



CIGRE Large Disturbances Workshop in Paris 2014

Simultaneous commutation failures and forced blocking of multi-in-feed HVDC in East China Power Grid

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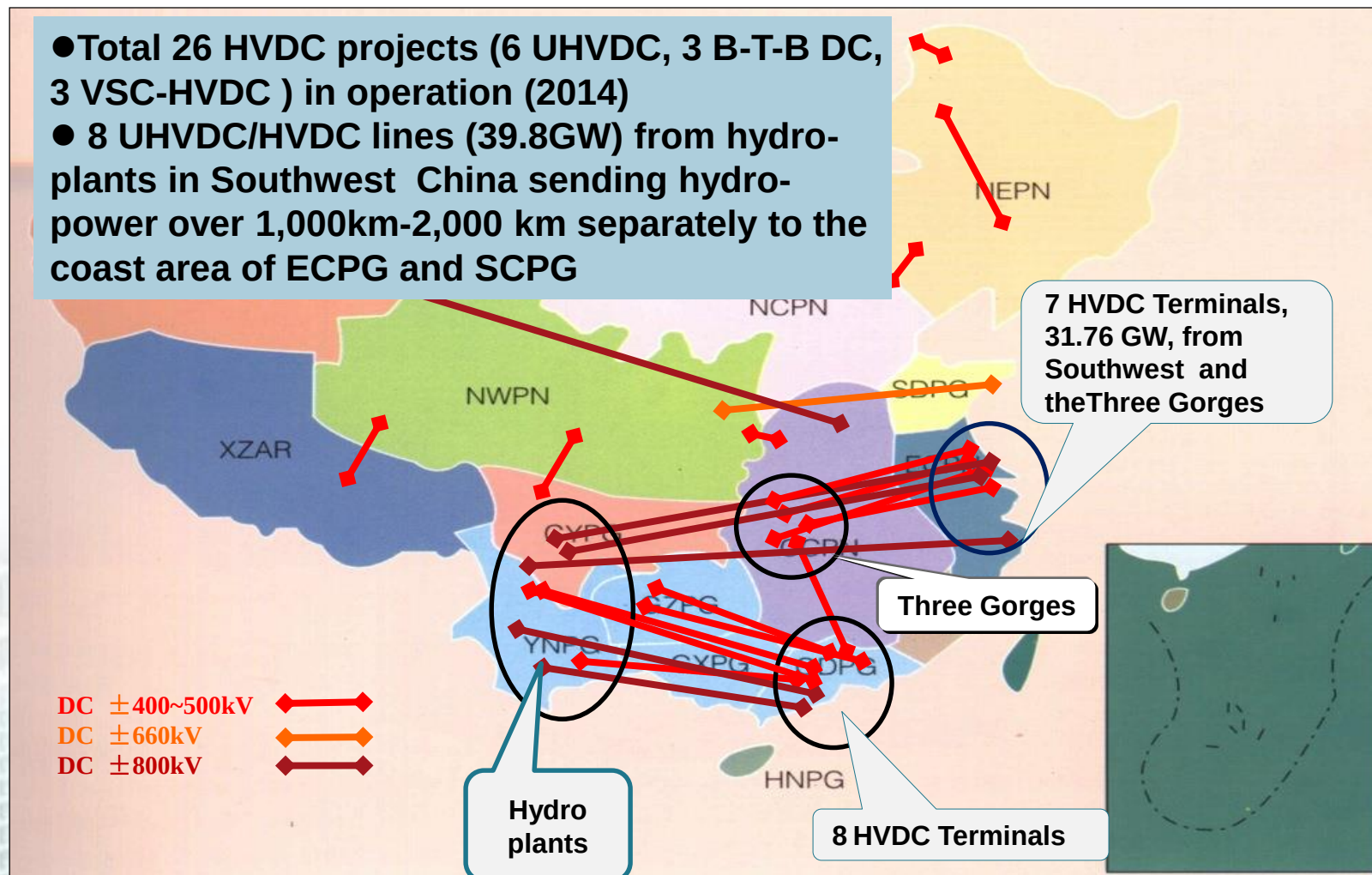


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HVDC transmission systems in China

- Total 26 HVDC projects (6 UHVDC, 3 B-T-B DC, 3 VSC-HVDC) in operation (2014)
- 8 UHVDC/HVDC lines (39.8GW) from hydro-plants in Southwest China sending hydro-power over 1,000km-2,000 km separately to the coast area of ECPG and SCPG



The profile of East China Power Grid

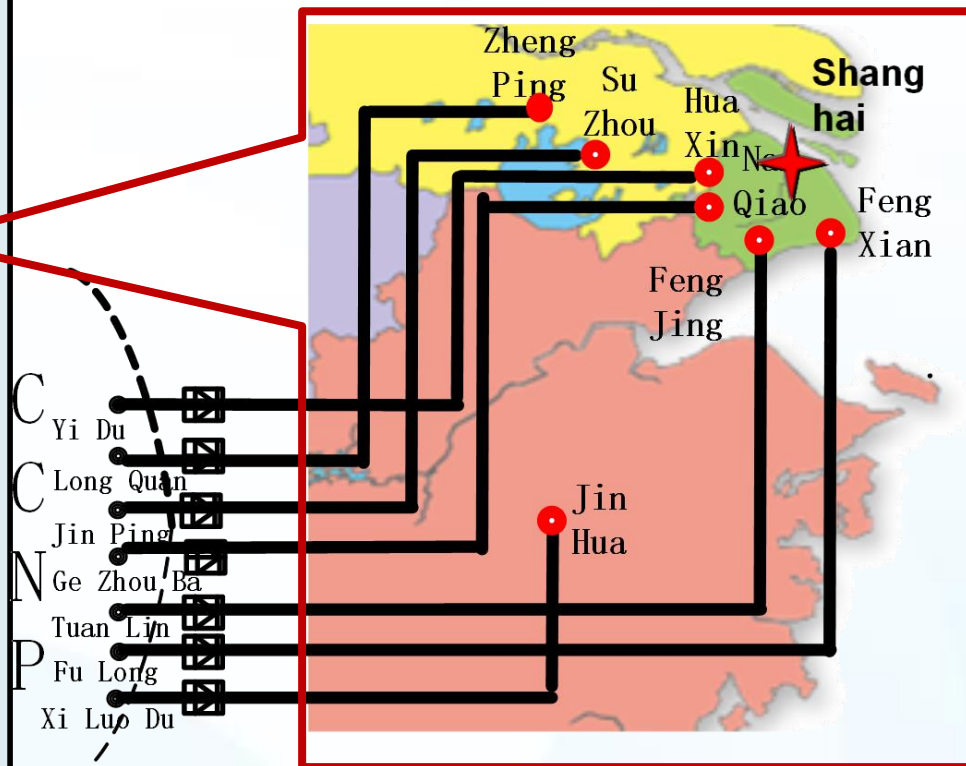
East China Power Grid (ECPG)

- covers 4 provinces and Shanghai area
- total generating capacity 242 GW



- System studies show that in some operation cases HVDC simultaneously commutation failures and forced blocking could bring security and stability problems in the NCPG-CCPG-ECPG interconnected systems:

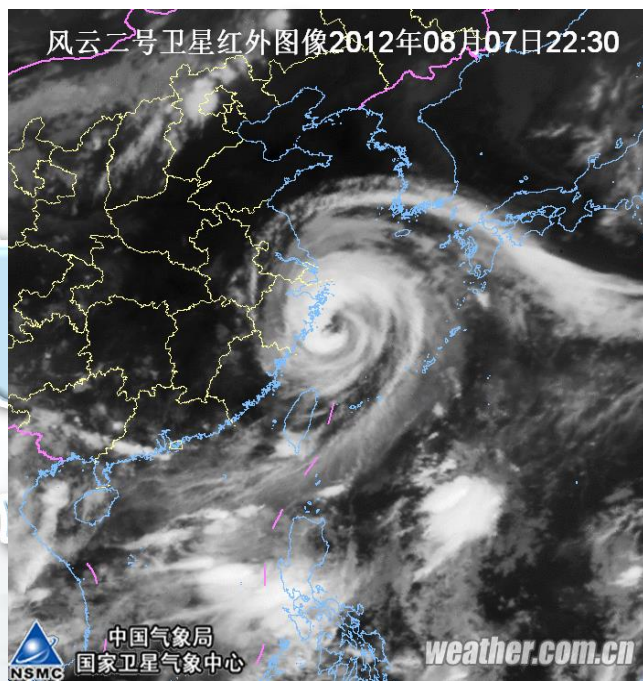
- ✓ low system frequency or voltage stability problem in ECPG
- ✓ Power and voltage oscillations in interconnected AC system



- 7 HVDC lines feed into whole ECPG
- 4 HVDC lines feed into Shanghai

Two disturbance events: “8.8”(2012) simultaneous commutation failures in four HVDC lines /1

On Aug. 8, 2012, Typhoo "Haikui" hit East China Power Grid



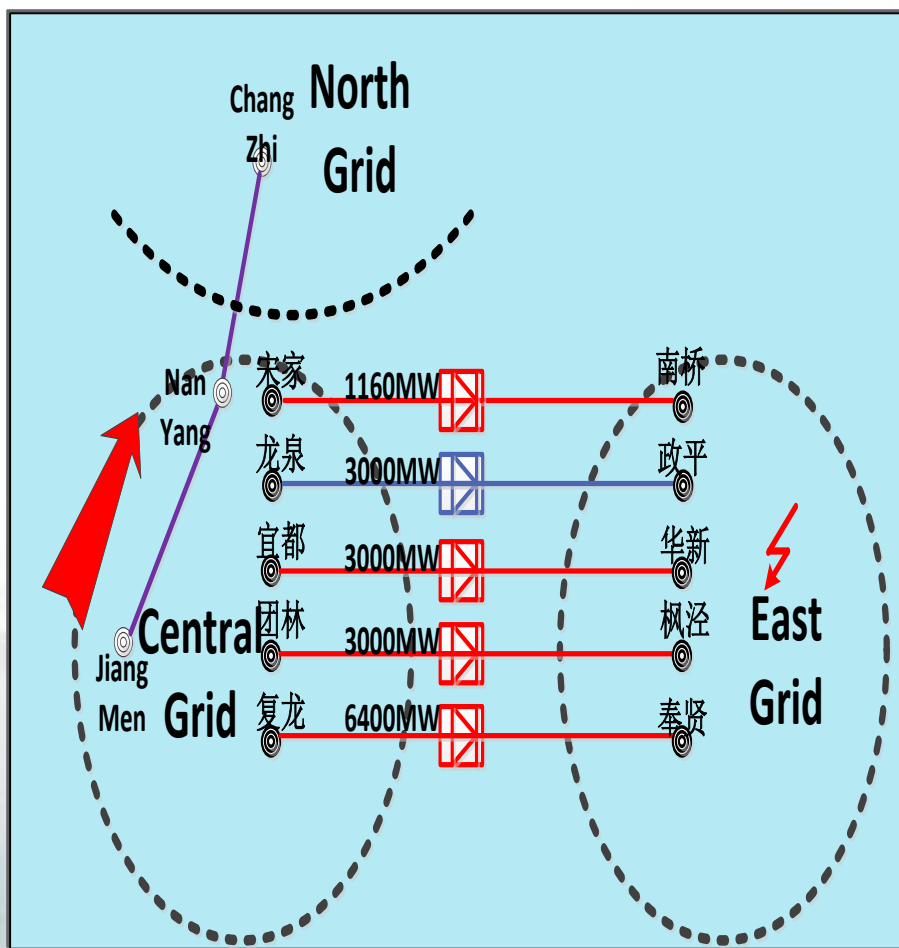
Before the accident

- ✓ 4 HVDC lines with power 9,173 MW feeding into ECPG (Shanghai grid)
- ✓ UHV AC tie line between NCPG and CCPG with power 1,500 MW from north to south

Events

- ✓ A 500kv line in Shanghai grid temporary short circuit and tripped the line
- ✓ 4 HVDC lines simultaneous commutation failures

Two disturbance events: “8.8”(2012) simultaneous commutation failures in four HVDC lines /2



Process of the accident

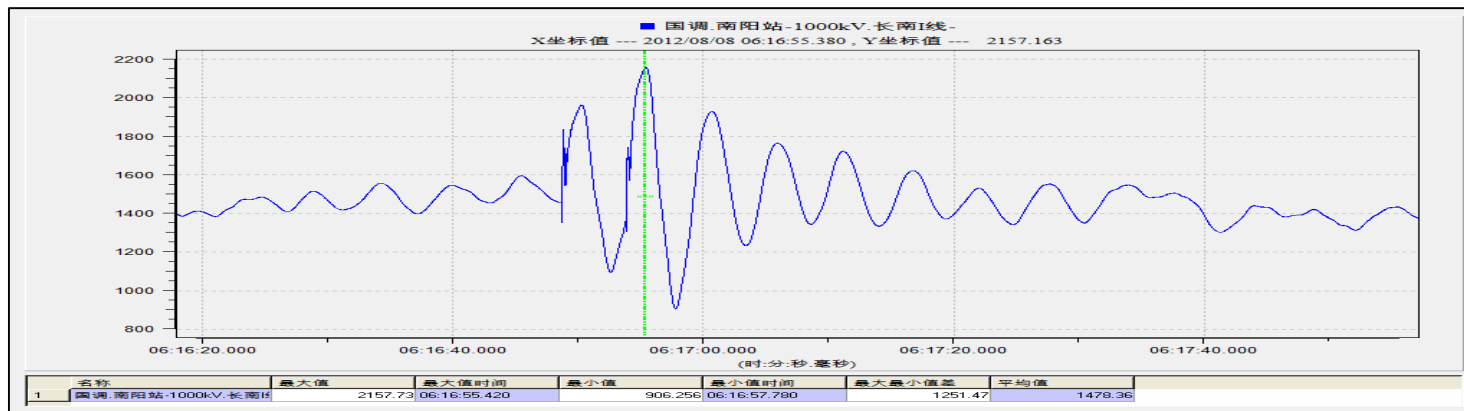
- Maximum power variation of 1,240MW on UHVAC tie-line between CCPG and NCPG.
- quick variation of reactive power exchange and obvious voltage sag

Restoration

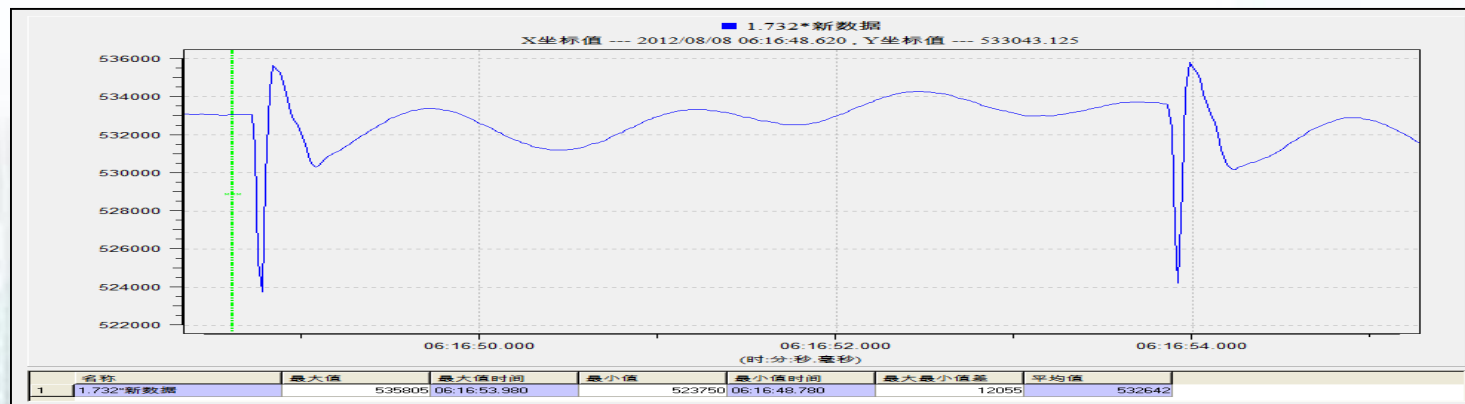
- HVDC transmission lines restored after 300ms.

2014/8/26

Two disturbance events: “8.8”(2012) simultaneous commutation failures in four HVDC lines / 3



The power fluctuation of UHV tie line

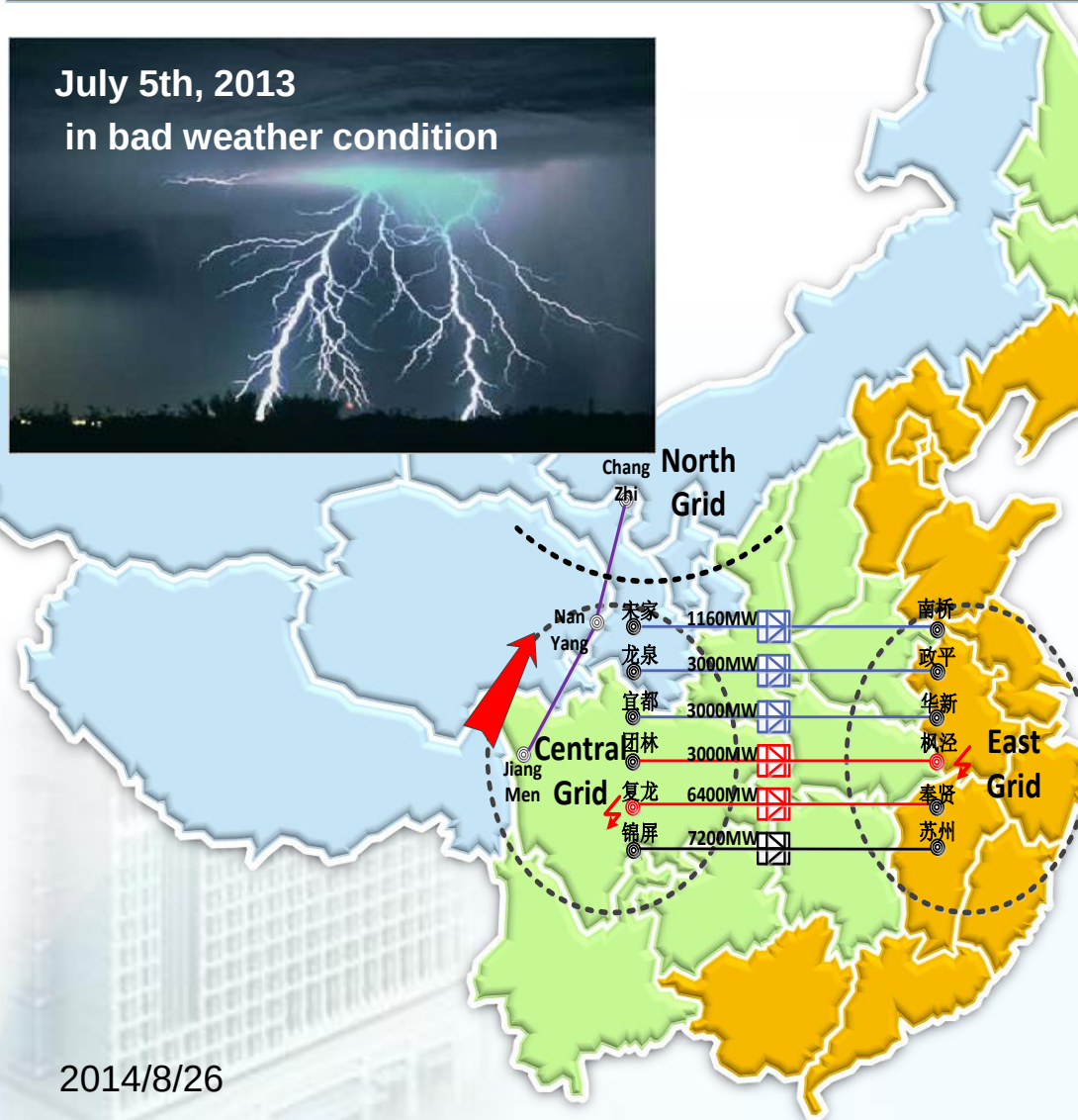


The voltage sag at Nanyang station

2014/8/26

Two disturbance events: “7.5”(2013) HVDC line simultaneous commutation failures and forced blocking /1

July 5th, 2013
in bad weather condition



Before the accident

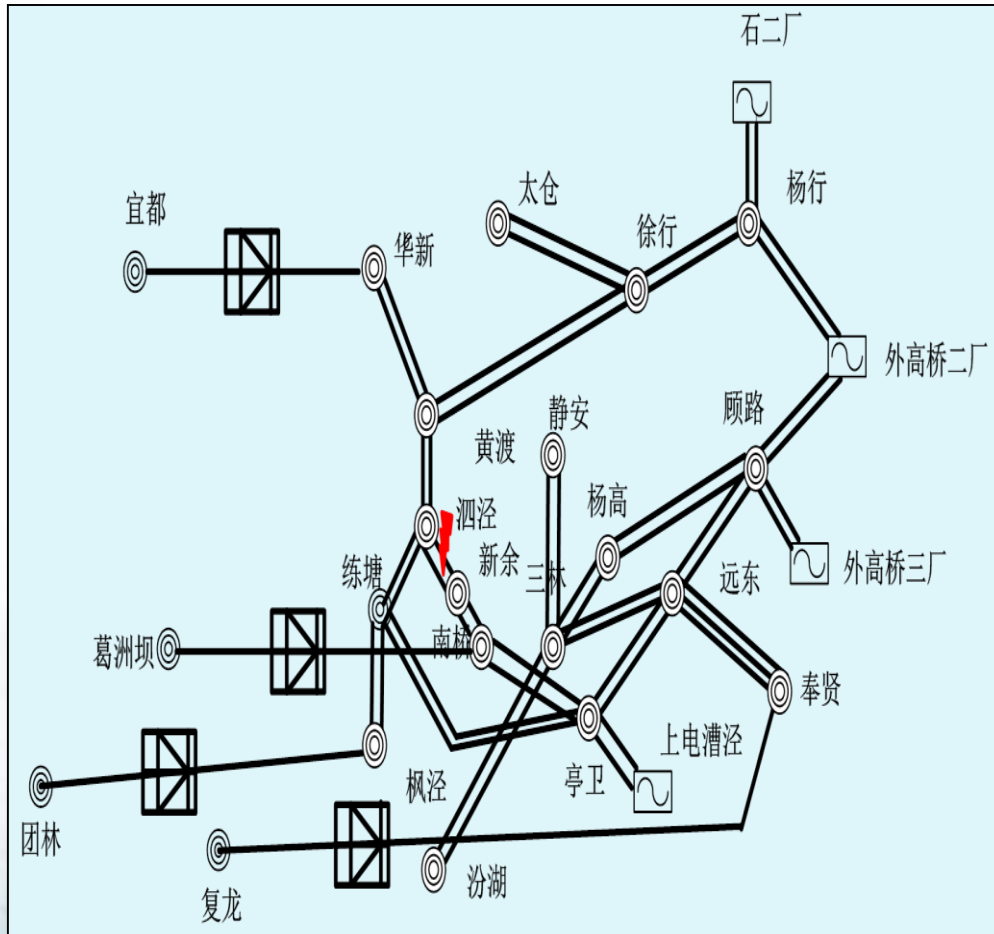
- 1) Load 186 GW in ECPG and 122 GW in CCPG
- 2) 4 HVDC feed power in Shanghai area: 14 GW
- 3) UHV AC tie line 400 MW

Events

- 1) A 500kv line in Shanghai tripped by transient single-phase fault
- 2) Two HVDC line commutation failures
- 3) single pole blocked at **Fengjing** inverter station by mal-triggered gas relay of smooth reactor
- 4) two low ends of bipolar at **Fulong** converter station blocked by cooling cycle pump failure

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Two disturbance events: “7.5”(2013) HVDC line simultaneous commutation failures and forced blocking /2



0ms

- phase B of a 500kv line in Shanghai tripped off by single-phase fault (stricken by lightning).

2ms

- commutation failure in HVDC L- Fengjing ($\pm 500\text{kV}$, 3,000MW).

3ms

- commutation failure in HVDC Fulong-F ($\pm 800\text{kV}$, 6,400MW).

50ms

- the AC fault line reclosed successfully.

245 ms

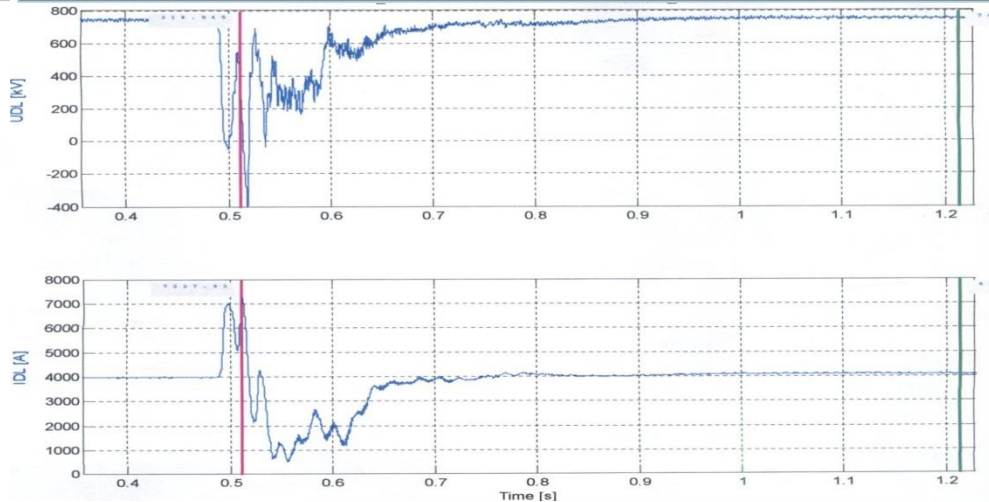
- single pole blocked at Fengjing inverter station with power loss **1,330 MW** by mal-triggered heavy gas relay of smooth reactor. One generator in Three Gorges tripped

7729 ms

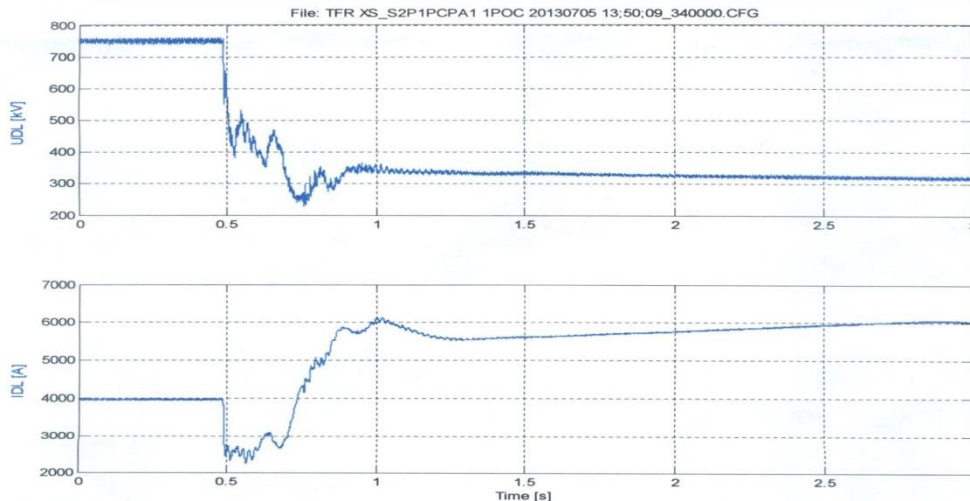
- two low ends of bipolar at Fulong converter station blocked by cooling cycle pump failure with power loss of **3,200 MW**. Five generators with total 2,700MW power were tripped.

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Two disturbance events: “7.5”(2013) DC line simultaneous commutation failures and forced blocking /3



The recording of Fufeng UHVDC during commutation failures



The recording of Fufeng UHVDC during DC blocking

System impacts

- ✓ The accident caused HVDC transmitted power reduced 4,530 MW
- ✓ The frequency of East China Grid decreased to 49.82Hz from 50.005Hz.
- ✓ The transmitted power of UHV AC tie line increased to 700MW

Restoration

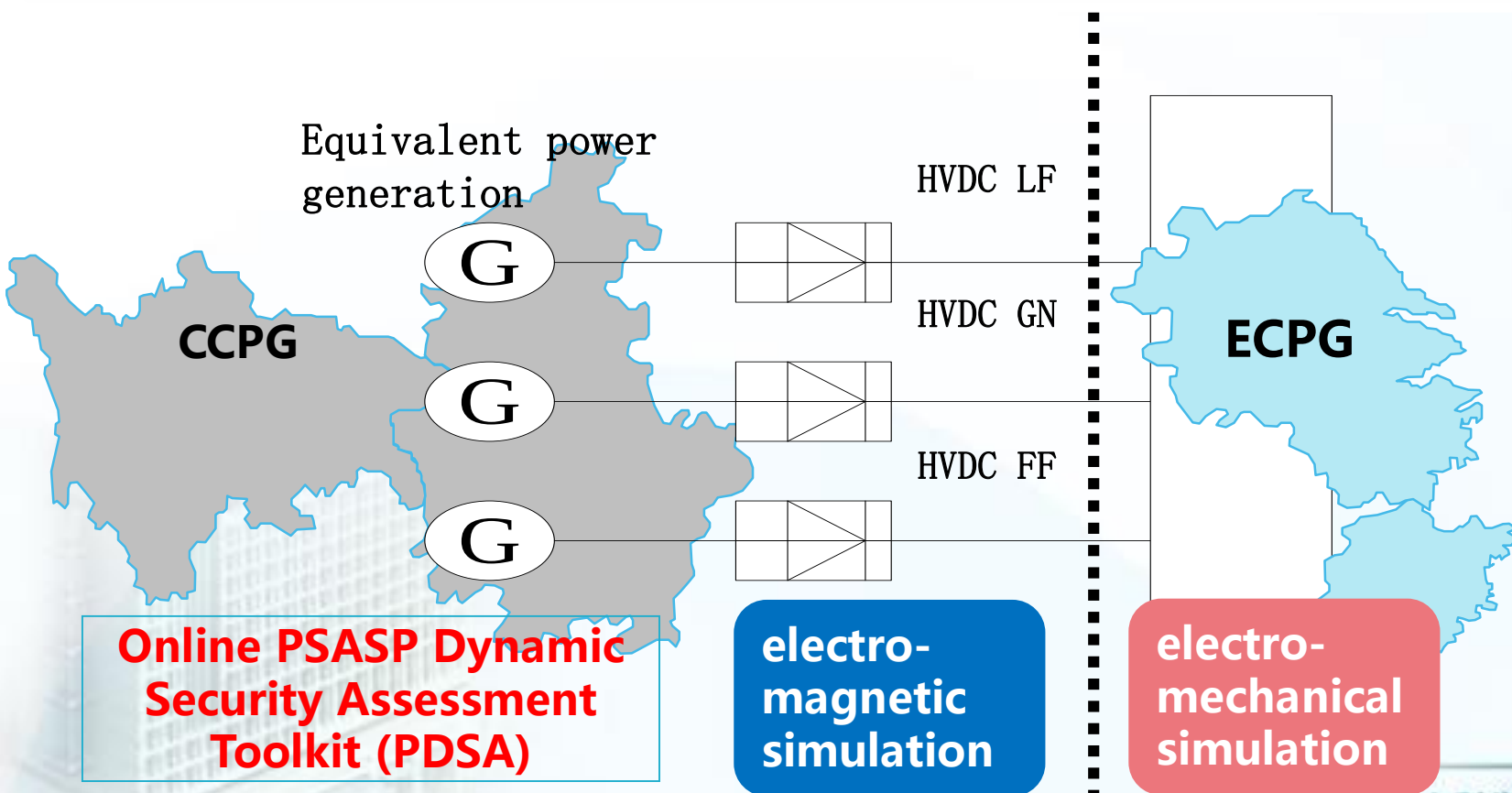
- ✓ 13:53 (3minutes), the spinning reserve acted with 4,500MW. The frequency recovered and no load was shed.
- ✓ 14:33 (43minutes) the generators restored in operation.
- ✓ 15:39 (1h49m) HVDC transmission recovered.

Simulation tool & post-accident simulation

- The above two accidents show that their system impacts were not serious. But this by no means the worse cases will not be happened.
- From system point of view, one of the most effective ways of countermeasures is to continually improve simulation tools and carry out more accurate system studies in order to find out effective protective and control actions to avoid the worse cases happened.

Simulation tool & post-accident simulation

Based upon PDSA and historical online data, a hybrid electro-mechanical-magnetic simulation model is set up.

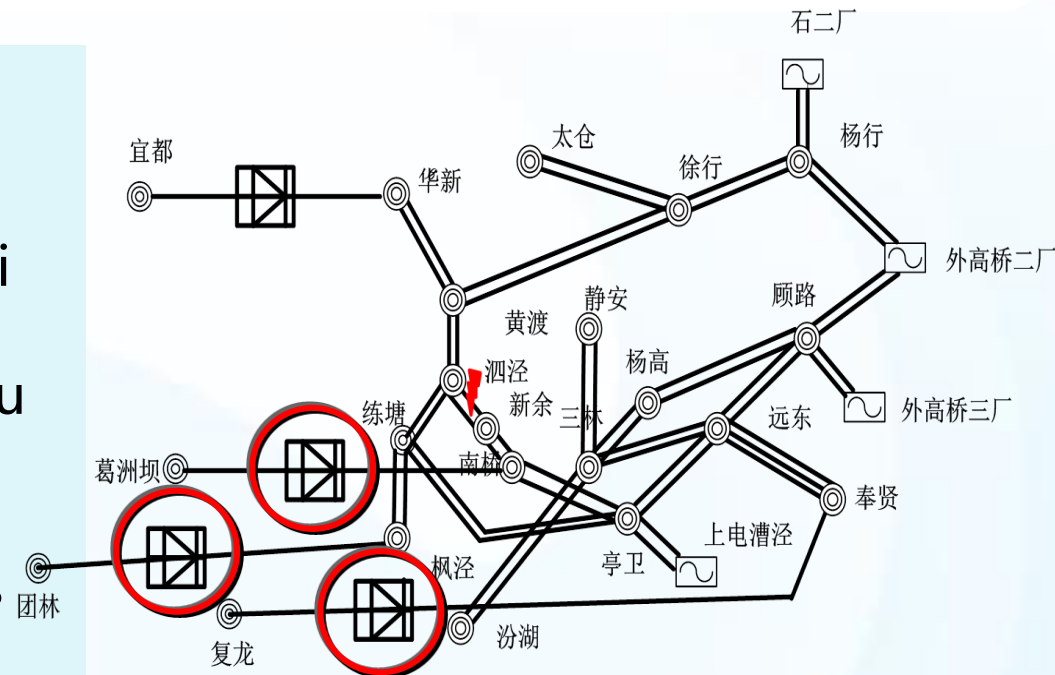


Simulation tool & post-accident simulation

Based on historical online data and hybrid electro-mechanical-magnetic simulation model, post-fault simulation for interaction of HVAC and HVDC is carried out.

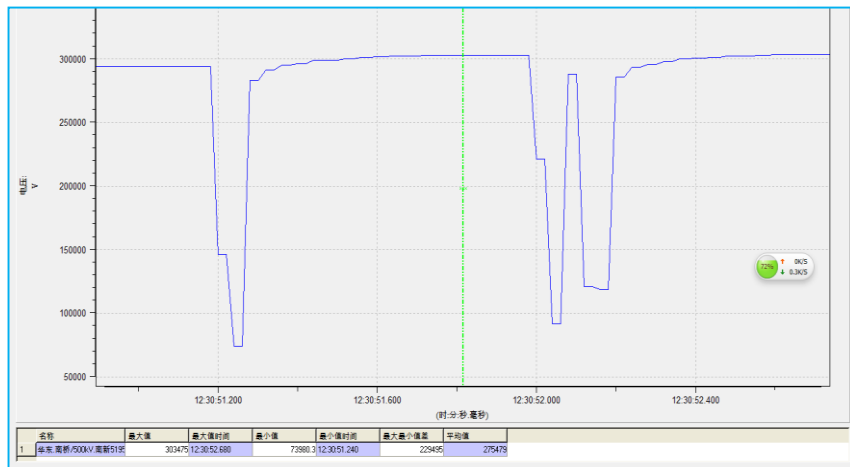
AC Fault Leading to DC Commutation Failure

Some day 16:59:12 in Shanghai of East China, single phase to earth fault occurs on HVAC Siyu line, leading to commutation failure of 3 HVDC lines. After fault, simulation and analysis is carried out using PDSA.

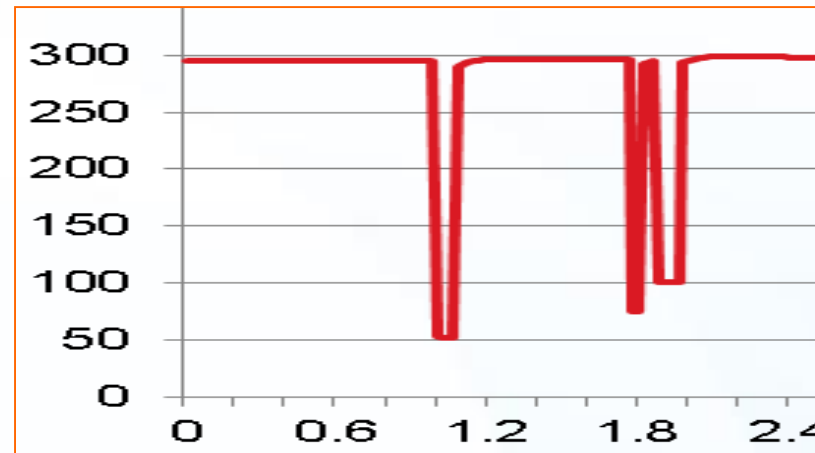


Simulation tool & post-accident simulation

HVDC voltage change due to HVAC fault and HVDC commutation failures



PMU measure curve



PDSA simulation curve

Content	PMU (kV)	DSA sim. (kV)	Diff. (kV)
Initial voltage	294	294	0
The first drop voltage	62	52	10
The second drop voltage	82	75	7
Post-steady-state voltage	294	294	0

- Seven HVDC terminals feeding into East China Power Grid, with total capacity over 31GW , 13% of the total generation capacity of East China grid.
- System studies show that heavy loaded multi-in feed HVDC transmissions could bring system security and stability problem in East China particularly in Shanghai areas.
- Two disturbance event cases show that simultaneous commutation failures and forced blocking of multi-in-feed HVDCs caused obvious power variation and generation shedding, but no serious harms to system operation in these particular cases. But this by no means the worse cases will not be happened.
- Simulation tool kits PDSA provide powerful platform of HVDC/HVAC hybrid simulation for system studies.



THANK YOU FOR YOUR ATTENTION

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