

# Stability Characteristics and De-icing Modes Analysis of JinSu UHVDC Transmission Line

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**Abstract**—After the operation of JinSu UHVDC transmission line, influence on the stability of the interconnected power grid especially in de-icing modes is studied from various sides. To cope with the DC block fault occurred in the UHVDC transmission line, the coordinated control strategy based on emergency DC power supply is researched, by which the total amount of load shedding and generator tripping can be reduced. According to the comparison and selection of generator tripping schemes, the voltage rise near sending-end after DC block fault is taken into account. The influence on power system stability is analyzed in two UHVDC de-icing modes. The feasibility and validity of these de-icing modes is proved.

**Keywords**- JinSu UHVDC; coupling characteristics; coordinated control strategy; de-icing mode

## I. INTRODUCTION

Jinping-Sunan  $\pm 800$ kV UHVDC transmission project (referred JinSu DC) was put into operation by the end of 2012. Its rated transmission capacity reaches 7,200 MW and is currently the largest DC line in the term of capacity in China. After its operation, stability characteristics such as long-distance and large capacity of the entire power system become more and more obvious. So it is needed to study power grid characteristics deeply and formulae stability control strategy to meet the demand of operation requirements.

Coordinated control methods of multi-DC are studied in some paper from different perspectives. References [4-5], respectively, use the additional controller and DC power modulation controller to improve dynamic stability of power system; reference [6] designs a DC power transfer controller after the DC block fault; reference [7] designs additional DC power controller with robust coordination control theory.

DC line's collapse in the ice disaster will cause power loss and it happened in several southern provinces of China in 2008. How to ensure the safe operation of the DC line

becomes an urgent research problem. There are many anti-icing and de-icing technologies. In this paper, the method of heating ice is adopted and the principle is to transmit large DC current to melt ice.

## II. SITUATION OF THE POWER GRID

### A. Introduction of sending and receiving end of JinSu DC

JinSu DC starts at Jinping converter station in Sichuan province and ends at Tongli converter station in Jiangsu province. The matching power plants of JinSu DC include JinDong, JinXi and GuanDi hydropower plants, whose total installed capacity reaches 10.8 GW. At sending end, JinPing converter station accesses to the power system with 500kV seven-circuit lines and at receiving end TongLi station accesses to the system with 500kV six-circuit lines. The structure of DC and its nearby grid is shown as Fig.1.

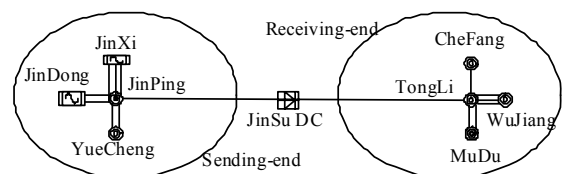


Figure 1. Scheme of transmission lines at sending and receiving end of Jinping-Sunan UHVDC

## III. COUPLING CHARACTERISTICS BETWEEN JINSU DC AND UHV AC LINES AND COORDINATED CONTROL STRATEGY

### A. Generator tripping and load shedding measures after JinSu DC block fault

The area grids are connected by UHV lines and the link lines are not strong enough at the early period of JinSu DC. Once bipolar block fault occurs, heavy power flow shifts to

the AC channel and causes greater pressure to the AC transmission interface. To keep power system stable, a great number of generators need to be tripped and much load must be shed when JinSu DC transmitting 7,200MW occurs bipolar block fault. Specific measures of stability control are shown as Tab.I. It is shown that amount of regular control measure such as generator tripping and load shedding is enormous after DC block fault. So it is important to study new control strategy to decrease impact.

TABLE I. STABILITY CONTROL MEASURES FOR JINSU UHVDC BIPOLAR BLOCK FAULT

fault type	measure of generator tripping at sending end/MW	measure of load shedding at receiving end/MW
bipolar block	7 200	2 600

#### B. Coordinated control strategy based on emergency DC power supply

The paper proposes a coordinated control strategy based on emergency DC power supply. Its aim is to reduce the amount of generator tripping and load shedding. Specifically, other DC lines will enhance their power to bear the power loss and reduce transmission on the AC interface after a DC block fault. The DC lines to supply emergency power should be chosen as following rules. Rule1:sending and receiving end of controlled DC lines should be consistent with fault DC line and their direction of power transmission is coincident.Rule2:DC line whose convert stations are nearby the fault DC in electric distance should be chosen preferentially. Rule3:DC line with larger rate capacity should be chosen preferentially.Rule4:DC line which has more margin power (rate power minus actual power) should be chosen preferentially.

Explanation: rule 1 can reduce the power loss both in sending and receiving end of DC; rule 2 can minimize the power flow influence to nearby area of fault DC; rule 3; rule 3 and 4 can supply more margin power to enhance power of controlled DC. In the situation of JinSu bipolar block fault, considering controlling effect and signal channel factor, six HVDC lines from central China to east China are chosen to be coordinated controlled lines.

When the coordinated controlled lines are chosen, enhancing power of each DC line should be calculated as following formula Eq.1:

$$P_i = kP_n - P \quad (1)$$

$P_i$  is enhancing power of DC line I;  $P_n$  is rate power of DC line I;  $k$  is coefficient of DC overload;  $P_a$  is actual transmission power of DC line I. The ability of overload is usually divided into short-term and long-term. This paper considers long-term overload coefficient  $k$  as 1.1. Therefore total enhancing power of six coordinated controlled DC lines amount to 2,020 MW.

The velocity of enhancing DC power can be set in the DC controlling system and it is beneficial for system stability to enhancing power faster. The set value of adjusting time is assumed 0.2 second in the simulation.

According to the coordinated control strategy and calculation condition, new measure of stability control is analyzed and shown as Tab. II. It can be concluded in Tab. 2 that measure of generator tripping reduces 2,400 MW and measure of load shedding reduces 2,000MW. The effect of coordinated control strategy is obvious.

With guidance of above strategy, JinSu DC project engineers designed stability control system and applied it in the system. It is noted that the power grid nearby sending and receiving end of the controlled DC lines should be analyzed deeply to guarantee power system stable.

TABLE II. EFFECT OF COORDINATE CONTROL MEASURES FOR JIN-SU UHVDC BIPOLAR BLOCK FAULT

fault type	Enhancing power of controlled DC/MW	measure of generator tripping at sending end /MW	measure of load shedding at receiving end /MW	decrement of generator tripping/MW	decrement of load shedding/MW
bipolar block	2 020	4 800	600	2 400	2 000

#### IV. COMPARISON OF DIFFERENT GENERATOR TRIPPING SCHEMES AT DC SENDING END

At the initial stage of JinSu DC, matching power plants cannot be put into operation on time and some power has to be supplied from AC lines nearby. In addition, power grids nearby sending end is not strong relatively. If bipolar block fault occurs and a large number of generators are cut, power flow of transmission lines near the DC gets lighter and bus voltage gets higher, even over the upper limit of allowable value. Therefore how to choose a generator tripping scheme to limit overvoltage is studied in this chapter.

In order to keep power system stable after JinSu bipolar block fault, 12 units(7200MW) is ought to be tripped at sending end. There are two alternative schemes of generator tripping. Scheme A: plants including Jinyi, Jiner and Guandi trip 9 generators in all, while Ertan and Pubugou plants which are not near convert station trip 3 units. Scheme B: plants including Jinyi, Jiner and Guandi trip 6 units, while Ertan and Pubugou plants trip 6 units.

Different scheme has different effect in avoiding overvoltage and it is shown in Tab.III. 500kV bus voltage increase of convert station in scheme B is 8kV less than that of scheme A. It is obvious that tripping certain generators a little far from convert station is better for controlling overvoltage. Meanwhile, as generators far from DC are cut down, power flow in this area is changed and it is needed to analyze power system stability.

TABLE III. VOLTAGE OF SENDING-END GRID UNDER VARIOUS SCHEMES OF GENERATOR TRIPPING

schemes of generator tripping	voltage rise of Jinping station/kV	voltage rise of Yuecheng station/kV
A: 9 units of Jinyi Jiner and Guandi,3 units of Ertan	22	18
B: 6 units of Jinyi Jiner and Guandi,6 units of Ertan	14	10

## V. ANALYSIS OF DE-ICING MODE OF UHVDC

According to the technical feature of UHVDC project, two schemes of de-icing for UHVDC line are studied in this chapter. One scheme that is called preventative de-icing scheme can produce rate line current to avoid conductor icing. This scheme can also make ice on line melt but it costs much time. The other scheme that is called emergency de-icing scheme can produce high current to melt ice fast.

### A. Preventative de-icing scheme

Overload mode is the regular function of UHVDC system, so it is easy to achieve de-icing scheme and not disturb system normal operation. However power system is usually at low load period when icing is apt to appear in winter. At this situation, rectifier cannot supply enough power and so DC system can run in low load operation mode. With new de-icing mode, in low load operation mode, two polar of UHVDC transmit opposite power to produce large current. Because of opposite power of two polar, the total power of DC is very small. One converter can be isolated at each polar as high voltage of DC is not necessary and DC operates in the mode of one converter earth-return line. The electric connection of scheme is shown as Fig. 2.

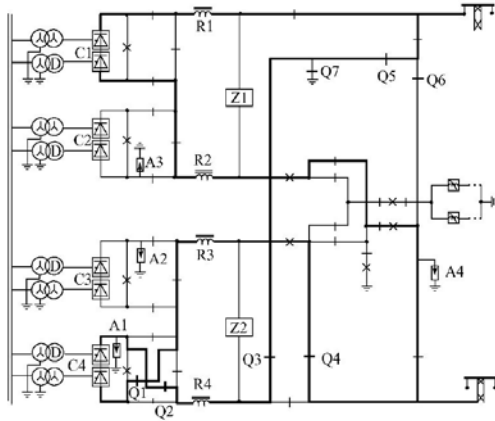


Figure 2. converter structure of preventative scheme

### B. Emergency de-icing scheme

If icing is so serious that threatens the safety of tower, it is needed to melt ice in short time. At this situation, rate current of DC line cannot meet requirement of melting ice. Emergency de-icing scheme should be adopted to supply large current. For its feature, UHVDC two converters operate in parallel to supply emergency de-icing current. Because the converters are designed as module, a small number of connected and isolated switches are added. After the modification of devices, UHVDC can change into de-icing operation mode conveniently. With this mode, UHVDC line is able to supply 8kA current or 9kA considering overload ability of converter. The connection mode of 2 converters in parallel is shown as Fig. 3.

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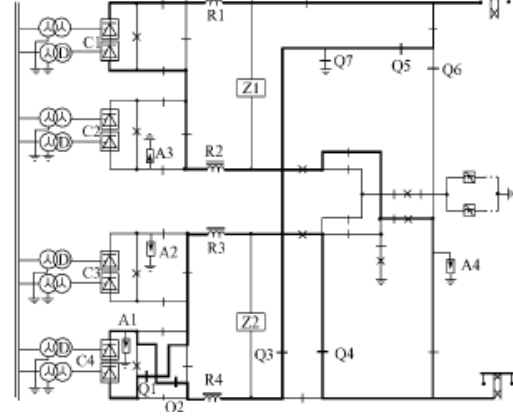


Figure 3. converter structure of emergency scheme

### C. Stability analysis of de-icing mode

In the preventative and emergency de-icing mode, system stability of nearby JinSu DC is analyzed. In preventative de-icing mode, the control strategy of DC system should be changed accordingly. As total power of DC is close to zero, no control measure will be adopted after bipolar block fault. When monopole block occurs, the other pole is ought to be blocked quickly to avoid power loss. Based on this new control strategy, power system can keep stable after DC fault. In emergency de-icing mode, the control strategy is the same as normal mode. In the two de-icing modes, DC system can keep stable after AC line fault.

## VI. CONCLUSIONS

1) When bipolar block fault occurs, coordinated control measure based on emergency DC power supply can reduce quantity of generator tripping and load shedding. DC lines that are close to the fault DC and have more power margin should be chosen preferentially.

2) In the scheme of generator tripping at sending end, tripping fewer units which are close to the converter station can restrict bus overvoltage after DC block fault.

3) The biggest advantage of reverse power transmission preventative scheme is that it does not cost extra money on primary equipment while control and protection system need little modification. Meanwhile the scheme has little influence on AC power system and it is suited at low load stage in winter. The advantage of emergency de-icing mode is that it can supply large DC line current to melt ice quickly. With preventative and emergency de-icing mode the anti-icing ability of DC lines is enhanced greatly and the feasibility of power system is improved.

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