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# OPERATION EXPERIENCE FROM BULK POWER HVDC LINKS FROM THREE GORGES COMPLEX

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## SUMMARY

The Three Gorges-Changzhou and Three Gorges-Guangdong HVDC bipolar transmission links associated with the world's largest hydroelectric power generation complex have been in continuous commercial operation since 2003 and 2004 respectively.

Considering their size, complexity and initial period of operation, the links have achieved a high availability and overall performance during the completed period of their operation. A few mal-operations and failure in a few converter station equipments as well as weather related DC line faults dampened, to some extent, even higher expectations of the supplier and the customer.

The corrective measures, refinements in operation & maintenance procedures and enrichment of experience of the operation & maintenance staff will henceforth improve the performance of the links.

## KEYWORDS

Three Gorges – HVDC- Bipole – Operation – Maintenance – MACH2 – SCADA

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## *INTRODUCTION*

The Three Gorges-Changzhou (3GC) and Three Gorges-Guangdong (3GG) HVDC bipolar links are a part of the power evacuation system for the world's largest hydroelectric power generation complex, Three Gorges, which will have an ultimate generation capacity of 22.4 GW. Each of these transmission links has a nominal rating of 3000 MW and the transmission voltage of ±500 kV. The links have been designed for a continuous overload capability of 3480 MW, and a 5-second overload capability of 4500 MW [1].

The two 3GC converter stations are at Longquan (in Yichang, Hubei province) and Zhengping (in Changzhou, Jiangsu province), about 890 km apart. Longquan converter station is situated some 50 km from the Three Gorges Dam. The receiving station at Zhengping is approximately 200 km from Shanghai.

The converter station at the transmitting end of the 3GG link is located 16 km from Jingzhou city, about 135 km from the Three Gorges power plant. The receiving station is at Huizhou, in Guangdong province. Power will be transmitted over a distance of 940 km.

The links are meant to supply power to economically booming regions in the eastern and southern coastal areas of China. Therefore, power will be transmitted to eastern and southern grids during the peak generation period and towards the central power grid whenever reservoir water needs to be conserved.

## *LINK POWER CIRCUITS*

The main circuit arrangement (Figure 1 and Figure 2) of the two links is identical except for the reactive power compensation equipment [2]. Stable steady state and dynamic operation of the AC-DC systems is ensured by optimized use of the reactive power capacity of the generators in the Three Gorges power plant and the AC networks at each end of the links. One-and-a-half breaker configurations are used on the AC side at both stations.

In addition to the bipolar transmission scheme, the links can be connected for monopolar transmission with either a ground or metallic return. The main circuit connection on the DC side is typical for an HVDC bipole with overhead transmission line. Metallic return transfer breakers and ground return transfer switches have been installed to meet the requirements of monopolar metallic return operation, and provide capability for uninterrupted power transfer. Neutral bus grounding switches are also installed at the neutral buses of both stations to meet temporary grounding requirements.

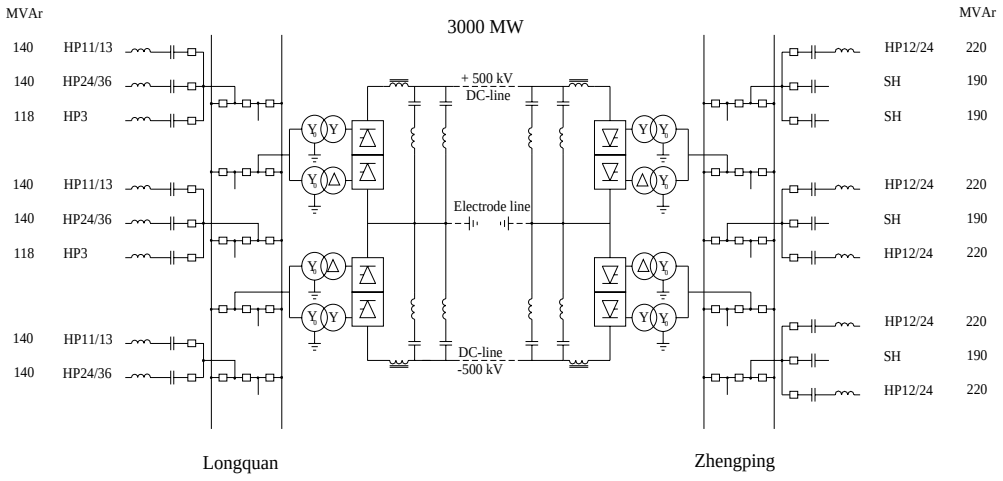


Figure 1: Main circuit arrangement for 3GC

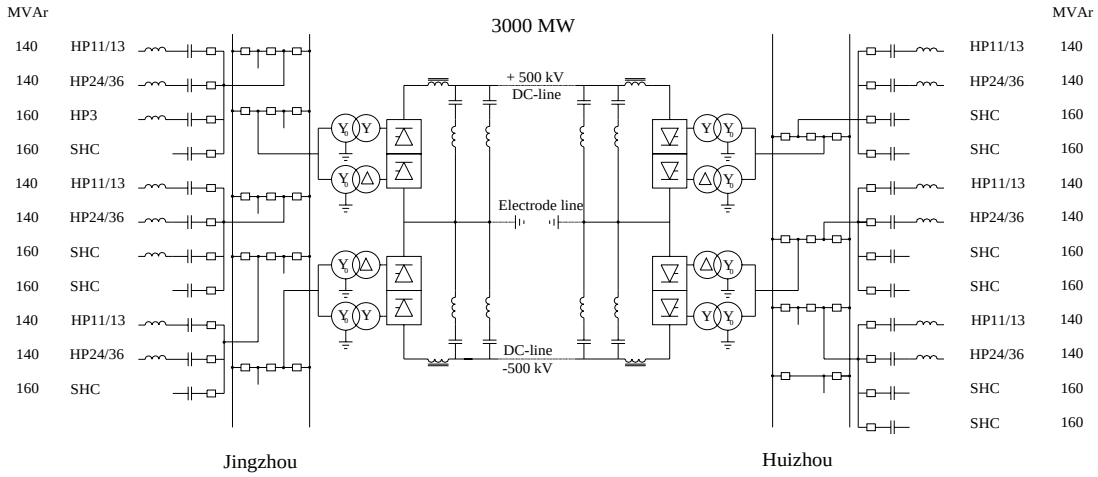


Figure 2: Main circuit arrangement for 3GG

## *COMMERCIAL OPERATION*

The 3GC and 3GG links went into commercial operation on 16th June 2003 and 27th May 2004, respectively. Since then, the links have been transmitting power continuously at varying power levels depending on the requirements of the connected grids.

## *PERFORMANCE REQUIREMENTS*

The contract requirements in respect of the important performance indices for the links are presented in Table I, Table II and Table III below. The guarantee period is earlier of the two: 36 months from the date of Acceptance or 50 months from the date of arrival of the last lot of the contract equipment at the port of destination.

Table I: Equipment failure rate targets for 3GC and 3GG

| **Equipment** | **Annual Failure Rate** |
|---|---|
| Thyristors | 0.2% |
| AC-DC filter capacitors | 0.2% |
| Circuit boards, per pole and station | 4 |

Table II: Reliability and availability targets for 3GC

| **Index/Parameter** | **Target Value** |
|---|---|
| Forced Energy Unavailability (FEU) | 0.5% or less |
| Schedule Energy Unavailability (SEU) | 1.0% or less |
| Single Pole Forced Outage Rate | 6 per year or less |
| Bipole Forced Outage Rate | 0.1 per year or less |

Table III: Reliability and availability targets for 3GG

| Index/Parameter | Target Value |
|---|---|
| Forced Energy Unavailability (FEU) | 0.5% or less |
| Schedule Energy Unavailability (SEU) | 1.0% or less |
| Single Pole Forced Outage Rate | 5 per year or less |
| Bipole Forced Outage Rate | 0.1 per year or less |

## *ACHIEVED PERFORMANCE*

### *Equipment Performance*

The performance of different station equipment for the two links have been generally in line with the equivalent links in terms of size, complexity, operating environment and the period of operation.

*Thyristors*

3GC and 3GG use a combined count of 8352 thyristors. Since being taken into commercial operation, there have been no thyristor failures in any of the four converter stations. No other disturbances directly related to thyristors have occurred.

*Converter transformers*

36 converter transformers and 6 smoothing reactors of ABB design are in operation at Longquan, Jingzhou and Huizhou converter stations. A small number of false trippings has occurred due to moisture in the gas relays. The relay covers have since been modified to allow better air circulation. Furthermore, rain protection has been provided and the input boards for tripping de-sensitized by adding parallel resistors across channels. Locally manufactured transformers have suffered from some gas generation. A loose contact has been found and corrected.

*Control & protection equipment*

There was, at first, some irregular behaviour from control/protection equipment in the 3GC link. The cause was traced to both hardware and software in the control and protection equipment – resulting in a crash of the active computer system. When this occurred, the system automatically switched to the redundant control and protection system and all functionality of the power transmission was maintained. Several software changes were successfully implemented. To eliminate the hardware problems, the computer main boards were replaced by newer and more reliable type. Current operational statistics suggest that these efforts have been fruitful and that the problems are not recurring.

In the 3GG link, which incorporated the experience gained from 3GC, very few instances of hardware and software problems were encountered.

*AC-DC Filter Capacitors*

There have been a few incidences of AC-DC filter capacitor unit failures, but none of these failures have any adverse impact on the power transmission capability of the links.

*Other outdoor equipment*

There has been one flashover on a DC voltage divider in Jingzhou under extreme fog conditions. The cause of this is now under investigation. At the moment an insulator batch problem is understood to be the cause.

AC filter OCT control boards' mal-operation in 3GG resulted into tripping of filter sub-banks a few times. But the tripping did not cause any outage of the links. The problem was traced to be related with a slight manufacturing deviation in a batch of the circuit boards. All the boards of the batch are planned to be replaced.

***Reliability and Availability***

The outage incidences and a summary of the availability of the two links for year 2004 and 2005 are presented under this section. The standard routines [3] for information gathering/compilation, analysis and reporting are being followed.

*3GC Link*

This link went into commercial operation on 16th June 2003. Operating experience has been very good with a high availability against forced outages [4].

The outages occurred in 2004 are listed in Table IV. No bipolar outage has occurred. In all, there have been 6 monopolar outages. Of which 5 outages were due to ABB supplied equipment, against a design target of 12 outages per year. This is not very unusual, considering the equipment burning-in period. One of the outages was due to DC line flashover on pole-2 near tower number 654.

In 2005, there were a total of 8 outages as shown in Table V below. Only 3 of theses outages were attributed to ABB supplied equipment. Majority of the outages were due to icing on the pole lines that led to repeated flashovers.

The equivalent outage hours varied from a few tens of minutes to a few hours. The maximum outage time has been below 10 hours (including administrative time), which represents a good record against a design target of 44 hours (excluding administrative time).

*3GG Link*

Operating experience from 3GG is considered to be also very good. Since the start of commercial operation on 27th May 2004, the availability against forced outages has been pretty high. The forced outages for 2004 and 2005 are listed in Table VI and Table VII respectively.

In 2004, there were a total of 6 outages of which only 3 outages were related to ABB supplied equipment. There were only 2 outages in 2005 that were caused by ABB's equipment. These monopolar outages against a design target of 10 per year are a very good record for a new system. The remaining faults were due icing on the DC line leading to repeated flashovers.

*Corrective Measures*

To prevent and reduce the incidences leading to outages in future, a number of measures – that include equipment/hardware and software modifications, refinement of operation & maintenance (O&M) procedures and incorporation of O&M training updates – have been implemented.

Table IV: Outages on 3GC during 2004

| Date | Outage | Category | Event |
|---|---|---|---|
| 2004-03-05 | Monopole | DC control & protection | Computer in standby mode when restarted/Supervision software bug |
| 2004-03-15 | Monopole | AC and AUX equipment | Transformer guard malfunction |
| 2004-07-20 | Monopole | DC line | Discharge fault on Pole-2 at tower #654 |
| 2004-07-26 | Monopole | AC and AUX equipment | Manual fire call point miss-operation |
| 2004-08-08 | Monopole | DC control & protection | Computer changing to standby mode after replacement/software bug |
| 2004-11-23 | Monopole | DC control & protection | False trip from transformer saturation protection |

Table V: Outages on 3GC during 2005

| Date | Outage | Category | Event |
|---|---|---|---|
| 2005-01-05 | Monopole | DC control & protection | Converter transformer's ETCS and PCP optic circuit fault |
| 2005-02-05 | Monopole | Others | Human error during DC disconnector maintenance work |
| 2005-02-11 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-02-12 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-02-14 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-02-14 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-04-01 | Monopole | AC and Aux | Malfunction of converter transformer tap changer pressure release function |
| 2005-11-20 | One pole followed later by other pole | DC control & protection | Mal-operation of station service power control system |

Table VI: Outages on 3GG during 2004

| Date | Outage | Category | Event |
|---|---|---|---|
| 2004-07-05 | Monopole | Other | Human error |
| 2004-07-17 | Monopole | AC and AUX equipment | Mal-operation of OLTC gas relay |
| 2004-10-13 | Monopole | DC line | DC line fault due to hill fire |
| 2004-11-07 | Monopole | Primary DC equipment | Flashover over DC voltage divider |
| 2004-12-22 | One pole followed later by other pole | DC control & protection | LAN network disturbance |
| 2004-12-23 to 26 | Monopole | DC line | Flashovers due to icing of the DC line pole conductors. The icing lasted 23$^{rd}$ to 26$^{th}$ Dec. |

Table VII: Outages on 3GG during 2005

| Date | Outage | Category | Event |
|---|---|---|---|
| 2005-02-12 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-02-12 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-02-13 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-02-13 | Monopole | DC line | DC line icing causing line fault. All the restart attempts failed. |
| 2005-04-09 | One pole followed later by other pole | AC and Aux | Malfunction leading to loss of station power supply |
| 2005-08-08 | Monopole | DC control & protection | Mal-operation due to system A & B being in inconsistent status |

## *CONCLUSION*

The 3GC and 3GG HVDC power transmission links were successfully commissioned and started commercial operation in June 2003 and May 2004 respectively. High performance levels have been achieved during the completed period of their operation. A number of corrective measures have been implemented to further improve the performance.

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