available within the region as well as outside the region to meet the regional demand including Data Centre/ Green Hydrogen/ Green Ammonia loads. Southern Region is expected to be deficit to the extent of about 22 GW in 2030-31 which is required to be met through the existing/planned Inter-regional corridors.

List of existing IR links to facilitate import/export requirements of the Southern Region are as follows :

- Narendra/ Narendra New -Xeldem 400 kV D/c line
- Narendra New – Kolhapur 765 kV D/c line (charged at 400 kV)
- Raichur-Solapur 765 kV D/c line
- Wardha-Nizamabad 765 kV D/c line
- Warora- Warangal 765 kV D/c line
- Srikakulam- Angul 765 kV D/c line
- Chandrapur- Bhadravathi Back-to-back HVDC
- Pugalur-Raigarh HVDC
- Gajuwaka-Jeypore Back-to-back HVDC
- Talcher-Kolar HVDC

In addition to the above, in order to meet the ever increasing demand of the region as well as to facilitate export of surplus power from Southern Region, following inter-regional links are under implementation :

- Narendra- Pune 765 kV D/c line
- Bidar-Parli 765 kV D/c line
- Angul-Srikakulam 765 kV D/c line (2nd)
- Upgradation of Narendra New – Kolhapur 765 kV D/c line (presently charged at 400 kV) at its rated voltage

System Study Analysis

Detailed system studies have been conducted for assessment of usefulness of Vizag BtB HVDC (2x500 MW) in 2030-31 timeframe. Since Southern Region is expected to import maximum power from nearby region in the evening peak scenario, so Scenario-8 (February evening peak case) has been considered for above studies. Further Scenario-4 (June Solar max) has been considered for necessary assessment during SR export conditions. Further, various scenarios w.r.t. availability of the under implementation IR links and availability of Vizag BtB HVDC have been studied to assess the sufficiency/adequacy of the transmission network in meeting the Southern Region demand. Studies have also been carried out for assessment of system strengthening required in Eastern Region to utilize the full capacity of Vizag BtB HVDC for 1000 MW in both import and export scenario.

Study assumptions and exhibits are attached at **Annexure-III**.

Scenario-8 (SR import)

All India Load Generation Balance is given below as **Fig-1**.

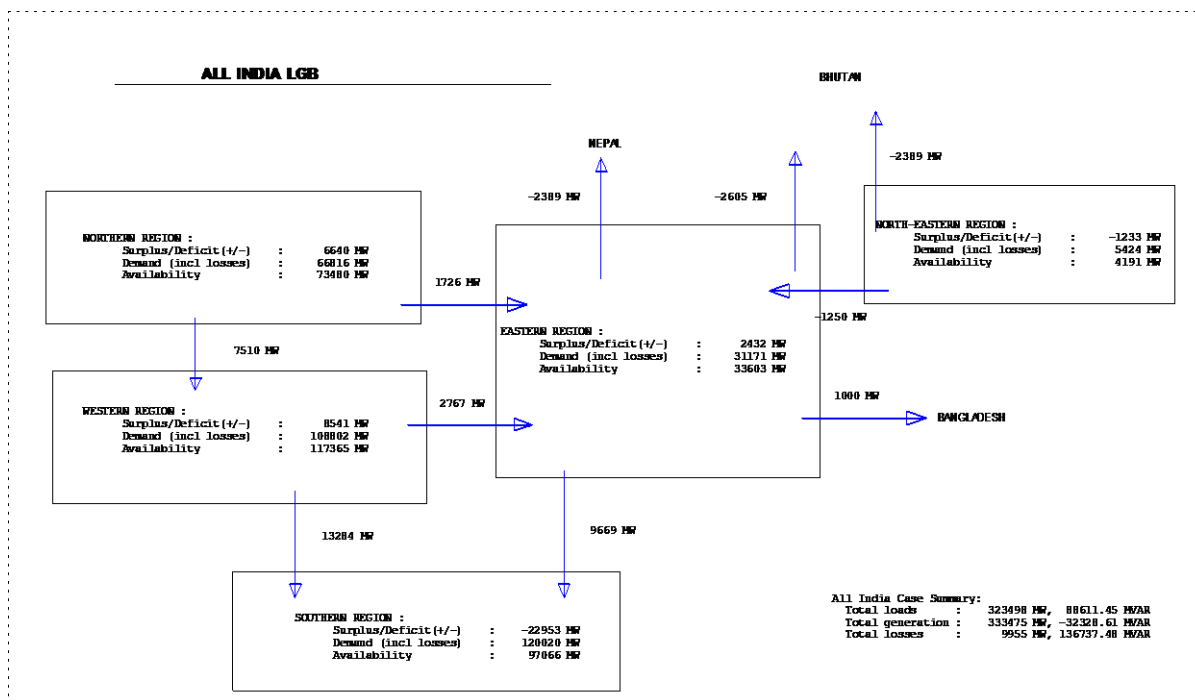


Figure 1 : All India - Load Generation Balance (Feb'2031)

Study result with loadings on inter-regional links between WR & SR grid and ER & SR grid is given below as **Fig-2** (with HVDC) and **Fig-3** (Without Gazuwka-BTB).

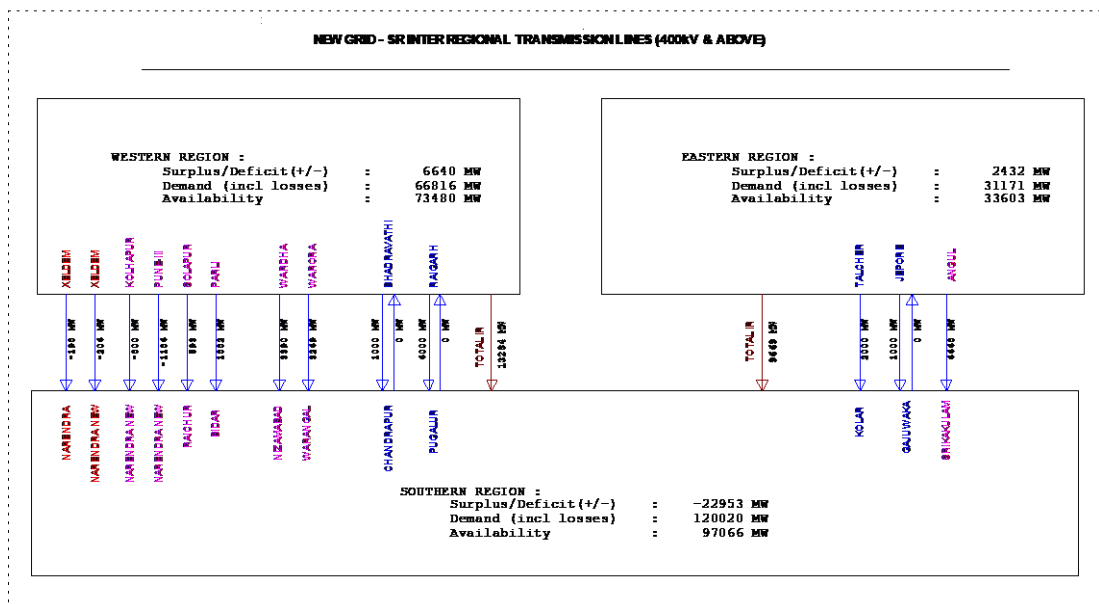


Figure 2 : NEW Grid & SR Grid - Inter-Regional (IR) flows (With Gazuwka-BTB)

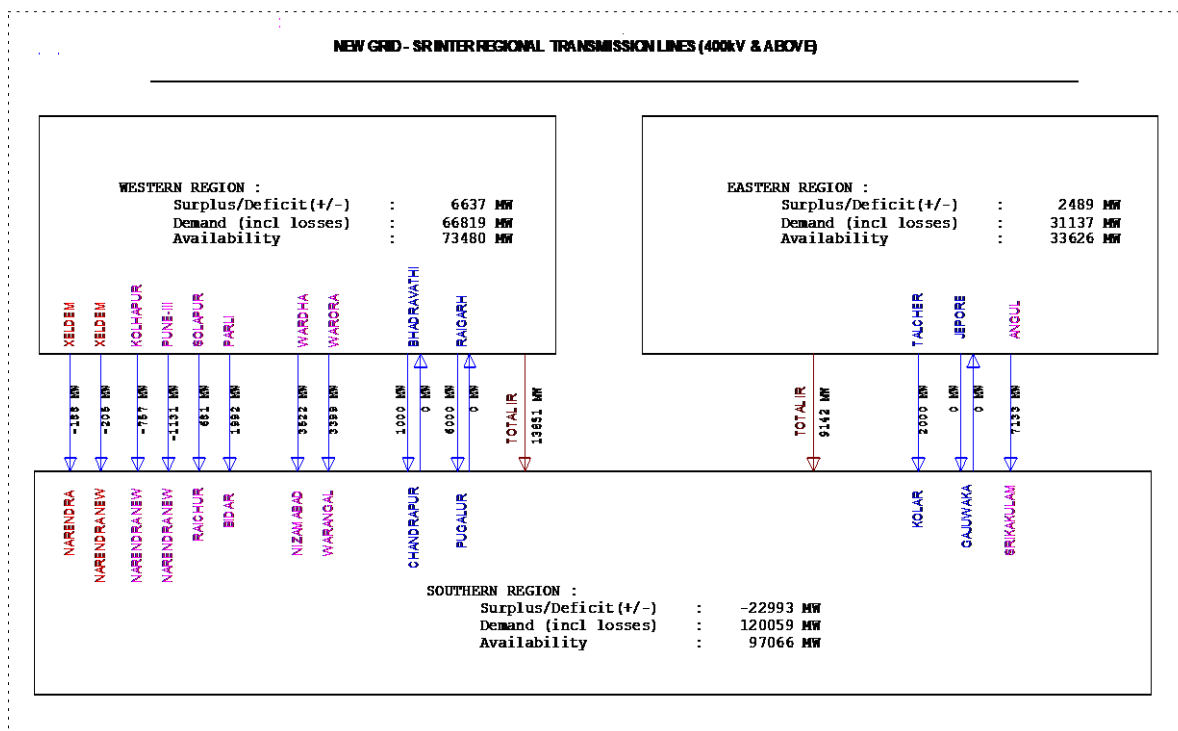


Figure 3 : NEW Grid & SR Grid - Inter-Regional (IR) flows (without Gazuwaka-BTB)

Sensitivity analysis of power flow of Gazuwaka-BTB HVDC on IR links in 2030-31 timeframe for import and export is given below at **Table-1**.

Table 1 : Sensitivity of power flow of Gazuwaka-BTB HVDC on IR links during import

Transmission elements	With Gazuwaka-BTB (MW) both poles	Without Gazuwaka-BTB (MW)	Increase in load flow (MW)	Sensitivity
Narendra-Xeldem	-198	-188	10	1%
Narendra New-Xeldem	-206	-205	1	0.1%
Narendra New – Kolhapur	-800	-757	43	4%
Narendra New-Pune-III	-1186	-1131	55	6%
Raichur-Solapur	593	681	88	9%
Bidar-Parli	1882	1992	110	11%
Wardha-Nizamabad	3390	3522	132	13%
Warora- Warangal	3269	3399	130	13%
Srikakulam- Angul	6668	7133	465	47%
Chandrapur- Bhadravathi	1000	1000	NA	NA
Pugalur-Raigarh	6000	6000	NA	NA
Talcher- Kolar	2000	2000	NA	NA

Comparative analysis of distribution of loadings on AC-IR transmission lines under various scenarios studied under both the cases (with and without Gazuwaka HVDC) are given below at **Table-2**.

Table 2 : Summary of results With and without Guzuwaka HVDC during import

Case	Narendra-Xeldem 400 kV S/c	Narendra New-Xeldem 400 kV S/c	Narendra New – Kolhapur 765 kV D/c	Narendra New-Pune-III 765 kV D/c	Raichur-Solapur 765 kV D/c	Bidar-Parli 765 kV D/c	Wardha-Nizamabad 765 kV D/c	Warora- Warangal 765 kV D/c	Srikakulam- Angul 2x765 kV D/c
With Guzuwaka HVDC (1000 MW)									
With all IR under implementation	-198	-206	-900	-1186	593	1882	3390	3269	6668
Without Bidar Parli	-165	-201	-657	-1030	1241	0	3712	3664	6877
Without Angul-Srikakulam 2 nd D/C	-177	-203	-708	-1066	783	2111	3667	3557	5506
Without Gazuwaka HVDC									
With all IR under implementation	-188	-205	-757	-1131	681	1992	3522	3399	7133
Without Bidar Parli	-153	-200	-605	-965	1368	0	3862	3818	7351
Without Angul-Srikakulam 2 nd D/C	-165	-202	-656	-1000	888	2241	3822	3710	5877

Further, the impact on TTC between SR & NEW grid under different alternatives was also studied and the same is given at **Table-3**

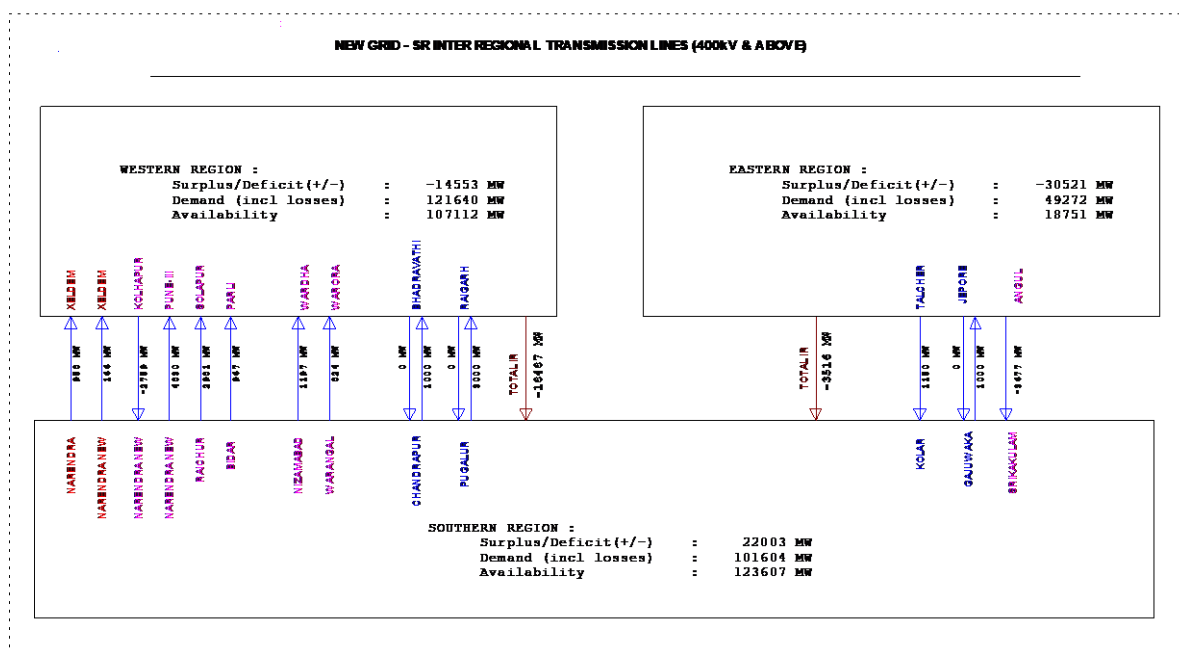
Table 3 : TTC between SR Grid & NEW Grid (import)

Transmission system	Import TTC (With HVDC) (MW)	Import TTC (without HVDC) (MW)	Limiting Constraint	Difference (MW)
With all IR under implementation	36253	35347	Wardha- Nizamabad 765 kV D/c line	906
Without Bidar Parli	31724	30889	Wardha- Nizamabad 765 kV D/c line	835
Without Angul-Srikakulam 2 nd D/C	33698	32703	Wardha- Nizamabad 765 kV D/c line	995

Scenario-4 (SR export)

All India Load Generation Balance is given below as **Fig-4**.

Study result with loadings on inter-regional links between WR & SR grid and ER & SR grid is given below as **Fig-5** (with HVDC) and **Fig-6** (Without Gazuwka-BTB).



Central Transmission Utility of India Ltd.

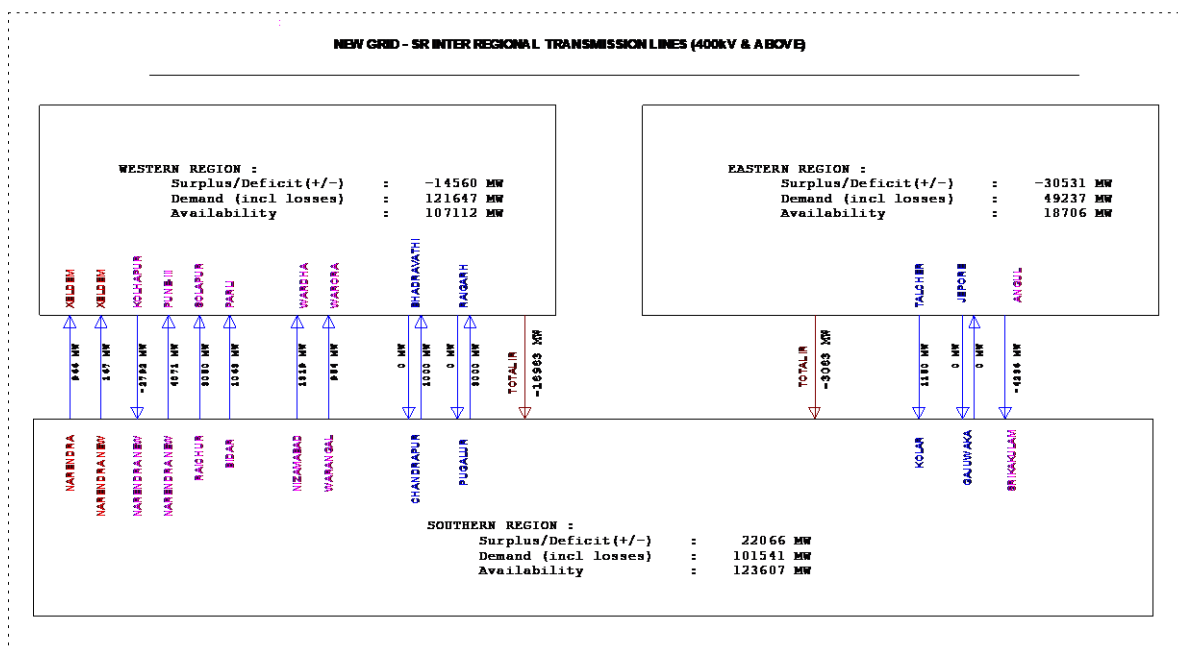


Figure 6 : NEW Grid & SR Grid - Inter-Regional (IR) flows (without Gazuwka-BTB)

Sensitivity analysis of power flow of Gazuwaka-BTB on IR links in 2030-31 timeframe is given below at **Table-4**.

Table 4 : Sensitivity of power flow of Gazuwaka-BTB HVDC on IR links during export

Transmission elements	With Gazuwka-BTB (MW)	Without Gazuwka-BTB (MW)	Increase in load flow (MW)	Sensitivity
Narendra-Xeldem	958	966	8	0.8%
Narendra New-Xeldem	166	167	1	0.1%
Narendra New – Kolhapur	2759	2792	33	3.3%
Narendra New-Pune-III	4830	4871	41	4.1%
Raichur-Solapur	2981	3050	69	6.9%
Bidar-Parli	967	1063	96	9.6%
Wardha-Nizamabad	1197	1319	122	12.2%
Warora- Warangal	824	954	130	13.0%
Srikakulam- Angul	-3677	-4236	559	55.9%
Chandrapur- Bhadravathi	1000	1000	NA	NA
Pugalur-Raigarh	3000	3000	NA	NA
Talcher-Kolar	1150	1150	NA	NA

Comparative analysis of distribution of loadings on AC-IR transmission lines under various scenarios studied under both the cases (with and Without Gazuwka-BTB HVDC) are given below at **Table-5**.

Table 5 : Summary of results With & Without Gazuwaka HVDC during export

Case	Narendra-Xeldem 400 kV S/c	Narendra New-Xeldem 400 kV S/c	Narendra New – Kolhapur 765 kV D/c	Narendra New-Pune-III 765 kV D/c	Raichur-Solapur 765 kV D/c	Bidar-Parli 765 kV D/c	Wardha-Nizamabad 765 kV D/c	Warora- Warangal 765 kV D/c	Srikakulam- Angul 2x765 kV D/c
With Guzuwaka HVDC (1000 MW)									
With all IR under implementation	958	166	2759	4830	2981	967	1197	624	-3677
Without Bidar Parli	975	169	2822	4905	3302	0	1367	1022	-3766
Without Angul-Srikakulam 2 nd D/C	969	167	2805	4886	3076	1090	1350	993	-3070
Without Gazuwaka HVDC									
With all IR under implementation	966	167	2792	4871	3050	1063	1319	824	-4236
Without Bidar Parli	984	170	2872	4952	3402	0	1504	1182	-4340
Without Angul-Srikakulam 2 nd D/C	978	169	2845	4935	3159	1204	1494	1148	-3537

Further, the impact on TTC between SR & NEW grid was also studied and the same is given at **Table-6**.

Table 6 : TTC between SR Grid & NEW Grid (export)

Transmission system	Import TTC (With HVDC) (MW)	Import TTC (without HVDC) (MW)	Limiting Constraint	Difference (MW)
With all IR links under implementation	26686	26370	Narendra-Pune 765 kV D/c line	316
Without Bidar Parli	25773	25431	Narendra-Pune 765 kV D/c line	342
Without Angul-Srikakulam 2 nd D/C	26223	25862	Narendra-Pune 765 kV D/c line	361

System Study Analysis

As per the System Studies, Southern Region is expected to import about 22 GW in 2029-30 with the consideration of Green Hydrogen/ Green Ammonia based projects at 10.5 GW at Kakinada, Pendurthi and Tuticorin. However, in the evening peak scenario, above demand shall be majorly met through import of power from other regions through existing and under implementation inter-regional links.

From the system studies, it is observed that most of the IR links i.e., Angul-Srikakulam, Wardha-Nizamabad, Bidar-Parli, Raichur-Sholapur, Warora-Warangal etc. are being utilized for import of power in evening peak scenario of Southern Region. All the IR links are importing power of about 1600-1700 MW per circuit

except Narendra-Pune 765 kV D/c line which is marginally exporting power on account of availability of generation at Narendra and loads in Maharashtra on the Southern Region boundary. Further all the existing HVDC links are being utilized to the full capacity for meeting the above import requirements i.e. Raigarh – Pugalur HVDC (6000 MW from WR to SR), Bhadrawati BtB HVDC (1000 MW from WR to SR), Gazuwaka BtB HVDC with 2-pole (1000 MW from ER to SR) and Talcher – Kolar HVDC (2000 MW from ER to SR). It is also seen that Angul-Srikakulam 765 kV 2xD/c lines have maximum contribution among all the IR links for meeting the demand.

As per the system studies, in case of non-availability of Gazuwaka BtB HVDC, the loadings shall be shifted to existing and planned inter-regional links. It is observed that Angul-Srikakulam 765 kV 2xD/c line has the greatest sensitivity of about 47% with respect to the power flow in Gazuwaka BtB HVDC.

Studies were also conducted with different scenarios on account of delay/non-implementation of IR links wherein it was observed that import requirement of the region in 2030-31 timeframe may not be met in case of non-availability of Gazuwaka BtB HVDC with 1-pole and outage or non-commissioning of under construction IR links. Particularly, in case Gazuwaka BtB HVDC is not refurbished and Angul-Srikakulam 2nd 765 kV D/c line is not available due to outage or delay in commissioning, about 6070 MW of power shall be imported to SR through the existing Angul- Srikakulam 765 kV D/c line and shall be 'N-1' non-compliant. Accordingly, additional Inter-regional links may be required to be implemented for meeting the regional demand in case of non-refurbishment of Gazuwaka BtB HVDC.

In case of export scenario of the Southern Region, Inter-regional links and existing HVDC links (except Talcher-Kolar HVDC which is being limited to 1150 MW import) are being utilized for transfer of surplus power from SR to WR/ER. In this case, maximum power is being pushed from Narendra-Pune 765 kV D/c lines which are loaded to about 2400 MW per circuit. Further, in case of non-availability of Vizag HVDC the loadings shall be shifted to existing and planned inter-regional links (details as per Table-2).

Accordingly, from the study analysis, it may be seen that in case of non-availability of Gazuwaka BtB HVDC and in the eventuality of outage/non availability of other inter-regional link, constraints are expected to be observed in import/export of power.

In addition to the above, in the Eastern Region, it is observed that loading on various lines in base case and under N-1 is within permissible limit, except for Jeypore – Gazuwaka 400kV D/c line which AAC Moose D/c line (designed at 75° C maximum operating temperature, thermal rating is 870MVA). The thermal rating of Jeypore – Gazuwaka 400kV D/c line is 870MVA. Under N-1 Contingency, Jeypore – Gazuwaka 400kV circuit is critically loaded. In view of above, it is proposed to reconductor Jeypore – Gazuwaka 400kV D/c with HTLS conductor, alongwith necessary upgradation in bay equipment at both ends, if required, such that 1000MW power from HVDC terminals can be safely evacuated in both the directions through this link under N-1 Contingency.

Further, Transmission system augmentation to facilitate 1000 MW power exchange between SR-ER through Gazuwaka HVDC Back-to-Back in both directions was discussed in the joint study meeting held at CEA on 12.08.2026 wherein it was agreed that root cause for low voltage issue at Gazuwaka B-t-B East side may be jointly ascertained by ERLDC & SRLDC, and a report may be shared with SRPC, ERPC, CEA, and CTUIL to identify the need for planning of any additional system or equipment for successful operation of Gazuwaka HVDC B-t-B to full capacity in both directions.

Presently, import TTC of 26700 has been declared for Southern Region which is expected to increase to 36250 MW with the commissioning of Bidar-Parli 765 kV D/c line, Angul-Srikakulam (2nd) 765 kV D/c line and consideration of transmission system for integration of potential REZ in Anantapur-III, Krishnagiri, Kadapa-II and Green Hydrogen/ Green Ammonia loads in Kakinada / Vizag area in Andhra Pradesh. Impact on import TTC of Southern Region was studied for various options with and without Vizag HVDC and it was observed that TTC for import of power from NEW grid to SR grid is expected to be reduced by about 850-950 MW during the 2030-31 timeframe.

Further, export TTC of 20700 has been declared for Southern Region which is expected to increase to 26700 with the commissioning of Bidar-Parli 765 kV D/c line, Angul-Srikakulam (2nd) 765 kV D/c line and consideration of transmission system for integration of potential REZ in Anantapur-III, Krishnagiri, Kadapa-II and Green Hydrogen/ Green Ammonia loads in Kakinada / Vizag area in Andhra Pradesh. Impact on export TTC of Southern Region was studied for various options with and without refurbishment of Vizag HVDC and it was observed that TTC for export of power from SR grid to NEW grid is expected to be reduced by about 300-360 MW during the 2030-31 timeframe.

D. Conclusion:

From the Technical analysis of the different alternatives, the following may be concluded :

- Gazuwaka BtB HVDC has significant role in meeting the demand of Southern Region through controlled power flow.
- Gazuwaka BtB HVDC is also instrumental in facilitating export of surplus power from Southern Region.
- Gazuwaka BtB HVDC is also utilized for voltage control in Southern Region as well as Eastern Region as per the operational feedback.
- TTC for import of power from NEW grid to SR grid is expected to be reduced by about 850-950 MW during the 2030-31 timeframe without Gazuwaka BtB HVDC. Further, reduction of about 300-360 MW is expected in TTC for export of power from SR grid to NEW grid in absence of Gazuwaka BtB HVDC
- In case Gazuwaka BtB HVDC is not refurbished, additional inter-regional links needs to be planned and implemented to meet the ever increasing demand of SR and GH/GA loads.

E. Recommendation:

- Gazuwaka BtB HVDC (2x500 MW) may be refurbished for facilitating inter-regional power flow particularly in meeting the import requirements of Southern Region states and Green hydrogen loads and avoid planning of more inter-regional links.
- Refurbishment of Gazuwaka BtB HVDC may be carried out to avoid reduction in TTC and optimal utilisation of already available infrastructure. The HVDC is also facilitating controlled transfer of power between NEW Grid & SR Grid as well as during the blackout conditions and shall continue to do the same in future as well.
- In order to utilize the full capacity of the Gazuwaka BtB HVDC terminal (1000 MW) in both the directions, it is also recommended to carry out reconductoring of Jeypore – Gazuwaka 400kV D/c with HTLS conductor and necessary upgradation in bay equipment at both ends, along with any other system strengthening, if required to mitigate the low voltage issue at Gazuwaka East bus.

* * * * *

Ref: - CC/AM/ADDCAP/VIZAG

Date- 21.04.2026

To,

COO,
CTUIL, Saudamini,
Plot No-2, Sector 29, Gurgaon,
Haryana-122001

Kind Atten: Sh K K Gupta

Subject: - Request for carrying out system studies for Vizag Back-to-Back HVDC station.

Dear sir,

Pole#2 of HVDC Vizag was commissioned on dated 01.03.2005 and has completed more than 21 years of service life.

Presently, Spare and service support from OEM has gradually diminished over the years. Hence, difficulties are being faced during troubleshooting of problems and routine O&M works. Further, OEM has informed that they are unable to provide further spare & service support due to technology obsolescence and proposed for upgradation of Pole-2 of HVDC Vizag. Hence, Pole-2 of HVDC Back-to-Back Vizag station is being proposed for refurbishment.

Presently Pole1 and Pole 2 Vizag are based on LCC Technology. The activities for refurbishment of Pole 1 (LCC) is under progress and Pole 2 refurbishment will be taken up with a separate timeline.

It may be noted that the integrated operation of two LCC HVDC system at the same location is challenging when the two systems are implemented by different OEMs. There could be issues with control and protection coordination, interaction between control algorithms, pole and station protection logic, communication interfaces, etc.

Therefore, it may be advantageous to take up the refurbishment of both LCC HVDC projects together so that they can be implemented by the same OEM avoiding challenges associated with C & P Integration of the two system. This will also allow for better spare management,, reducing inventory requirements, simplifying logistics, and improving overall system availability and reliability.

In view of above, it is kindly requested to study the combined LCC refurbishment option for refurbishment of Pole 1 and 2 and a study report along with suitable recommendation may please be forwarded to us for taking up with CERC for ADDCAP works.

Thanking you.

Yours faithfully



Rajil Srivastava
ED(AM)

For kind information please:

- Director (Operations)



ग्रीड कंट्रोलर ऑफ इंडिया लिमिटेड
(भारत सरकार का उद्यम)
GRID CONTROLLER OF INDIA LIMITED
(A Government of India Enterprise)



[formerly Power System Operation Corporation Limited (POSOCO)]
राष्ट्रीय भार प्रेषण केन्द्र / National Load Despatch Centre

कार्यालय : बी-9, प्रथम एवं द्वितीय तल, कुतुब इंस्टीट्यूशनल एरिया, कटवारिया सराय, नई दिल्ली - 110016
Office : 1st and 2nd Floor, B-9, Qutab Institutional Area, Katwaria Sarai, New Delhi -110016
CIN : U40105DL2009GOI188682, Website : www.grid-india.in, E-mail : gridindiacc@grid-india.in, Tel.: 011- 42785855

संदर्भ: NLDC/SO/HVDC/Gazuwaka/UTZ/

दिनांक: 19th June 2025

To,

Chief Operating Officer (CTUIL)

Central Transmission Utility of India Ltd.
Floors No. 5 -10, Tower – 1, Plot No. 16,
IRCON International Tower,
Institutional Area, Sector 32, Gurugram, Haryana 122001

विषय: Report on Usefulness & Utilization of Gazuwaka back-to-back HVDC – Reg.

Ref: CTUIL email dated 23rd May 2025 regarding the Usefulness of Gazuwaka back-to-back HVDC

Dear Sir,

This has reference to the CTUIL email dated 23rd May 2025, wherein GRID-INDIA was requested to provide the views on the usefulness of the HVDC Back-to-Back Gazuwaka link in the present and future time frame.

In this regard, the report on the usefulness of HVDC Back-to-Back Gazuwaka on behalf of RLDCs/NLDC is attached as **Annexure-I**.

सधन्यवाद,

भवदीय,

(S Usha)

Executive Director, NLDC

Encl: As above

Copy for kind information to:

1. CMD, Grid-India
2. Member (GO&D), CEA
3. Member (Power System), CEA
4. Director (SO), Grid-India
5. Chief Engineer (PSP&A-I / PSP&A-II), CEA
6. Member Secretary, ERPC / SRPC
7. Executive Director, ERLDC / SRLDC



REPORT ON USEFULNESS AND UTILIZATION OF BACK-TO-BACK HVDC GAZUWAKA LINK



JUNE 19, 2025

GRID CONTROLLER OF INDIA LIMITED

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1. Background

- +/- 205 kV, 2x500 MW back-to-back HVDC Gazuwaka link is an inter-regional HVDC link between Eastern Region and Southern Region, connecting Jeypore (PG) station in Odisha (ER) to Gazuwaka (PG) station in Andhra Pradesh (SR).
- There are two buses at Gazuwaka station, denoted as East Bus and South Bus, where HVDC is an interconnection between these buses. A 400 kV double-circuit line connects the 400 kV Jeypore and Gazuwaka East bus stations. POWERGRID owns both stations.
- The power order on HVDC is the sum of the flow on 400 kV Jeypore-Gazuwaka-D/c lines.
- The details of the HVDC system as available with GRID-INDIA are as follows:
 - **Type:** Back-to-Back LCC Converter Station
 - **Voltage Level:** ± 205 kV
 - **Power Transfer Capacity:** 1000 MW (Both in forward and reverse direction)
 - Operational capacity is limited to 650-700 MW in both directions due to AC system constraints. Details are provided in Section 4.
 - **OEM:** Pole 1 (Alstom) and Pole 2 (ABB)
 - **Commissioning Year:** Pole 1 (1999) and Pole 2 (2005)
 - **400 kV Jeypore – Gazuwaka D/C:** Length - 220 km, Twin Moose Conductors and FSCs present on both circuits
- The pole-1 of the HVDC has completed more than 25 years of service life. As per inputs from CTUIL vide email dated 23rd May 2025, OEMs are unable to provide further spare and service support due to technology obsolescence and have proposed for upgradation of the HVDC. Accordingly, the requirement for refurbishment and the usefulness of HVDC have been studied and presented in this report.

2. Network connectivity & Fault Level at Jeypore and Gazuwaka Buses

- The figure below shows the network connectivity at Jeypore (Odisha – ER) and Gazuwaka (Andhra Pradesh – SR).

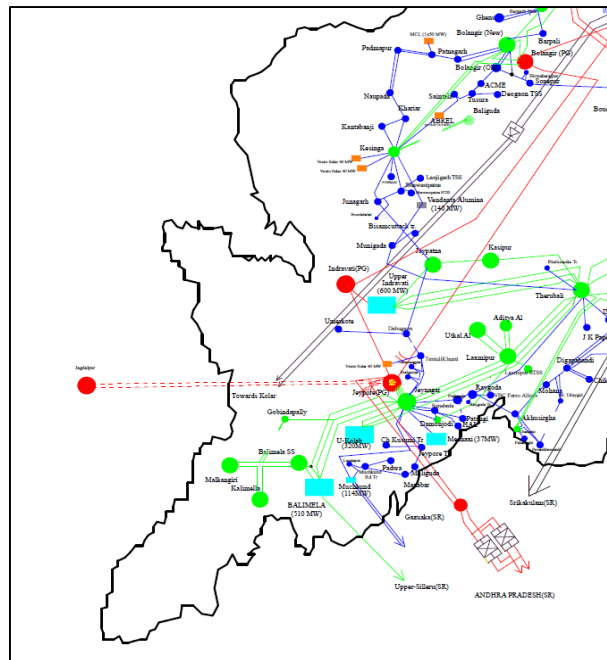


Figure 1: Geographical EHV network showing connectivity at Jeypore end showing 400 kV Jeypore – Gazuwaka (East) D/C line and Gazuwaka BtB HVDC

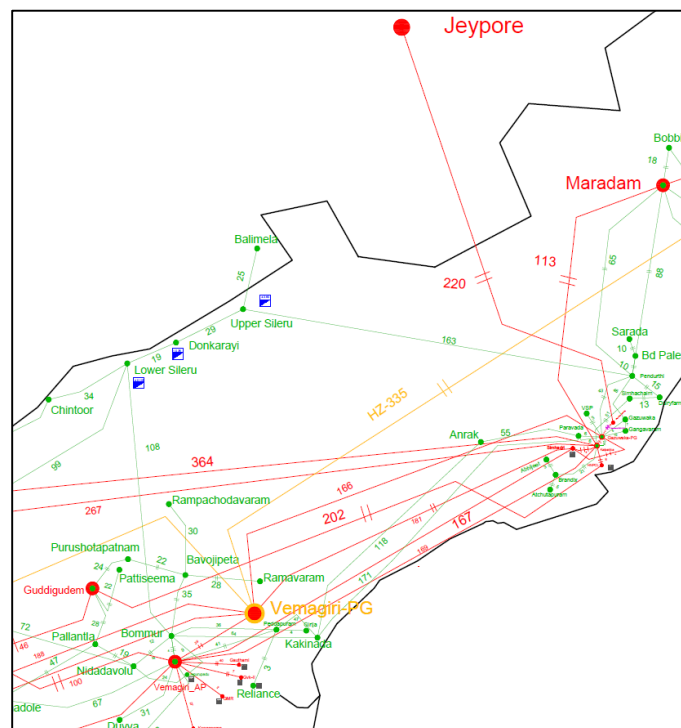


Figure 2: Geographical EHV network showing connectivity at Gazuwaka end showing 400 kV Jeypore – Gazuwaka (East) D/C line and Gazuwaka BtB HVDC

- The transmission elements at both ends of lines, i.e. Jeypore and Gazuwaka end, are listed below:

Connectivity	Name of transmission lines
Eastern region (Jeypore)	400 kV Jeypore (PG) – Gazuwaka (PG) D/C lines (FSC installed on each circuit)
	400 kV Jeypore (PG) – Indravati (PG) S/c line
	400 kV Jeypore (PG) – Bolangir (PG) S/c line (FSC installed)
	400 kV Jeypore (PG) – Jagdalpur D/C lines
	400/220 kV, 2x630 MVA ICTs
	220 kV Jeypore (PG) – Jeynagar (OD) Q/C lines (Four Circuits)
	STATCOM with 200 MVA VSC Unit, 2x125 MVar MSC and 2x125 MVar MSR
Southern Region (Gazuwaka)	400 kV Jeypore (PG) – Gazuwaka (PG) D/C lines (FSC installed on each circuit)
	+/- 205 kV, 2x500 MW back-to-back HVDC LCC Converter Station (Inter-regional HVDC Link)
	400 kV Gazuwaka (PG) – Kalapaka (AP) D/C lines
	400 kV Gazuwaka (PG) – Vemagiri (PG) D/C lines
	400 kV Gazuwaka (PG) – NTPC Simahadri D/C lines
	400/220 kV, 2x315 MVA, 1x500 MVA ICTs
	220 kV Gazuwaka (PG) – Gazuwaka (AP) S/c
	220 kV Gazuwaka (PG) – Parawada (AP) D/c
	220 kV Gazuwaka (PG) – Kalapaka (AP) D/C lines
	220 kV Gazuwaka (PG) – Pendurthi (AP) D/C lines
	220 kV Gazuwaka (PG) – Gangavaram (AP) D/C lines
	220 kV Gazuwaka (PG) – Vizag Steel Plant (AP) D/C lines

- The fault level of the Jeypore, Gazuwaka – East and Gazuwaka – South buses is tabulated below. Very low fault level at Gazuwaka East bus indicates its vulnerability to low voltages during higher power flow and voltage collapse

Sl No	Bus Name	Fault Level
1	400 kV Jeypore Bus	10700 MVA, 15.5 kA
2	400 kV Gazuwaka East Bus	3300, 4.8 kA
3	400 kV Gazuwaka South Bus	26200, 37.8 kA

3. Operational Usage of HVDC BtB Gazuwaka

a. HVDC B-t-B Gazuwaka for inter-regional power flow

SR Import Period

- The BtB Gazuwaka link is a vital inter-regional transmission corridor between the Eastern Region (ER) and Southern Region (SR), playing a crucial role in facilitating power transfer from ER to SR.
- The Southern Region primarily meets its demand through internal generation and by power imports from neighbouring regions, i.e. the Western Region (WR) and Eastern Region (ER). The Southern region experiences peak SR import during its peak demand season from the months of January to April each year.
- The power flow trend of the ER–SR corridor, along with the net import of SR over the past year, is given below.
- It has been observed that on several occasions, the ER–SR corridor flow and net SR import exceeded the declared TTC/ATC limits, suggesting stress on the corridor and the requirement of additional inter-regional transmission links.

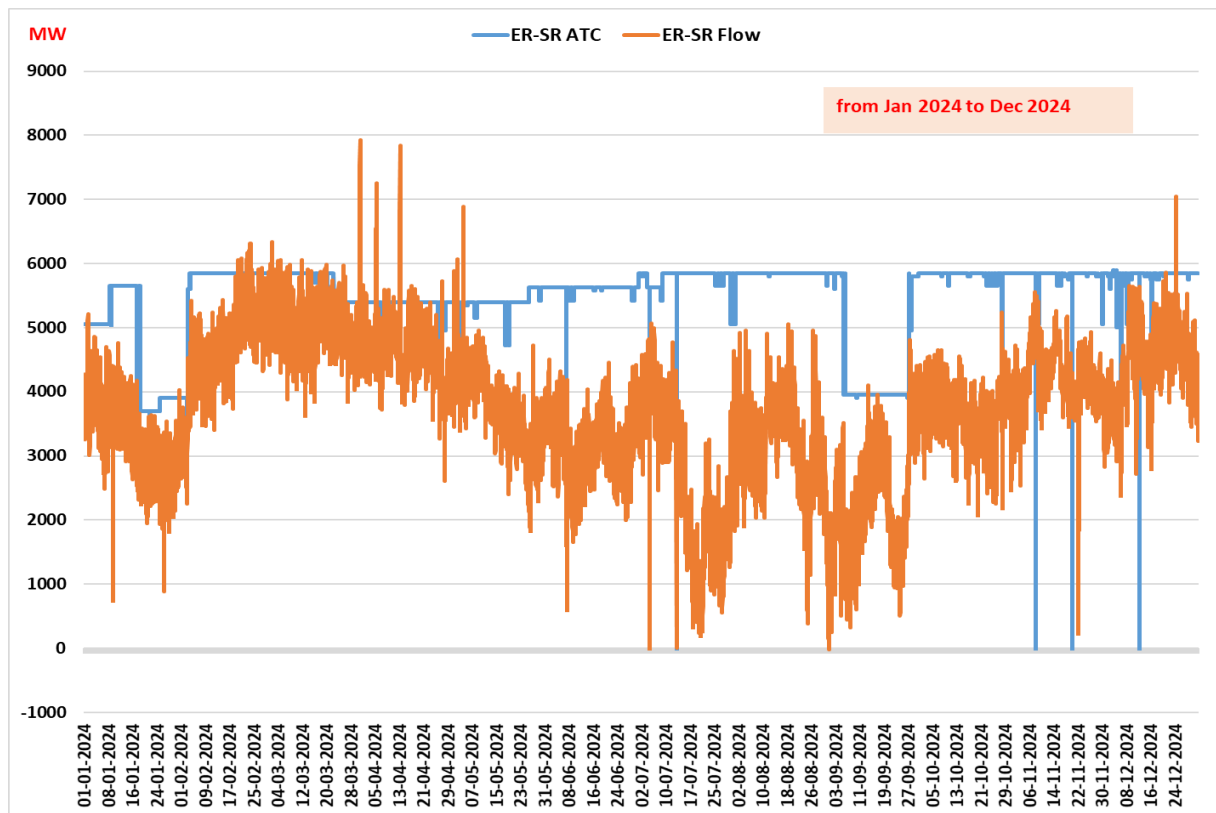


Figure 3: ER-SR power flow for 2024

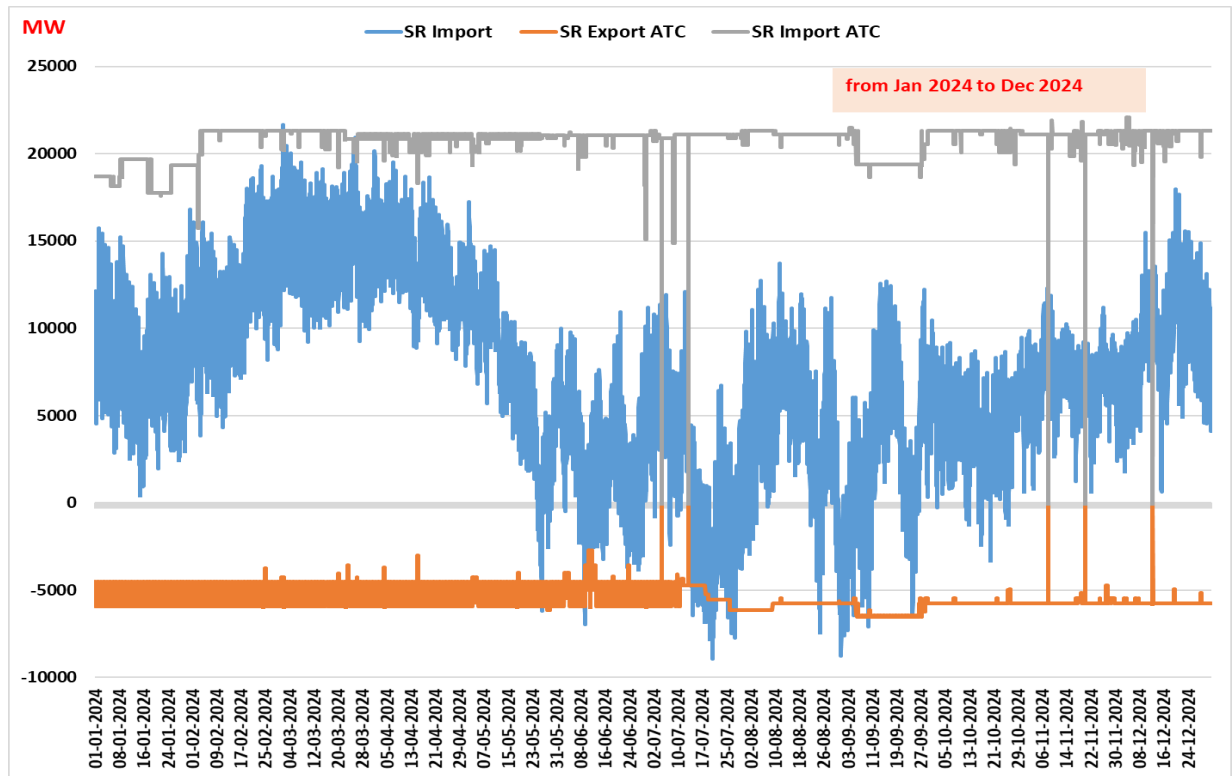


Figure 4: Net SR Import power flow for 2024

- A list of all the inter-regional links between the Eastern Region and the Southern Region is provided below.

Voltage Level (kV)	Inter-Regional Lines	Circuit ID	Tower configuration S/C or D/C	line length in Km	Conductor Type
+/- 205	HVDC Back to Back Gazuwaka (2 x 500MW)	-	-	-	Twin Moose (D/C Line from Jeypore to Gazuwaka)
+/- 500	2x1000 MW, Talcher(ER) - Kolar(SR) HVDC Bipole	-	Bipole	1369	Quad Bersimis
765	Angul-Srikakulam	1	D/C	276	Hexa Zebra
	Angul-Srikakulam	2	D/C	276	Hexa Zebra
400	Jeypore-Gazuwaka	1	D/C	220	Twin Moose
	Jeypore-Gazuwaka	2	D/C	220	Twin Moose
220	Balimela -Upper Silleru (The line is under idle charged condition from 8 th January 2015 from Upper Sileru end)	-	S/C	24.64	ACSR Zebra
132	Machkund-Vizag (Araku Valley)	1	S/C	160	ACSR Panther
	Machkund-Vizag (Araku Valley)	2	S/C	160	ACSR Panther

- The Total Transfer Capability (TTC) between regions is determined based on the most critical (limiting) network constraints. The currently declared TTC/ATC for SR import and SR export are assessed considering HVDC BtB Gazuwaka at a suitable power (700 MW) due to constraints in the operation at higher power orders as mentioned in section 4.
- The SR import TTC/ATC figure without HVDC BtB Gazuwaka will be as below:

Corridor	Present TTC (MW)	TTC (MW) Without HVDC BtB Gazuwaka	Limiting Constraint
WR-SR	16100	15950 (-150)	1. Outage of one ckt of 765 kV Angul - Srikakulam DC will lead to an Angular separation of 20 degrees between Angul & Srikakulam 2. The outage of the any one of the 2x1500 MVA, 765/400 kV ICTs at Maheshwaram overloads the other ICT 3. Low voltage observed at 400 kV Gazuwaka – East bus
ER-SR	6200	5700 (-500)	
SR Import	22300	21650 (-650)	

The non-availability of HDVC G'waka would lead to a reduction of ~650 MW in SR Import TTC/ATC.

- During periods of high demand in the SR, power is imported from both the Western and Eastern Regions, resulting in heavy loading on inter-regional AC transmission lines. To manage this, the power order of all the WR-SR and ER-SR HVDC links is maximised towards the Southern region. HVDC BtB Gazuwaka link is modulated to control the loading on the parallel AC corridors. The sensitivity of the HVDC BtB Gazuwaka link on the inter-regional AC line loadings is given below.

S.N	Elements	Change in Power flow with 100 MW increase in HVDC B-t-B Gazuwaka (ER to SR Direction)
1	765 kV Angul - Srikakulam D/C (each)	-20 MW
2	765 kV Wardha - Nizamabad D/C(each)	- 10 MW
3	765 kV Solapur - Raichur D/C(each)	-8 MW
4	765 kV Warora - Warangal D/C(each)	-10 MW
5	765 kV Nizamabad- Maheshwaram D/C(each)	-4 MW
6	2*1500 MVA, 765/400 kV Maheshwaram ICTs (each)	-4 MW
7	2*1500 MVA, 765/400 kV Raichur Single ICTs (each)	-3 MW
8	2*1500 MVA, 765/400 kV Srikakulam ICTs (each)	-12 MW

- The major constraints that limit the transfer capability of the ER-SR/SR Import corridor are high loading of 2*1500 MVA, 765/400 kV Maheshwaram ICTs and 765 kV Angul - Srikakulam D/C.

- Further, the tripping of any one circuit of the 765 kV Angul–Srikakulam-D/c leads to angular separation of ~ 20.3 degrees between the terminal buses.

The CEA manual on planning criteria suggests that,

“Generally, the lines for which the angular difference between its terminal buses is more than 20 degrees after contingency of one circuit may be selected for performing stability studies”

Given that Angul is connected to multiple generating units, such a condition may pose transient stability concerns.

- An increase of 350 MW in the HVDC Gazuwaka power order towards SR reduces the angular separation between the terminal buses of the 765 kV Angul–Srikakulam double circuit by about 1 degree under N-1 contingency.

SR Export Period

- The maximum Southern region export is experienced in the months from June to September when there is high wind generation in the Southern region and demand is on a lower side. During the SR export period, power typically flows from the SR to the WR. However, even in this scenario, the power flows from the ER to the SR. The constraints are mostly faced in the lines connecting the Karnataka (SR) –Maharashtra (WR) corridor and the lines in the intra-state Maharashtra network.
- The major constraints in the SR-WR corridor are as follows,
 - Under the N-1 contingency of the 400 kV Kudgi–Kolhapur-D/c, the angular separation between Kudgi and Kolhapur touches 30 degrees
 - N-1 contingency of the 765/400 kV, 1500 MVA ICTs at Raichur-PG, leads to overloading of the other ICT.
- To address the transmission constraints, the HVDC links in the WR-SR corridor (HVDC Pugalur – Raigarh & HVDC BtB Bhadrawati) are operated in the SR-to-WR direction.
- There are several occasions when SR is in surplus and Talcher generation is also high. Reduction of power order on HVDC Talcher-Kolar helps. However, the operational flexibility of HVDC is limited. As per the currently implemented SPS-1000 at the Talcher complex, the minimum power order required to trigger the SPS is 1150 MW. Hence, operating the HVDC at a power order below 1150 MW is not feasible.
- In the ER-SR corridor, as the HVDC Talcher-Kolar link cannot be operated in the reverse direction or even reduced below 1150 MW (due to constraints in ER AC system), HVDC BtB Gazuwaka becomes very useful with its reverse operation capability.
- Hence, modulation of the HVDC BtB Gazuwaka power order is necessary even during the SR export period to manage transmission constraints.

The sensitivity figures are given below.

S.No.	Elements	Change in Power flow with 100 MW increase in HVDC B-t-B Gazuwaka (SR to ER Direction)
1.	400 kV Kudgi - Kolhapur D/C	-2.1
2.	400 kV Kolhapur (PG) - Kolhapur (MS) D/C	-1.9
3.	400 kV Narendra - Kudgi D/C	-0.8
4.	400 kV Kolhapur (PG) - Mapusa (PG) D/C	-0.1
5.	400 kV Kolhapur (MS) - Karad (MS) D/C	-1.2
6.	765 kV Raichur - Solapur D/C	-7.5
7.	765/400 kV, 1500 MVA Raichur ICT - 1	-2

b. HVDC BtB Gazuwaka for managing the line loadings in Eastern Region (Odisha Network)

- During solar hours ER imports power from both WR and NR. During high imports from WR towards Odisha (ER), 400 kV OPGC-Lapanga, 400 kV Lapanga-Meramundali and 400 kV Talcher-Meramundali lines in the WR-ER corridor get overloaded. HVDC BtB Gazuwaka has a sensitivity of 6%,9%, and 6%, respectively on the above lines. Hence, modulation of the HVDC BtB Gazuwaka power order is necessary during the ER high import (especially from WR) period to manage transmission constraints.
- HVDC BtB Gazuwaka is also modulated to control the loading of 400 kV Angul- Bolangir during the high-demand period of Odisha in non-solar hours and the other 220 kV lines network near Jeypore.
- Odisha is a highly cyclone-prone area, and almost every year, some EHV transmission lines near the coastal area of Odisha (capital region) go under long outages due to Tower collapse. During such a scenario, modulation of HVDC BtB Gazuwaka plays a major role in maintaining the stability of Odisha state's power system.
- During the other major contingencies, such as restriction in the power order of HVDC Talcher Kolar due to long outage of the converter transformer at Talcher end in March-July of 2024, HVDC BtB Gazuwaka helped provide flexibility in the inter-regional power flows as well as manage the constraints in Odisha.

c. HVDC BtB Gazuwaka for managing the line loadings in the Southern Region (AP Network)

- The following constraints in the Vizag area can be controlled with the modulation of HVDC BtB Gazuwaka power order.
 - 400/220 kV, 3x315 MVA Kalpakka ICTs (2-3% Sensitivity of HVDC BtB Gazuwaka)
 - 400/220 kV, 2x315 + 1x500 MVA Gazuwaka ICTs (2-3% Sensitivity of HVDC BtB Gazuwaka)
 - 2x1500 MVA, 765/400 kV Vemagiri ICTs (15%)
 - 400/220 kV Maradam ICT (3%)
 - 400 kV Vemagiri (PG) – Vemagiri (AP) D/C (4.5%)

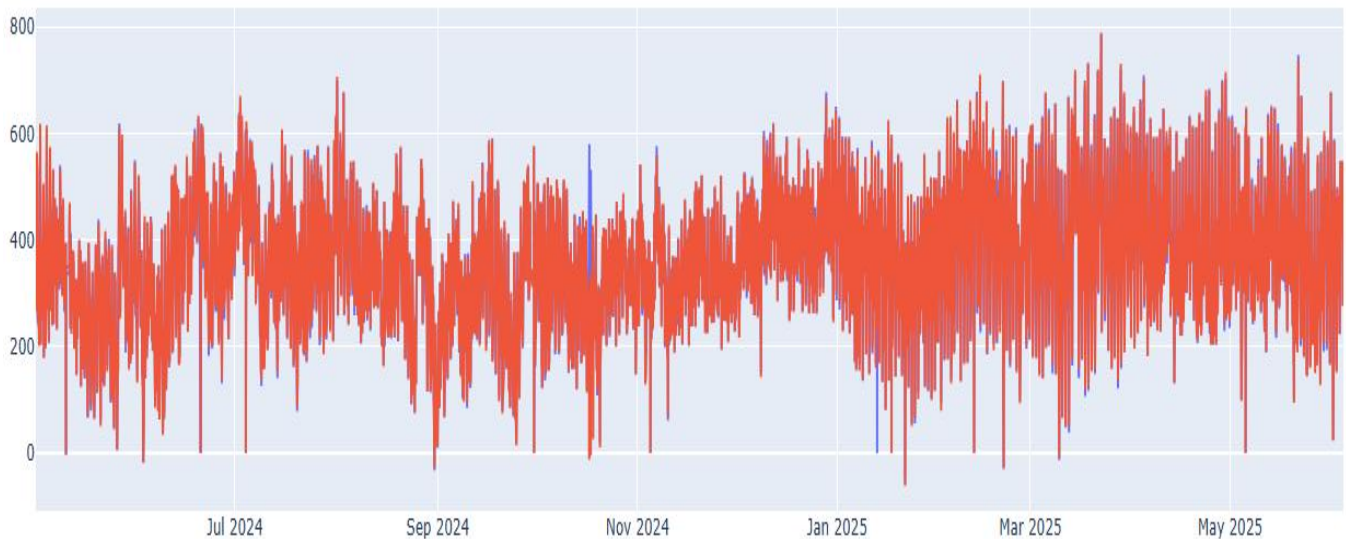


Figure 5: 765/400kV Vemagiri ICT power flow in 2024-25

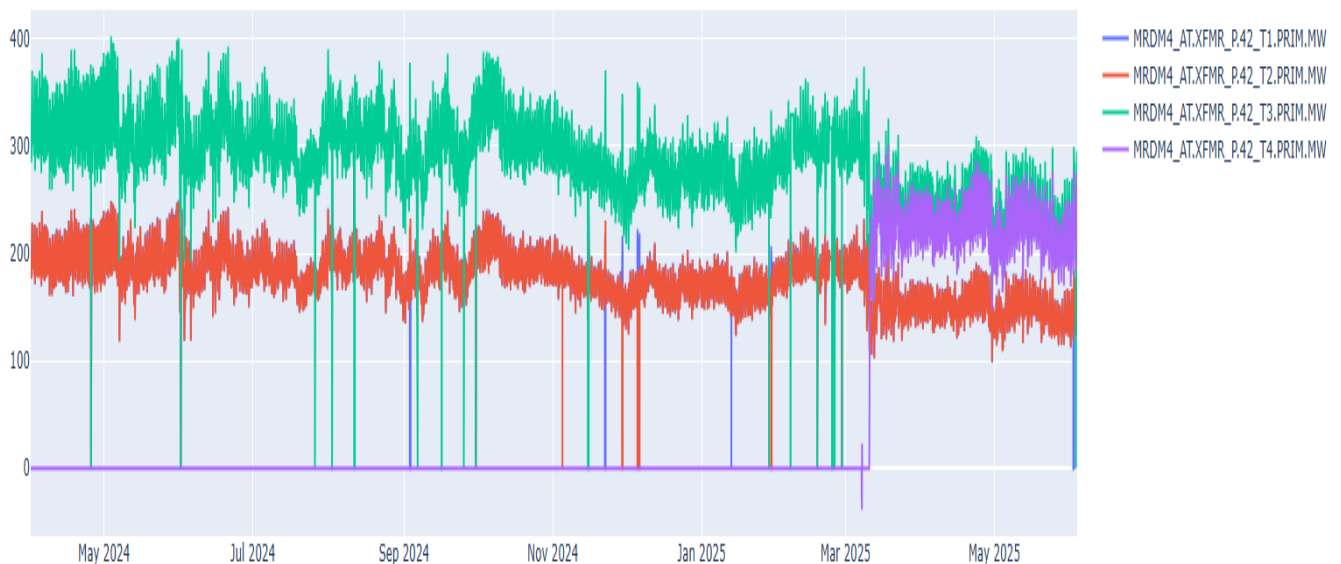


Figure 6: 400/220kV Maradam ICT power flow in 2024-25

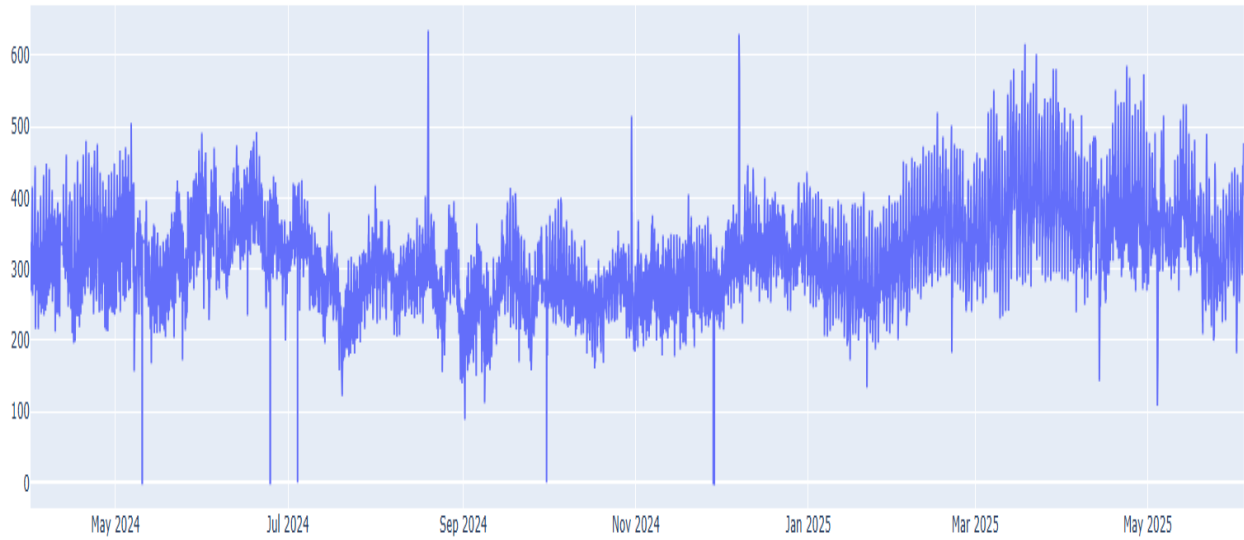


Figure 7: 400kV Vemagiri_PG-Vemagiri_AP D/C power flow in 2024-25

d. HVDC HVDC BtB Gazuwaka for Voltage control in Southern Region

- Both during low-demand - high voltage and high-demand - low voltage periods in Andhra Pradesh, the HVDC BtB Gazuwaka power order becomes crucial for managing the voltages near the Gazuwaka/Vizag area.
- The impact of reactive power support from the AC filter banks present in the AC side of Gazuwaka converter stations on the voltage profiles of nearby substations is also taken into consideration while modulating the power order of the HVDC link.

400kV Station	Voltage (kV) - Gazuwaka HVDC Blocked	Voltage (kV) (MW) -Gazuwaka HVDC 600 MW (towards SR)	Change in kV
GAZUWAKAEAST	394	399	-5.2
SRIKAKULAM	398	401	-2.4
MARADAM4	398	400	-1.6
VEMAGIRI_PG	403	403	-0.7
CUDDAPAH	416	416	-0.5
CPETA_PG	405	406	-0.5
KURNOOL-PG	414	414	-0.5
KURNOOL4	414	414	-0.5
GHANI	414	415	-0.5

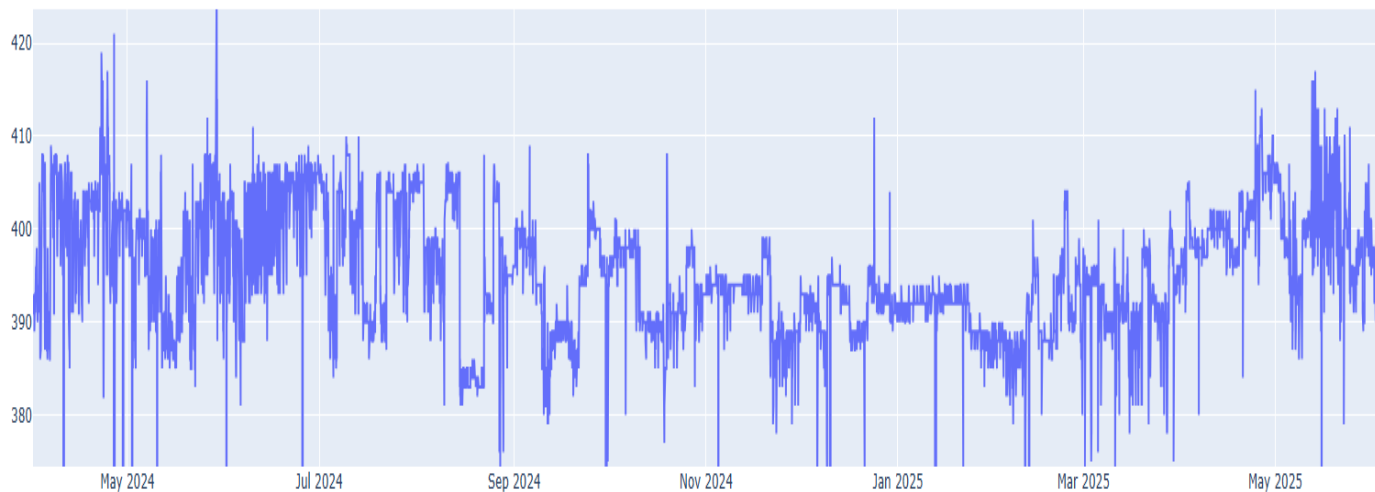


Figure 8: Typical Bus Voltage Profile of 400 kV Gazuwaka East Bus

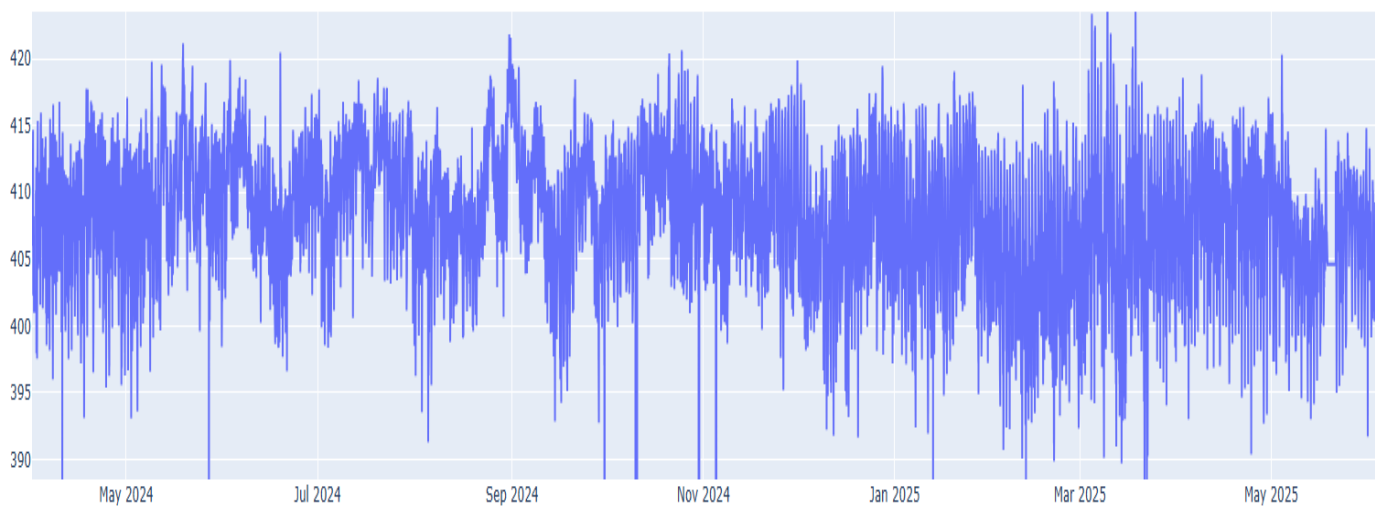


Figure 9: Typical Bus Voltage Profile of 400 kV Srikakulam S/S

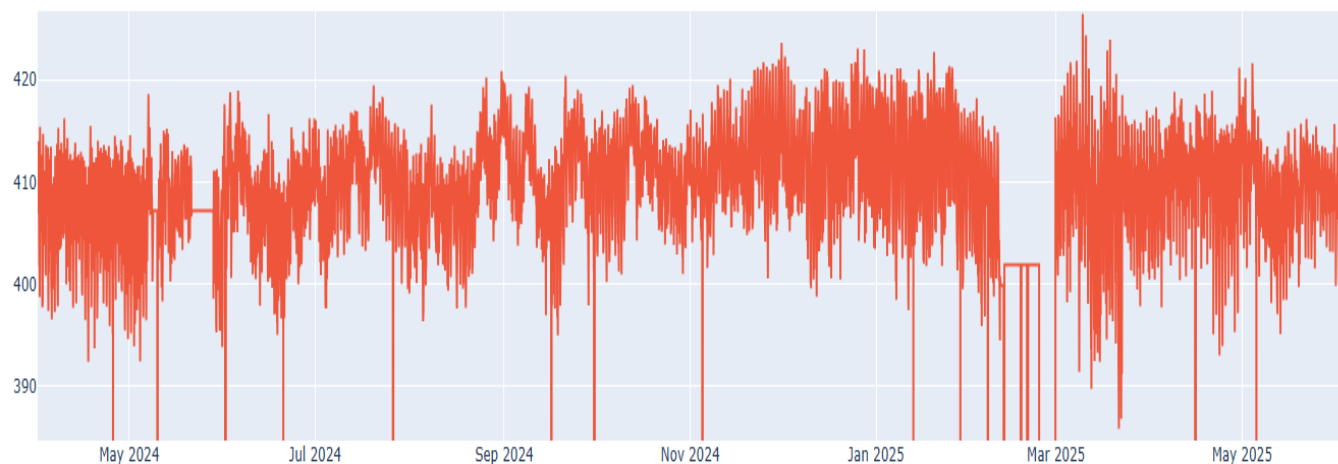


Figure 10: Typical Bus Voltage Profile of 400kV Maradam S/S

e. HVDC HVDC BtB Gazuwaka for Voltage control in Eastern Region

- During periods of high demand in Odisha, severe low-voltage conditions are observed in the 400 kV Bolangir and downstream areas.
- To mitigate these issues, the power order of the HVDC BtB Gazuwaka link is modulated accordingly.

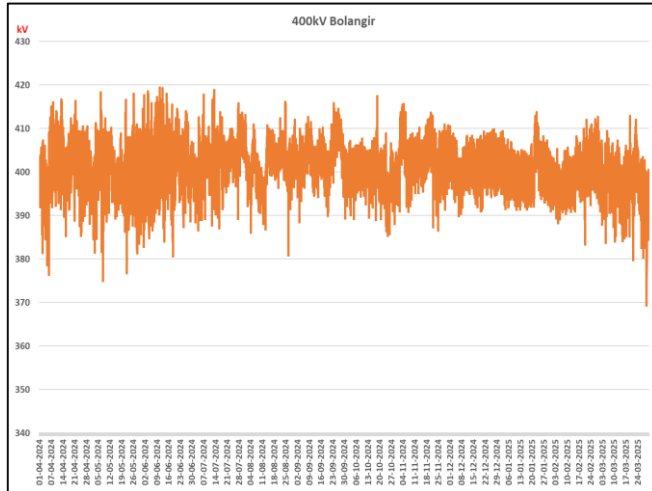


Figure 11: Typical Bus Voltage Profile of 400 kV Bolangir Bus

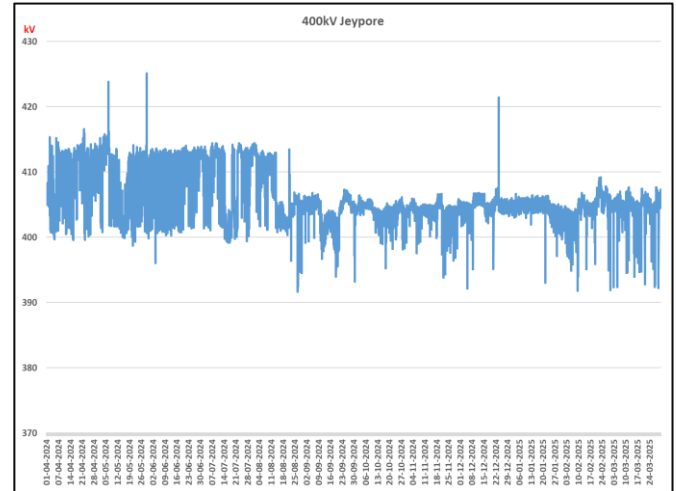


Figure 12: Typical Bus Voltage Profile of 400 kV Jeypore Bus

f. Extension of Power during Blackout

- HVDC BtB Gazuwaka also provides the facility to bypass the HVDC converter station and extend supply through the AC bypass. The facility can be utilised for system restoration for extending start-up power from ER to SR or vice versa, post-blackout
- Mock drills are conducted every year when the HVDC Poles (any one) are blocked, and the supply is extended to NTPC Simhadri (SR) via the AC bypass of HVDC Gazuwaka. The last successful mock drill was conducted on 21 November 2024.

4. Constraints in the Operation of HVDC BtB Gazuwaka

a. Constraint in the operation of HVDC BtB Gazuwaka at rated capacity due to low voltages and transmission constraints

- Although HVDC BtB Gazuwaka has a full capacity of 1000 MW in both directions, the HVDC cannot be utilised at its full capacity due to the following constraints.
 - With the increase in power order of HVDC BtB Gazuwaka in ER-SR direction beyond 650-700 MW, low voltage at Gazuwaka East bus and Bolangir are observed. Due to low fault level and absence of sufficient dynamic reactive power resources in the complex, the east bus at Gazuwaka station, which is synchronously connected to Jeypore through AC lines, faces severe low voltages when power in the HVDC link is increased beyond a certain level (650-700 MW). This poses a serious threat of voltage instability. The real-time voltage profile and snapshot from the simulation study are the same.
 - Further, the poor availability of the FSCs of the 400 kV Jeypore – Gazuwaka D/C lines has also posed challenges in managing the voltage at the Jeypore and Gazuwaka East bus.
 - Similarly, in the SR to ER direction, when the HVDC link is operated beyond a power order of 650-700 MW, overloading of the following lines in the Odisha network are observed, especially during high Odisha hydro period.
 - 220 kV Jaynagar-Lakshmipur
 - 220 kV Lakshmipur-Therubali
 - 220 kV Therubali-Bhanjanagar
- The same power orders (650-700 MW) are also considered for SR Import/Export TTC assessment.

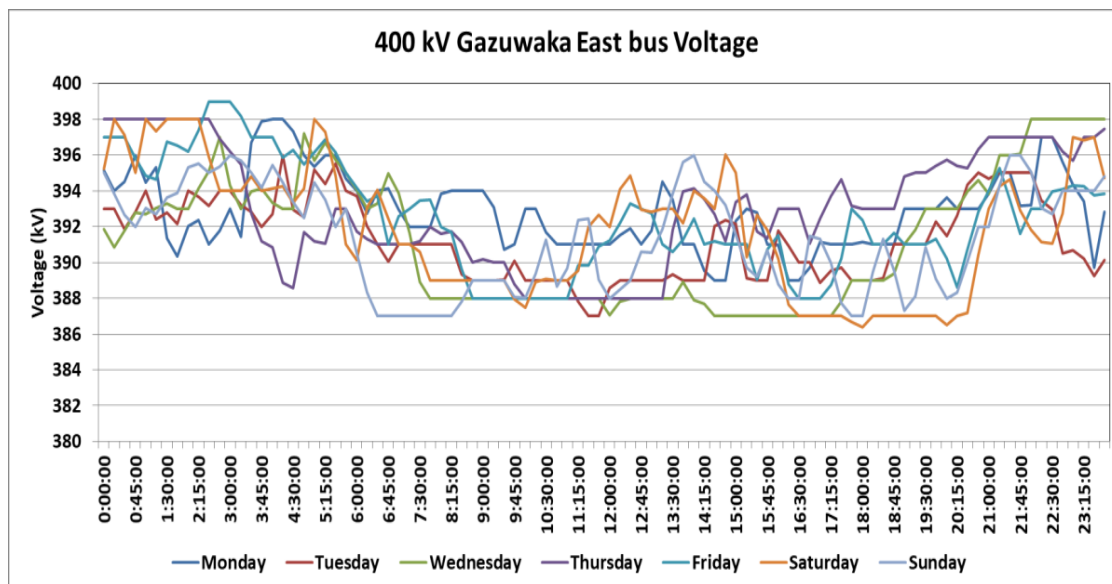


Figure 13: Typical Bus Voltage Profile of Gazuwaka East Bus

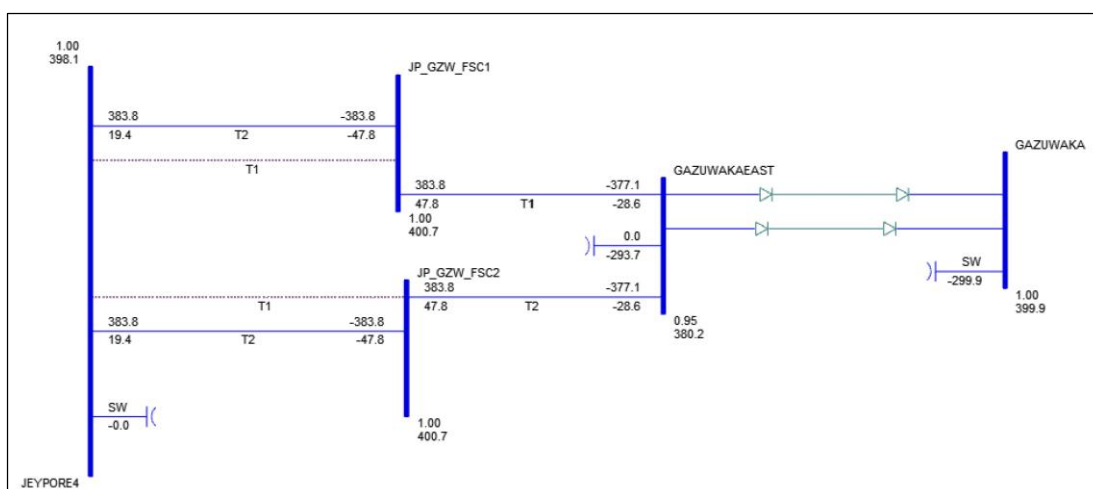


Figure 14: Severe low voltage at Gazuwaka East bus with a power order of 750 MW from ER to SR in the simulation study

b. Past experiences of Oscillations and Fluctuations in Power and Ferro-resonance:

- In the past, there have been several instances of severe fluctuations and oscillations observed in the AC system parameters of the HVDC Gazuwaka station as well as the Jeypore substation. In such scenarios, automatic reduction in the power order was also observed. On some occasions, the tripping of generators in Odisha was also reported.

A few instances of the tripping of the HVDC BtB Gazuwaka Poles due to ferroresonance are tabulated below.

S.No.	Name of the Element	Tripping Date and Time		Remarks
1	HVDC GAJUWAKA POLE 2	01-Feb-18	00:23	Tripping of Poles due to detection of Ferro resonance
2	HVDC GAJUWAKA POLE 2	02-Mar-18	01:38	
3	HVDC GAJUWAKA POLE 1	31-Jan-20	14:51	
4	HVDC GAJUWAKA POLE 1	15-Jun-20	01:54	
5	HVDC GAJUWAKA POLE 2	15-Jun-20	01:54	
6	HVDC GAJUWAKA POLE 2	26-Jun-20	20:22	
7	HVDC GAJUWAKA POLE 1	26-Jun-20	20:19	

- In a Special meeting held on the tripping of Pole–1 & 2 at HVDC Gazuwaka SS held on 2nd April 2018, the following long-term measure was identified for implementation by POWERGRID,

“As a long-term measure for avoiding pole trippings under ferro-resonance conditions, it was agreed that POWERGRID would carry out necessary refurbishment works of controller protections at Jeypore end for detecting ferro-resonance locally at FSC location (Jeypore end) and effect automatic by-passing of FSCs by putting necessary infrastructure in place at Jeypore end. POWERGRID was requested to furnish a concrete proposal with suitable timelines in this regard”

- The presence of HVDC Converter station, FSC, STATCOM at Jeypore and generators in the south Odisha system in close vicinity enhances the possibility of control interactions. Therefore, a detailed simulation-based root cause analysis report and remedial measures in this regard are necessary.

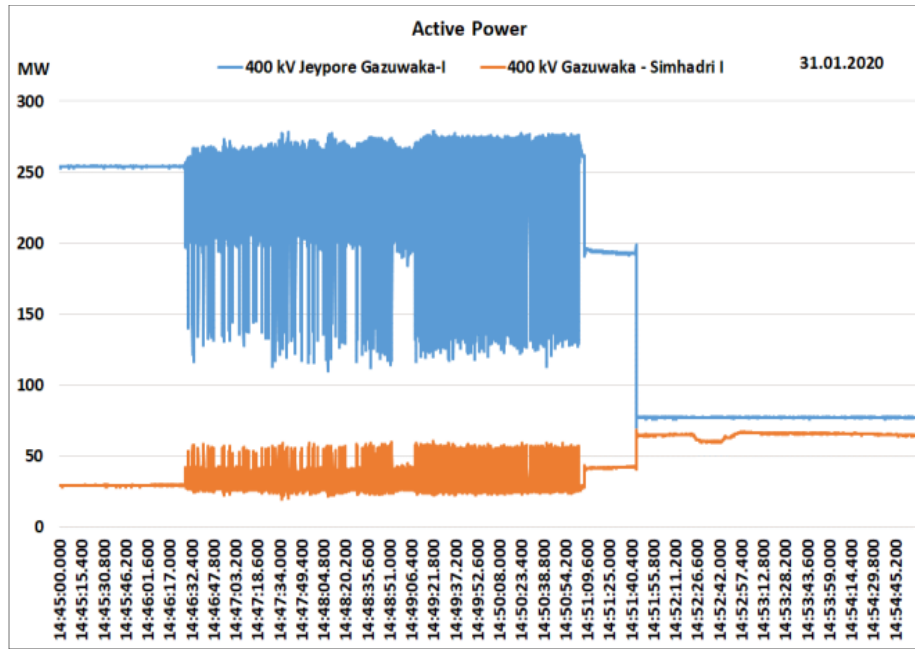


Figure 15: Fluctuations in AC power in Jeypore - Gazuwaka 400 kV D/c lines in one of the events in Jan 2020

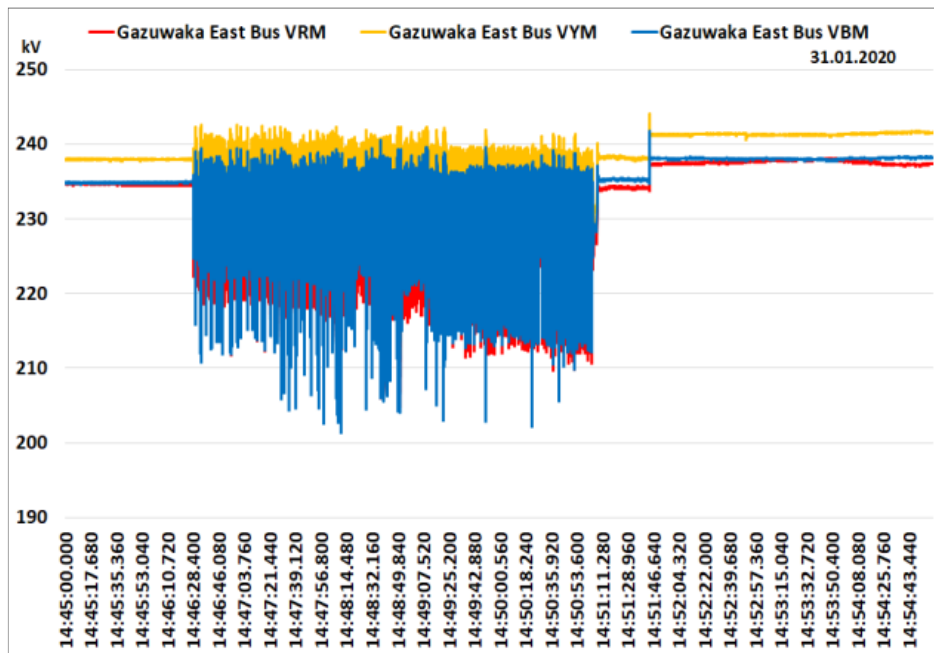


Figure 16: Fluctuations in voltages of the 400 kV Gazuwaka bus in one of the events in Jan 2020

5. Operational Availability and Utilisation of HVDC BtB Gazuwaka

a. Operational Availability Factor of HVDC BtB Gazuwaka

- The operational availability of HVDC BtB Gazuwaka for the year 2024-25 is tabulated below
(**Source:** SRLDC Metering Data).

HVDC BtB Gazuwaka Availability	Duration (Hrs)	Outage Duration (hrs)	Duration for which available (hrs)	% Availability	HVDC BtB Gazuwaka Energy Flow in 2024-25 (MU)	
HVDC Poles	8760	47.5	8712.5	99.45	ER to SR – 2899.12	Cumulative Energy Flow in Either Direction: 3390.03
					SR to ER – 490.91	

b. Plots of Operational Utilisation of HVDC BtB Gazuwaka

- The time-series plot and the duration curve of HVDC BtB Gazuwaka power order 2024-25 are provided below.
- From the plots, it is clear that HVDC BtB Gazuwaka is used both in the forward as well as reverse directions based on the operational requirement.
- It can also be seen that the HVDC is never operated at its maximum capacity of 1000 MW because of the constraints explained in the previous section. This leads to severe underutilization of this transmission asset.

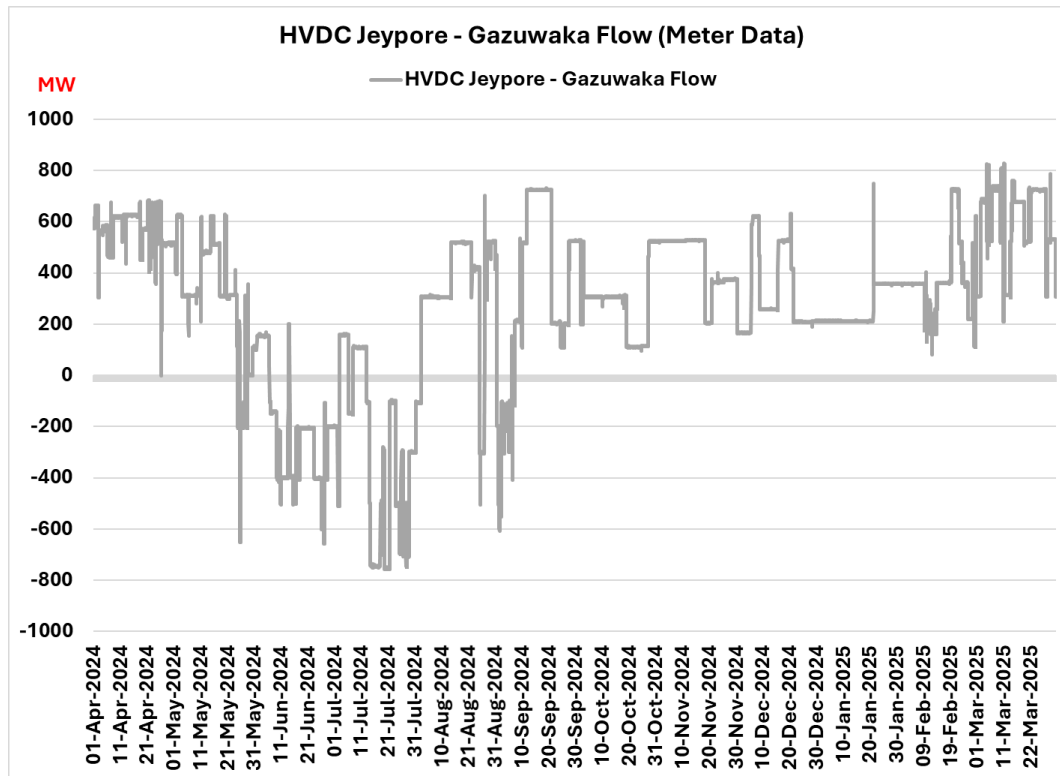


Figure 17: Time Series of HVDC BtB Gazuwaka 2024-25

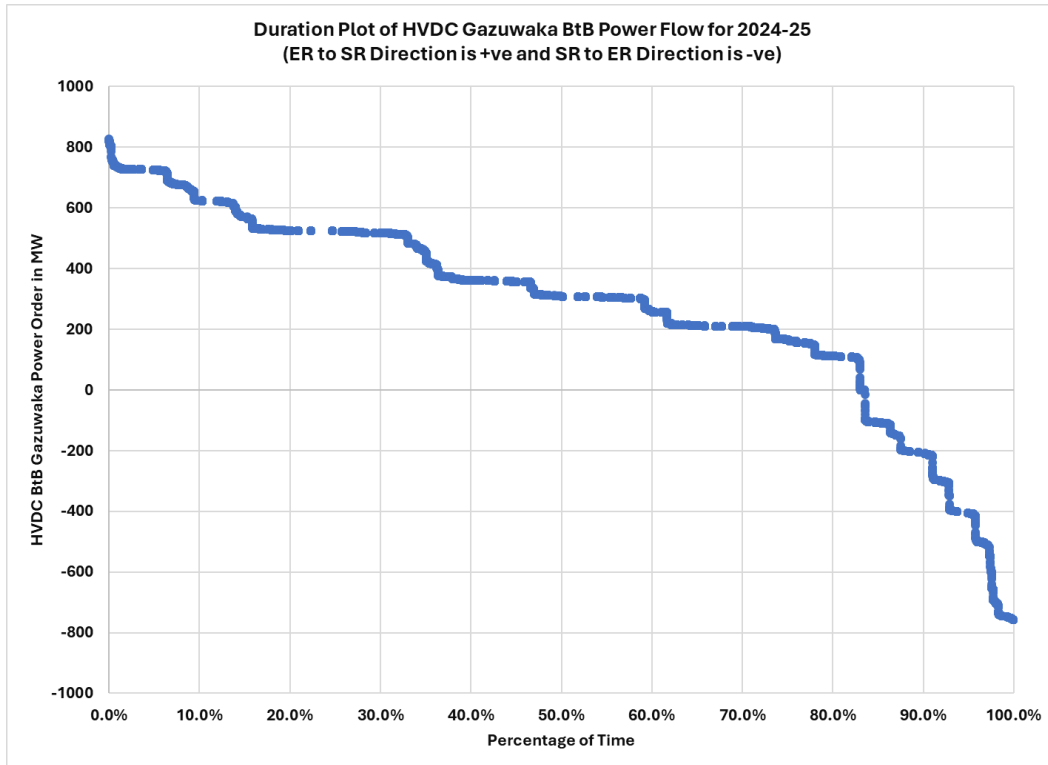


Figure 18: Duration plot of power order HVDC BtB Gazuwaka for 2024-25 (Source: Meter Data)

c. Details of tripping of HVDC Gazuwaka BtB Poles during Mar 2024 to May 2025

S. No.	Name of the Element	Tripping Date and Time		Remarks	Restoration Date and Time	
1	HVDC 500KV GAZUWAKA Pole 1	3-May-22	3:17	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of South bus voltage.	3-May-22	7:33
2	HVDC 500KV GAZUWAKA Pole 2	3-May-22	3:17	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of South bus voltage.	3-May-22	6:40
3	HVDC 500KV GAZUWAKA Pole 1	16-Aug-22	14:52	The 400 KV Main I Bus I protection 96 Relays have operated due to Bus bar maloperation.	16-Aug-22	17:03
4	HVDC 500KV GAZUWAKA Pole 2	16-Aug-22	14:52	The 400 KV Main I Bus I protection 96 Relays have operated due to Bus bar maloperation.	16-Aug-22	17:27
5	HVDC 500KV GAZUWAKA Pole 2	4-Jul-23	17:36	Communication failing between Pole control (PCP) to AC Control & protection(ACP)Servers	4-Jul-23	21:09
6	HVDC 500KV GAZUWAKA Pole 1	27-Mar-24	6:24	Pole -1 got blocked due to failure of changeover of Valve Cooling Pump.	27-Mar-24	14:57
7	HVDC 500KV GAZUWAKA Pole 2	26-Apr-24	18:50	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of East bus voltage.	26-Apr-24	22:25

S. No.	Name of the Element	Tripping Date and Time		Remarks	Restoration Date and Time	
8	HVDC 500KV GAZUWAKA Pole 1	26-Apr-24	18:50	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of East bus voltage.	26-Apr-24	22:25
9	HVDC 500KV GAZUWAKA Pole 2	26-Apr-24	16:24	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of East bus voltage.	26-Apr-24	18:50
10	HVDC 500KV GAZUWAKA Pole 1	26-Apr-24	16:24	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of East bus voltage.	26-Apr-24	18:50
11	HVDC 500KV GAZUWAKA Pole 1	29-May-24	9:39	OV Protection	29-May-24	12:34
12	HVDC 500KV GAZUWAKA Pole 1	15-May-25	17:19	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of East bus voltage.	15-May-25	18:18
13	HVDC 500KV GAZUWAKA Pole 2	15-May-25	17:19	Gazuwaka HVDC pole 1&2 was blocked due to non-availability of East bus voltage.	15-May-25	18:18

6. Alternatives of HVDC BtB Gazuwaka

- HVDC BtB Gazuwaka not only plays an important role in the inter-regional power transfer, but also manages the voltage profile and line loadings in the local Odisha and Andhra Pradesh networks. In the absence of this transmission asset, there will be a requirement for investment at both Odisha and AP ends.

a. Impact of non-availability of Jeypore – Gazuwaka BtB HVDC Link

- The following tables show the impact of the absence of HVDC Gazuwaka on the line loadings of major transmission constraints during the SR Import period. It can be seen that the absence of HVDC Gazuwaka impacts the line loadings of all the ER-SR and WR-SR links and the major ICTs in the Southern region which limit the inter-regional transfer capability.
- The highest impact of the HVDC BtB Gazuwaka can be seen on the parallel AC line, like 765 kV Angul – Srikakulam D/c whose loading would increase by ~150 MW during peak SR import scenario. This can pose challenges from both high loading and angular instability points of view. However, it may be noted that the 2nd D/c of 765 kV Angul - Srikakulam D/c lines has been approved in the 29th NCT with a time frame of 30 months. But looking at the growing demand in the Southern region and envisaged green hydrogen bulk loads in Andhra Pradesh, the lines are expected to carry heavy power from Angul to Srikakulam. Having a controllable HVDC link in a parallel corridor will be helpful in any eventuality in the future time frame.

COMPARISON OF LINE LOADINGS UNDER HIGH SR IMPORT SCENARIO WITH AND WITHOUT HVDC BtB GAZUWAKA							
FROM BUS NAME	FROM BUS VOLTAGE LEVEL	TO BUS NAME	TO BUS VOLTAGE LEVEL	CIRCUIT	Loading (HVDC BtB Gazuwaka = 700 MW)	Loading (HVDC BtB Gazuwaka is Blocked)	Change in Power Flow
JEYPORE	400	GAZUWAKAEAST	400	T1	358	0	-358
JEYPORE	400	GAZUWAKAEAST	400	T2	358	0	-358
ANGUL7	765	SRIKAKULAM	765	H1	1775	1918	142
ANGUL7	765	SRIKAKULAM	765	H2	1775	1918	142
WARORA-PS	765	WARANGAL_NEW	765	H1	1694	1767	73
WARORA-PS	765	WARANGAL_NEW	765	H2	1694	1767	73
WARDHA-PG	765	NIZAMABAD	765	H1	1758	1828	70
WARDHA-PG	765	NIZAMABAD	765	H2	1758	1828	70
SOLAPUR-PG	765	RAICHUR-PG	765	B1	1091	1152	61
SOLAPUR-PG	765	RAICHUR-PG	765	B2	1091	1152	61
SRIKAKULAM	765	VEMAGIRI_PG	765	H1	1219	1273	55
SRIKAKULAM	765	VEMAGIRI_PG	765	H2	1219	1273	55
MAHESWARAM	765	MAHESWARAM	400	ICT -1	1060	1089	29
MAHESWARAM	765	MAHESWARAM	400	ICT - 2	1060	1089	29

COMPARISON OF LINE LOADINGS UNDER HIGH SR IMPORT SCENARIO WITH AND WITHOUT HVDC BtB GAZUWAKA

FROM BUS NAME	FROM BUS VOLTAGE LEVEL	TO BUS NAME	TO BUS VOLTAGE LEVEL	CIRCUIT	Loading (HVDC BtB Gazuwaka = 700 MW)	Loading (HVDC BtB Gazuwaka is Blocked)	Change in Power Flow
VEMAGIRI_PG	765	VEMAGIRI_PG	400	ICT -1	599	702	103
VEMAGIRI_PG	765	VEMAGIRI_PG	400	ICT - 2	599	702	103
SRIKAKULAM	400	SRIKAKULAM	400	ICT -1	537	621	84
SRIKAKULAM	400	SRIKAKULAM	400	ICT - 2	537	621	84
JEYPORE4	400	BOLANGIR	400	T1	64	184	120
GAZUWAKA	400	KALAPAKA4	400	T1	66	163	97
GAZUWAKA	400	KALAPAKA4	400	T2	66	163	97
SRIKAKULAM	400	MARADAM4	400	Q1	537	621	84
SRIKAKULAM	400	MARADAM4	400	Q2	537	621	84
MERAMUNDLI4	400	LAPANGA4	400	A1	144	206	62
MERAMUNDLI4	400	LAPANGA4	400	A2	144	206	62
STER_OPT	400	LAPANGA4	400	A1	493	537	44
STER_OPT	400	LAPANGA4	400	A2	493	537	44

- In the absence of the BtB Gazuwaka link, loading on 765/400kV Vemagiri ICTs, 400/220kV Maradam ICTs, and 400kV Vemagiri_PG-Vemagiri D/C may increase and may reach close to N-1 limits.
- Similarly, HVDC BtB Gazuwaka is also important for managing the transmission constraints during SR Export periods as well as during peak demand periods in Odisha.
- The 400 kV network around Jeypore area is also weak, and it is difficult to control voltages on various occasions. Gazuwaka provides flexibility to manage the power flow.

b. Impact of connecting Jeypore and Gazuwaka with an AC interconnection

- The impact of bypassing HVDC Gazuwaka BtB and connecting the 400 kV Jeypore and Gazuwaka with a 400 kV AC interconnection is studied under two cases, and the results are presented here.
- i. Case – 1 (Power Flow Pattern Under High SR Import Scenario - ER and WR are surplus and SR under deficit condition)**
- Heavy power flow is observed in 400 kV Jeypore – Gazuwaka D/C lines (beyond N-1 limit) towards the Southern region. The loadings are severe when FSCs in the 400 kV Jeypore – Gazuwaka D/C are in service.
 - The connection of 400 kV Jagdalpur to Jeypore will further push power towards SR through Jeypore - Gazuwaka

Power Flow Pattern Under High SR Import Scenario (ER and WR are Surplus and SR Under Deficit Condition)						
Transmission Lines & power flows under different conditions	Conductor Type	With HVDC BtB Gazuwaka in Service (700 MW Power Flow in ER to SR Direction)	With HVDC Gazuwaka bypassed and 400 kV Jeypore – Gazuwaka D/C in service		With HVDC Gazuwaka bypassed and N-1 of 400 kV Jeypore - Gazuwaka D/c	
			FSCs in 400 kV Jeypore - Gazuwaka D/C in Service	FSCs in 400 kV Jeypore - Gazuwaka D/C not in Service	FSCs in 400 kV Jeypore - Gazuwaka D/C in Service	FSCs in 400 kV Jeypore - Gazuwaka D/C not in Service
400 kV Jeypore - Gazuwaka - 1	Twin Moose, N-1 Limit (With FSC: 583 MW, Without FSC: 633 MW)	357	719	587	0	0
400 kV Jeypore - Gazuwaka - 2		357	719	587	1080	803
400 kV Jagdalpur - Jeypore D/C (Each Ckt)	AL59 Quad	31	189	131	110	50
400 kV Indravati - Jeypore	Twin Moose	365	549	482	458	388
400 kV Bolangir - Jeypore	Twin Moose	47	191	138	119	64
2x630 MVA, 400/220 kV ICTs at Jeypore	-	122	162	147	142	127
1x500 MVA Gazuwaka ICT	-	286	302	296	294	288
2x315 MVA Gazuwaka ICTs	-	180	190	187	185	182
765 kV Angul - Srikakulam D/C (Each Ckt)	Hexa Zebra	1871	1740	1786	1808	1856

ii. Case – 2 (Power Flow Pattern Under High SR Export Scenario - SR is Surplus with high Demand in Odisha & high generation in South Odisha hydro plants)

- a. High loadings are observed in 400 kV Jeypore – Gazuwaka D/C lines from SR to ER direction
- b. The loading of critically loaded lines in South Odisha, like 220 kV Jeypore - Laxmipur D/C, 220 kV Laxmipur – Theruvali D/c & 220 kV Theruvali - Bhanjanagar D/C, gets further aggravated and loadings cross N-1 limits.
- c. Voltage profiles in the South Odisha system also worsen to some extent

Power Flow Pattern Under High SR Export Scenario (SR is Surplus and High Odisha Demand & High South Odisha Hydro Gen)						
Transmission Lines & power flows under different conditions	Conductor Type	With HVDC BtB Gazuwaka in Service (700 MW Power Flow in SR to ER Direction)	With HVDC Gazuwaka bypassed and 400 kV Jeypore – Gazuwaka D/C in service		With HVDC Gazuwaka bypassed and N-1 of 400 kV Jeypore - Gazuwaka D/c	
			FSCs in 400 kV Jeypore - Gazuwaka D/C in Service	FSCs in 400 kV Jeypore - Gazuwaka D/C not in Service	FSCs in 400 kV Jeypore - Gazuwaka D/C in Service	FSCs in 400 kV Jeypore - Gazuwaka D/C not in Service
400 kV Jeypore - Gazuwaka - 1	Twin Moose, N-1 (With FSC: 583 MW, Without FSC: 633 MW)	-348	-436	0	-350	0
400 kV Jeypore - Gazuwaka - 2		-348	-436	-638	-350	-484
400 kV Jagdalpur - Jeypore D/C (Each Ckt)	AL59 Quad	31	-67	-21	-32	14
400 kV Indravati - Jeypore	Twin Moose	-549	-597	-537	-552	-493
400 kV Bolangir - Jeypore	Twin Moose	4	-36	-5.2	4.3	38
2x630 MVA, 400/220 kV ICTs at Jeypore	-	34	43	32	35	23
220 kV Jeynagar - Laxmipur D/C (Each Circuit)	Zebra, N-1 Limit: 140 MW	136	142	136	138	131
220 kV Laxmipur - Theruvali D/C (Each Circuit)	Zebra, N-1 Limit: 130 MW	114	118	112	114	108
220 kV Theruvali - Bhanjanagar D/C (Each Circuit)	Zebra, N-1 Limit: 160 MW	155	163	155	157	149
1x500 MVA Gazuwaka ICT	-	248	255	251	250	255
2x315 MVA Gazuwaka ICTs	-	156	155	158	157	161
400 kV Kudgi - Kolhapur D/C (Each Ckt)	Hexa Zebra	1362	1358	1361	1360	1363

Observations on the effect of bypassing HVDC BtB Gazuwaka Link

- The AC lines between Jeypore and Gazuwaka (after bypass) will carry power in both directions based on load generation balance and strengthen the ER-SR inter-regional corridor.

However, in this scenario, transmission constraints like high loading of 400 kV Jeypore – Gazuwaka D/C lines (SR import scenarios) and downstream 220 kV AC lines in Odisha (SR Export/High Odisha demand scenario) are envisaged.

Therefore, the bypassing of the HVDC link will require re-conductoring of the 400 kV Jeypore – Gazuwaka D/C to high-capacity conductors and system strengthening in the associated AC system at both ends.

- The terminal equipment at Gazuwaka station needs to be upgraded along with the refurbishment. Planning of suitable reactive power compensation devices for managing the voltage issues would also be required at both ends.
- Without the HVDC BtB configuration, the power flow will be completely governed by LGB, and the flexibility in changing the power flow across the critical corridor during contingencies and grid requirements may be limited.
- Further, considering the vulnerability of the transmission network in cyclone-prone areas of Odisha, system strengthening measures aimed at enhancing resilience may also be undertaken.
- Overall, AC interconnection would require system augmentation in ER as well as SR and it could be evaluated at the end of useful life of the BtB G'waka.

7. Recommendations

- Back to Back (BtB) HVDC systems have played a crucial role in the evolution of the national grid. The present Indian grid is one large synchronous grid with multiple cross-border connections also. The HVDC BtB system at critical locations could play a strategic role in enhancing the system resiliency of current and the future grid.
- HVDC BtB Gazuwaka is one of the 4 back-to-back HVDC links operating in parallel with EHVAC system in India. These links play a critical role in enhancing the stability and reliability of the National power system in India. At the National level, the power order on these links are modulated for congestion management and voltage regulation. The importance of these inter-regional HVDC links is growing with the increase in penetration of VRE in India particularly in SR, WR and NR, which has resulted in a large variation in power flow in the interstate system. The capabilities of the HVDC BtB system i.e. fast reversal of direction and ramp up provide the necessary flexibility in transmission and grid operation. HVDC links facilitate the reduction of transmission losses as well.
- Based on the operational usages of +/- 205 kV, 2x500 MW back-to-back HVDC Gazuwaka as highlighted in Section 3 of this report, this HVDC link is a useful transmission asset providing the following benefits:
 - Facilitating inter-regional power transfer in both ER-SR & SR-ER direction
 - Managing the intra-regional transmission constraints in Odisha (ER) and AP (SR)
 - Managing SR-WR power flow during periods of high RE and low demand in SR
 - Voltage control at nearby substations (both ER and SR side)
 - AC Bypass facility for providing black-start

Therefore, refurbishment of the BtB HVDC Gazuwaka and improvement in its availability are desirable in the near term. Post completion of its useful life, interconnection of the 400 kV Jeypore and Gazuwaka stations through AC lines, along with the necessary system strengthening on both the ER and SR sides as outlined in Section 6, may be explored.

- During the refurbishment of the HVDC, the following points shall be considered for effective utilisation of the HVDC:

- a) As highlighted in section 4, HVDC Gazuwaka cannot be operated at full power order (1000 MW) in the ER to SR direction due to because of low voltages at the Gazuwaka East bus. Suitable reactive power planning shall also be taken up to ensure utilization of the HVDC at rated capacity in ER-SR direction.

Similarly, the operation of HVDC BtB Gazuwaka is constrained in the SR-ER direction due to constraints in the 220 kV network in Odisha system. Necessary system strengthening measures shall be taken up in the Odisha system to ensure utilization of the HVDC at rated capacity in the SR-ER direction.

- b) The overload capability over and above the continuous rated capacity shall be designed for utilisation during stressed operating conditions (contingencies, very high import etc.) which require short-term measures. CTUIL may also examine the requirement of additional inter-regional capacity between ER and SR corridors in future. In case of such requirement, the possibility of augmentation of HVDC BtB Gazuwaka beyond 1000 MW using the same corridor may also be explored.
- c) The presence of HVDC Converter station, FSCs, STATCOM at Jeypore and generators in the south Odisha system in close vicinity enhances the possibility of controller interactions between these devices. The same has also been experienced in the past on several occasions. Further, several Green Hydrogen electrolyzer loads are expected to come up in the Visakhapatnam area which are also converter interfaced loads and can enhance the vulnerability to these issues. Therefore, a detailed simulation-based root cause analysis study shall be carried out and remedial measures shall be implemented during the refurbishment.
- d) The HVDC after refurbishment shall comply with all the technical and connection requirements specified in the relevant CEA standards, CERC regulations and procedures (including FTE&I) of Grid-India and CTUIL. The simulation models (both EMT and RMS), user model guides, main design parameters, control and protection documents etc. of the refurbished HVDC shall also be submitted as per the latest Grid-India and CTUIL procedures. HVDC shall also be refurbished along with the testing of features like quick & frequent reversal of power order, frequency controller, runback schemes and power oscillation damping.
- e) The outage of the HVDC during refurbishment would lead to system constraints on both the ER and SR sides. It is suggested that outage of only one pole at a time (along with other operational

measures) shall be taken for refurbishment purposes. Other interim measures for ensuring system reliability may be planned in consultation with the stakeholders to facilitate the long outage of the HVDC for refurbishment.

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Annexure-III

System studies for refurbishment of Gazuwaka HVDC (2x500 MW)

A1. Assumptions and important Considerations for the study

- Study time frame: 2030-31
- Scenarios: Scenario 8 - February Evening peak (SR Import)
- **Major Assumptions for Scenario 8 - February Evening peak (SR Import)**
 - State wise demand considered as per inputs from the STUs are as below:

State	Demand as per 20 th EPS (MW)	Peak Demand provided by STUs (MW)	STU Demand considered in Scenario(MW)	ISTS Demand (MW) (100% of GH potential)*	Total Demand considered in study (MW)
Andhra Pradesh	23243	25000	22800	7500	30300
Telangana	25639	30000	27400	0	27400
Karnataka	20954	26765	24089	0	24089
Kerala	6707	8255	7430	0	7430
Tamil Nadu	27033	29381	26443	3000	29443
Puducherry	639	740	666	0	666
Total	104215	120141	108827	10500	119327

**Green Hydrogen demand has been considered under ISTS*

- Load and generation considered :

Region	Demand (GW)	Generation (GW)	Surplus(+) / Deficit(-) (GW)
SR	119 GW (including Green Hydrogen demand of 10.5 GW in ISTS)	97	-22

- Following Dispatch factors has been considered as per the profiling and LGB :
 - Solar – 0 %
 - Wind – 20%
 - Thermal – 90%
 - Nuclear – 80%
 - Hydro – 40%
 - ESS / PSPs – 100% in generation mode
- HVDC power orders considered:
 - Raigarh – Pugalur HVDC (6000 MW from WR to SR)
 - Bhadrawati BtB HVDC (1000 MW from WR to SR)
 - Gazuwaka BtB HVDC (1000 MW from ER to SR)
 - Talcher – Kolar HVDC (2000 MW from ER to SR)

• **Major Assumptions for Scenario 4 - June solar max (SR Export)**

- State wise demand considered as per inputs from the STUs :

State	Demand as per 20 th EPS (MW)	Peak Demand provided by STUs (MW)	STU Demand considered in Scenario (MW)	ISTS Demand (MW)*	Total Demand considered in study (MW)
Andhra Pradesh	23243	25000	19500	7500	27000
Telangana	25639	30000	23500	0	23500
Karnataka	20954	26765	20074	0	20074
Kerala	6707	8255	6191	0	6191
Tamil Nadu	27033	29381	22036	3000	25036
Puducherry	639	740	555	0	555
Total	104215	120141	91856	10500	102356

**Green Hydrogen demand has been considered under ISTS*

- Load and generation considered :

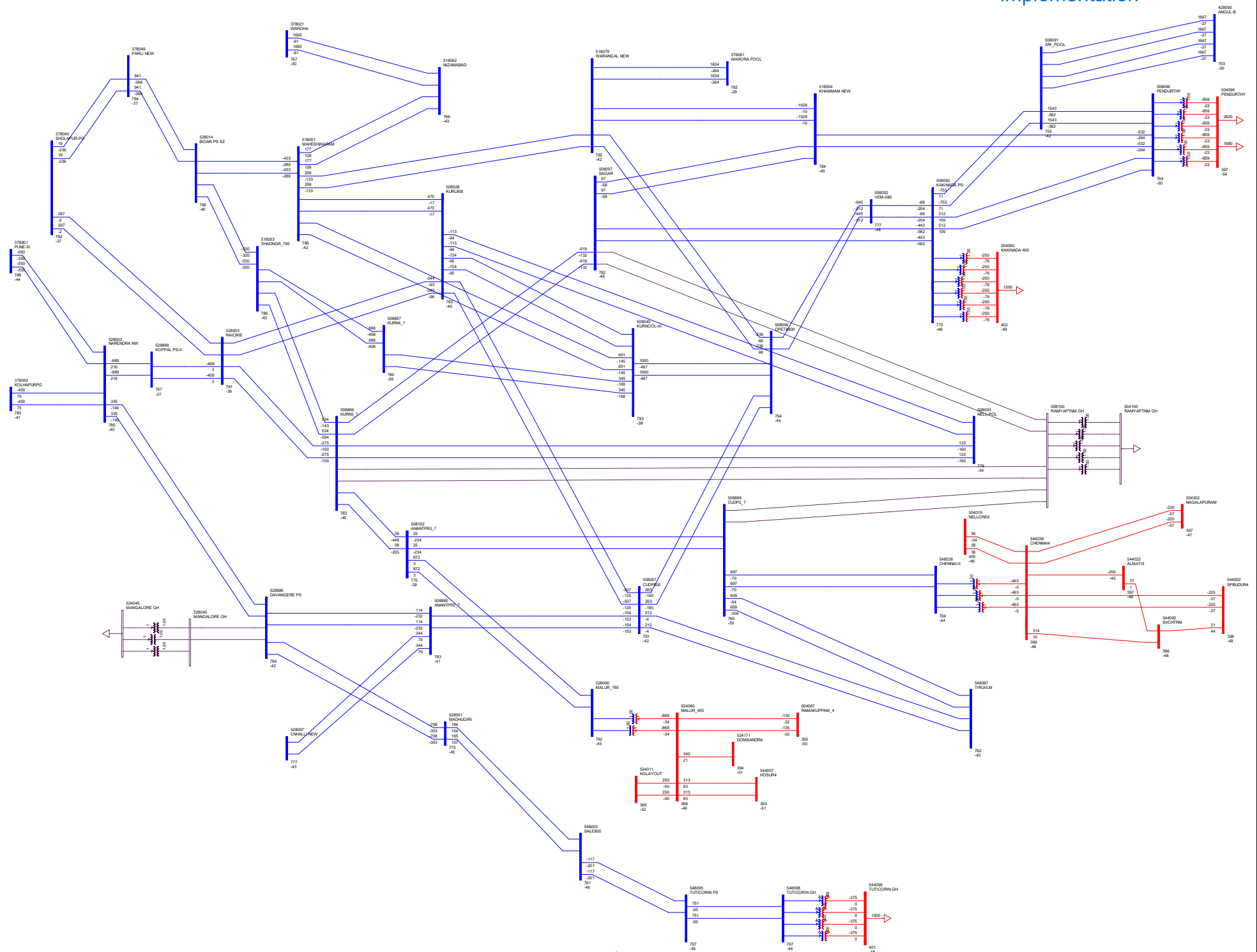
Region	Demand (GW)	Generation (GW)	Surplus(+) / Deficit(-) (GW)
SR	102 GW (including Green Hydrogen demand of 10.5 GW in ISTS)	122.8	+22

- Following Dispatch factors has been considered as per the profiling and LGB :
 - Solar – 85 %
 - Wind – 50%
 - Thermal – 55% as per the variable cost of the generators
 - Nuclear – 80%
 - Hydro – 40%
 - ESS / PSPs – 100% in absorption / motoring mode
- HVDC power orders considered:
 - Raigarh – Pugalur HVDC (3000 MW from SR to WR)
 - Bhadrawati BtB HVDC (1000 MW from SR to WR)
 - Gazuwaka BtB HVDC (1000 MW from SR to ER)
 - Talcher – Kolar HVDC (1150 MW from ER to SR)

Study exhibits

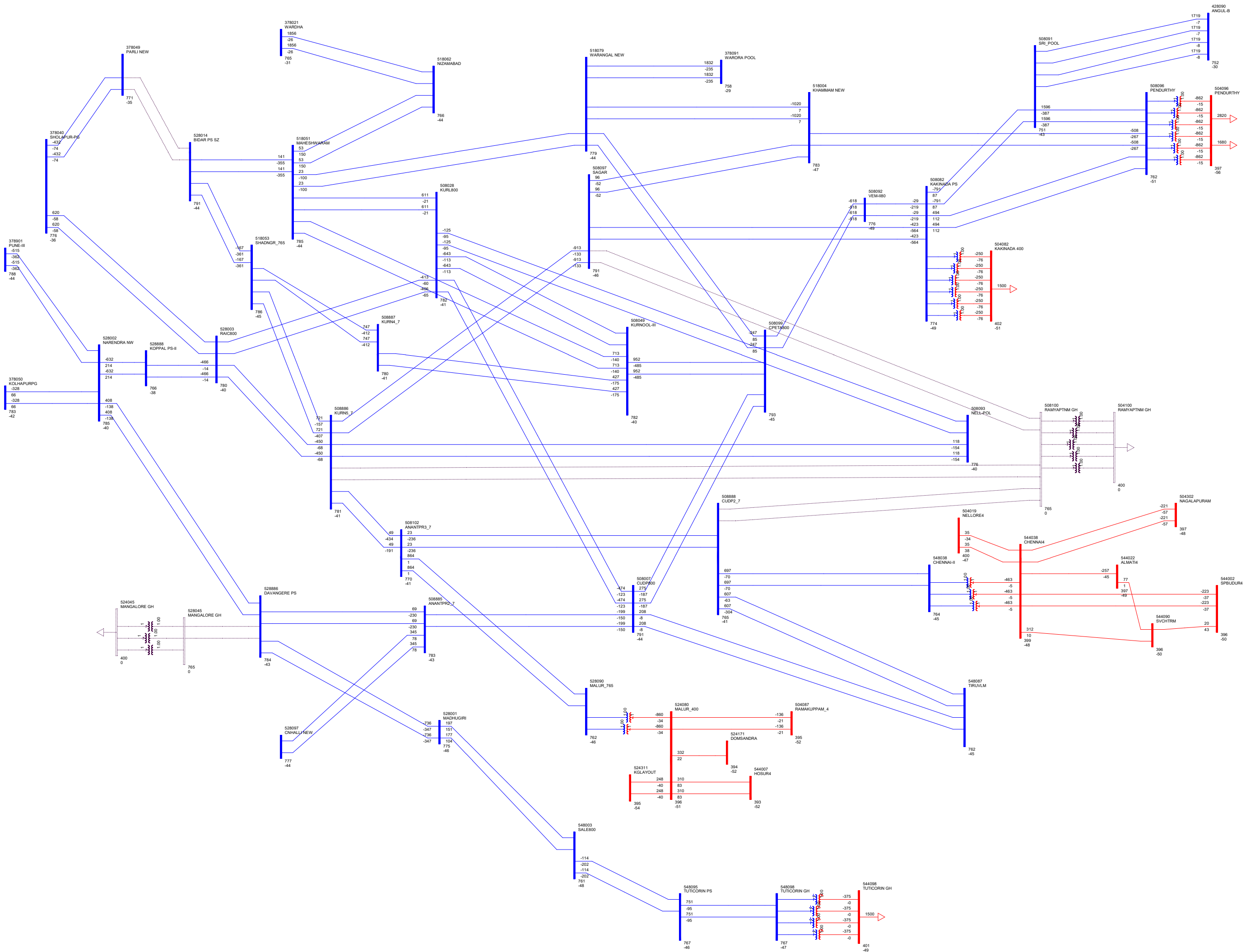
Scenario	Case	Case details	Exhibit
Scenario 8 - February Evening peak (SR Import)	With Gazuwaka BTB HVDC (2x500 MW)	With all IR under implementation	I
		Without Bidar Parli	I-A
		Without Angul-Srikakulam 2nd D/C	I-B
	Without Gazuwaka BTB HVDC	With all IR under implementation	II
		Without Bidar Parli	II-A
		Without Angul-Srikakulam 2nd D/C	II-B
		Without Angul-Srikakulam 2nd D/C and 'N-1' of Angul-Srikakulam 1 st D/C	II-C
Scenario 4 - June solar max (SR Export)	With Gazuwaka BTB HVDC (2x500 MW)	With all IR under implementation	III
		Without Bidar Parli	III-A
		Without Angul-Srikakulam 2nd D/C	III-B
	Without Gazuwaka BTB HVDC	With all IR under implementation	IV
		Without Bidar Parli	IV-A
		Without Angul-Srikakulam 2nd D/C	IV-B
		Without Bidar Parli and 'N-1' of Narendra-Pune D/c	IV-C
		Without Angul-Srikakulam 2nd D/C and N-1 of Narendra-Pune D/c	IV-D

Ex-I_Sc-8: With all IR under implementation



USEFULNESS OF VIZAG (GAZUWAKA) BACK-TO-BACK HVDC (2X500 MW)

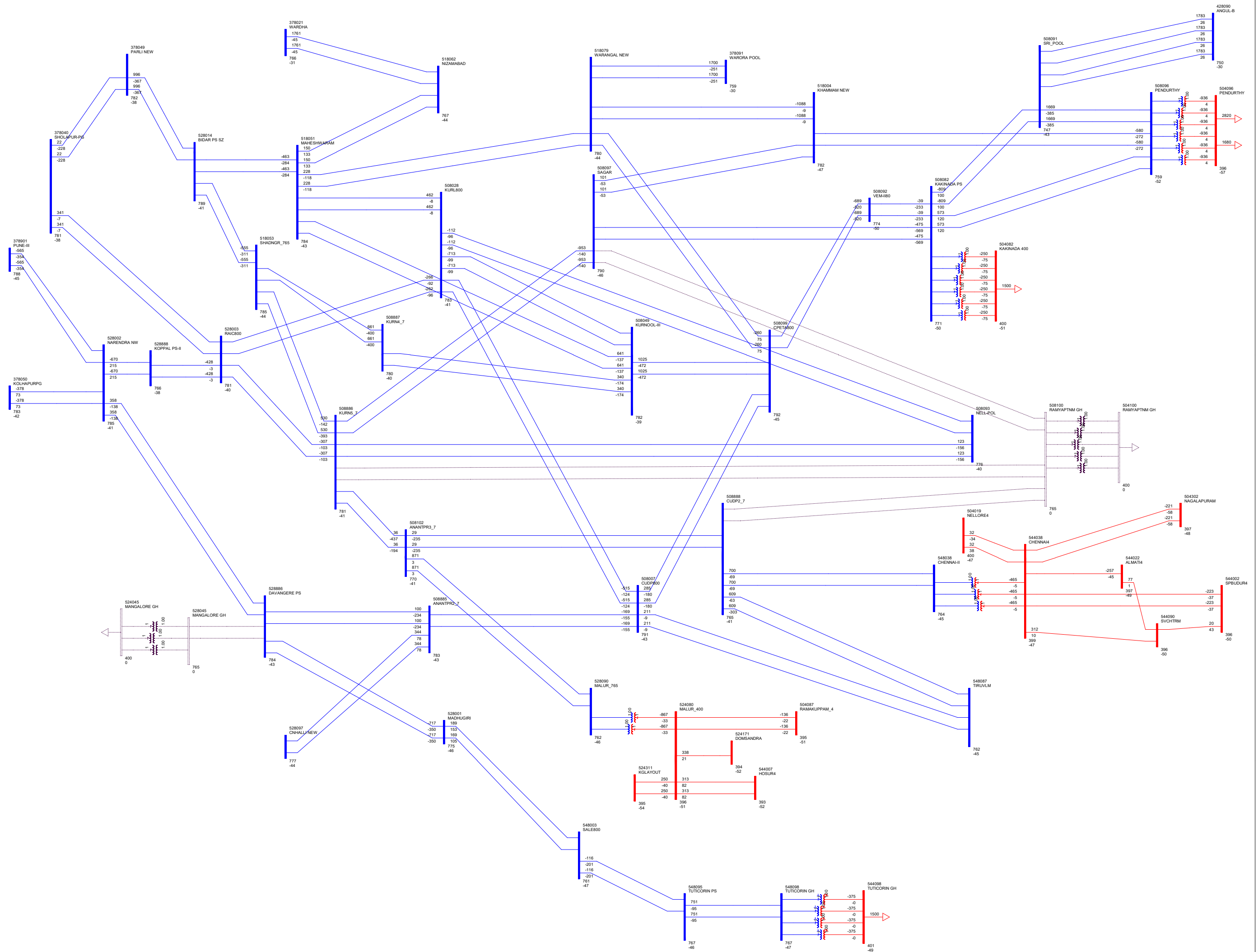
Ex-I-A_Sc-8: Without Bidar Parli



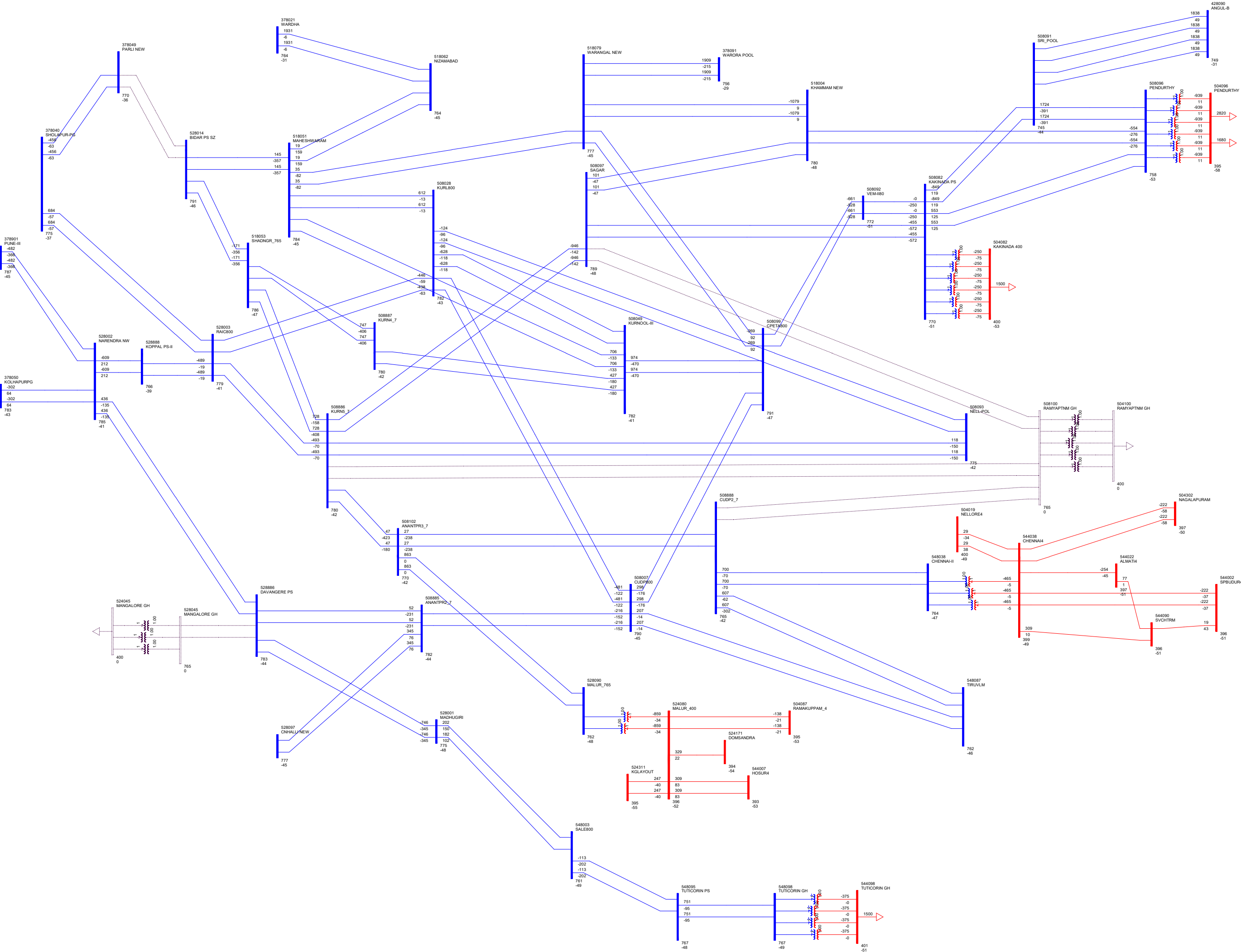
Ex-I-B_Sc-8:Without Angul-Srikakulam 2nd D/C



Ex-II_Sc-8:With all IR under implementation



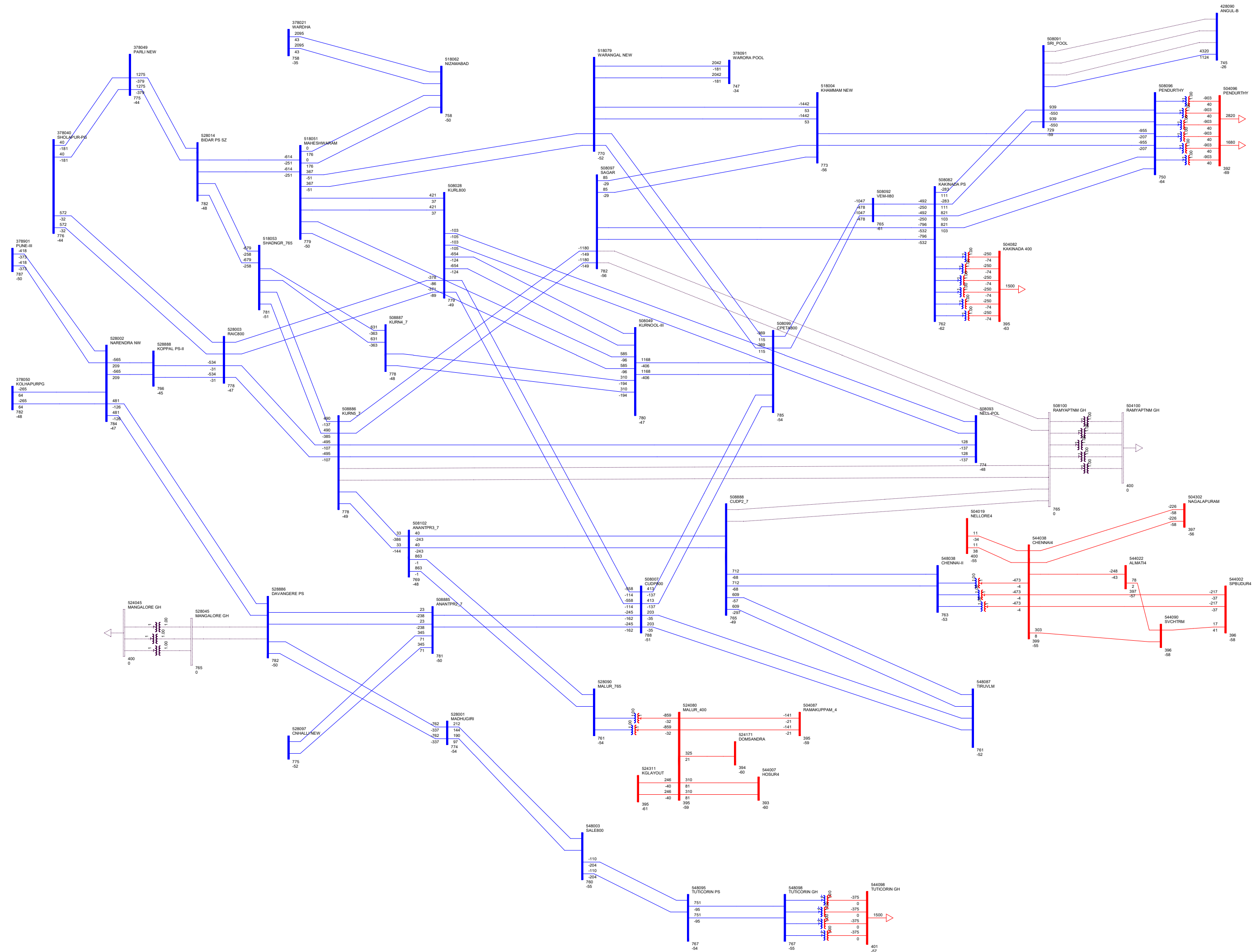
USEFULNESS OF VIZAG (GAZUWAKA) BACK-TO-BACK HVDC (2X500 MW)



Ex-II-B_Sc-8:Without Angul-Srikakulam 2nd D/C



Ex-II-C_Sc-8: Without Angul-Srikakulam 2nd D/C and 'N-1' of Angul-Srikakulam 1st D/C



Ex-III_Sc-4:With all IR under implementation



Ex-III-A_Sc-4:Without Bidar Parli



Ex-III-B_Sc-4:Without Angul-Srikakulam 2nd D/C



Ex-IV_Sc-4: With all IR under implementation



Ex-IV-A_Sc-4: Without Bidar Parli

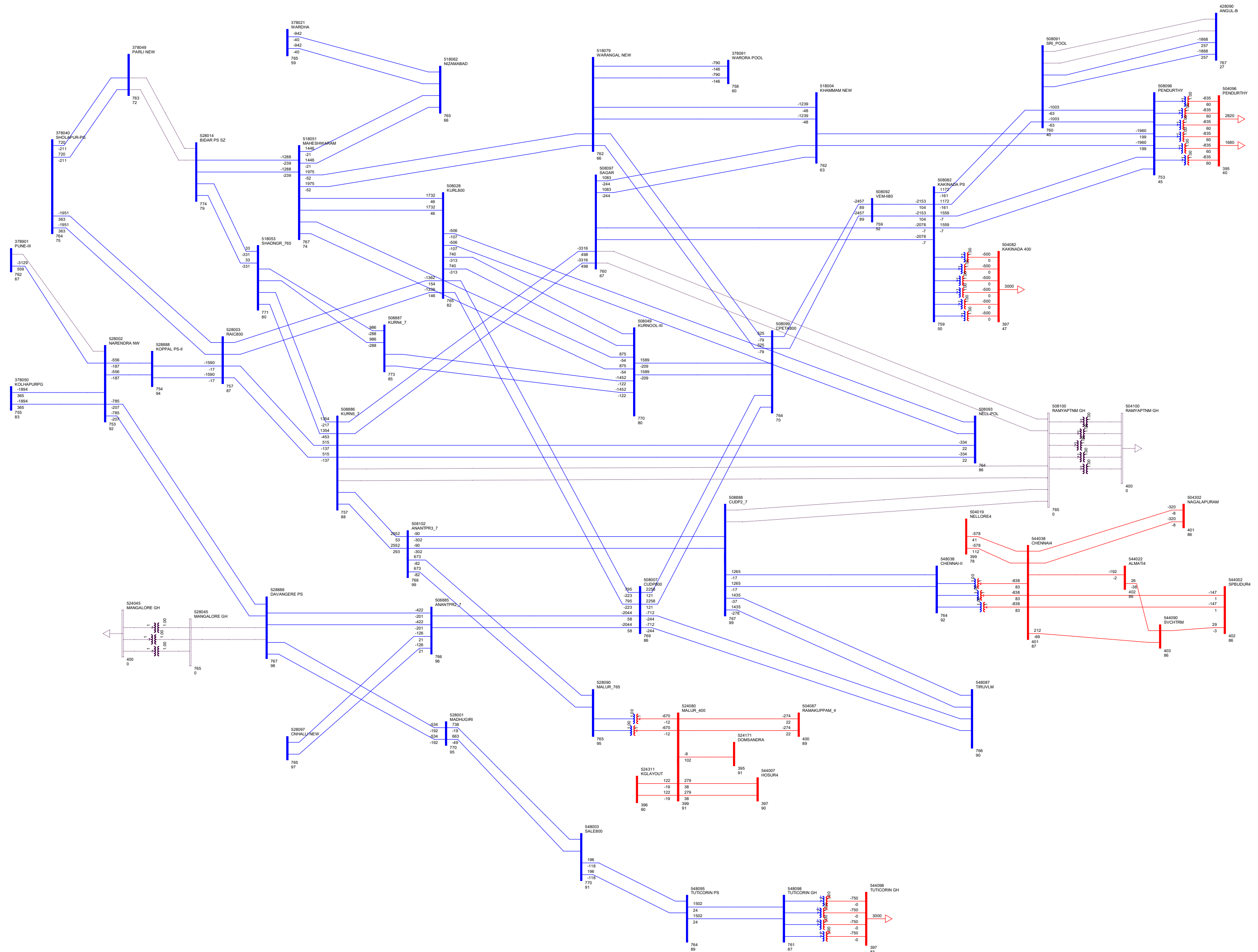


Ex-IV-B_Sc-4:Without Angul-Srikakulam 2nd D/C



USEFULNESS OF VIZAG (GAZUWAKA) BACK-TO-BACK HVDC (2X500 MW)

Ex-IV-C_Sc-4: Without Bidar Parli and 'N-1' of Narendra-Pune D/c line



Ex-IV-D_Sc-4: Without Angul-Srikakulam 2nd D/C and N-1 of Narendra-Pune D/c line

