

# Study on Control Strategy of Nujiang Power Grid in Cooperative Operation

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**Abstract.** After the Nujiang grid is divided, the overall grid structure is divided into two parts. That is, the power delivery channel and the distribution network load power supply channel. The basic grid of Nujiang has been fundamentally changed. The inherent difficulties in the operation of the Nujiang grid will remain and may lead to new problems. This paper systematically expounds the problems existing in the operation of power grids. For the new problems and some of the original problems, specific solutions are given.

## 1. Introduction

Nujiang power grid at the end of Yunnan power grid, mainly through two channels. The grid architecture is not strong and relatively weak power grid. After the operation of isolated networks, the high frequency problems and low frequency problems are very prominent [1]. The special geographical environment caused the load to be far from the power center. There is long distance power transmission over high altitude. If the line is out of order, it is very difficult to overhaul and maintain [2]. The grid structure of regional power grid has obvious long chain characteristics of centralized collection of small hydro power and long distance sending. The water resources in Nujiang area are rich, and the power transmission pressure of regional power grid is relatively large. The dynamic stability level of regional power grid is relatively low. Due to the uneven distribution of load and power supply, the problem of high frequency is common in the local power grid after partial disconnection, and the low-frequency voltage exists in some areas, too [3]. In the stable operation of power grid dispatching, aiming at the market of transportation stability and power consumption, the balance of power and electricity is analyzed scientifically. Nujiang power grid has access to small hydropower, many single machine capacity and wide distribution. Because of the power plant protection level is low, with the power grid protection action difficult [4]. The automatic switching device can restore the power supply to the voltage loss bus as soon as possible, and effectively improve the stability of the regional power grid [5]. Fault of Nujiang power grid send contact line caused part of Yunnan power grid and Southern Power Grid splitting [6]. With the increase of the load of the Nujiang grid and the increase of the power supply, this will change the network structure and power allocation of the power system [7]. This paper systematically expounds the problems existing in

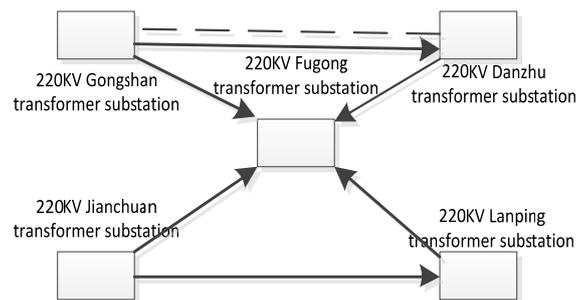


the operation of the power grid, and gives concrete solutions to the new problems and some of the original problems.

## 2. The grid structure of Nujiang changes before and after operation

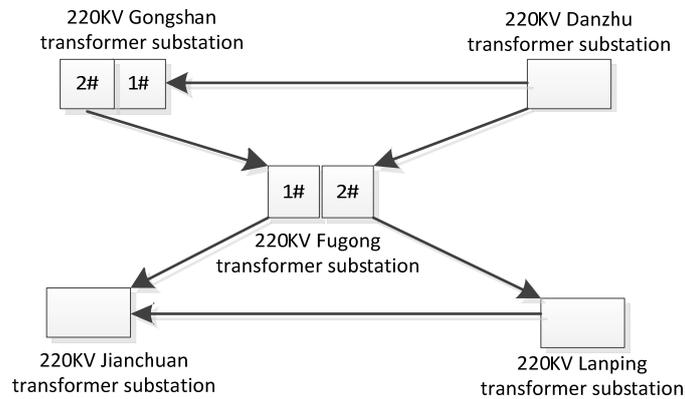
### 2.1. Before Nujiang power grid is splitting up:

After 220KV Fugong substation of series compensation put into operation, between 220kV Fugong substation and 220KV Gongshan substation can run in parallel operation or run respectively. In parallel operation mode, triangle loop operation in 220kV Fugong grid system that remains 220kV Fu-Jian circuit line, Lan-Fu line circuit and Dan-gong line circuit or 220kV Dan-Fu line circuit, Gong-Fu line circuit and Dan-gong line circuit. In the separate operation mode 220kV Fu-Jian line circuit, Lan-Fu line, line ring network and 220kV Dan-Fu line circuit, Gong-Fu line circuit, Dan-Gong line ring circuit network can open loop operation. 220kV Fu-Jian line circuit starting point for the 220kV Fugong substation main transformer No. 1#, the ending point is 220kV Jianchuan substation; 220kV Lan-Fu line circuit starting point for 220kV Lanping substation, the ending point is No. 2# main transformer in 220kV Fugong substation; 220kV Dan-Fu line circuit starting point for Danfu river power station, the ending point is No. 2# main transformer for 220kV Fugong substation; 220kV Gong-Fu line starting point for 220kV Gongshan substation, the ending point is NO.1# main transformer in 220kV Fugong substation.



**Fig 1.** Normal operation diagram of Nu River power grid

After the Nujiang power grid is out of operation, the connection mode of the 220kV line circuit has changed. 220kV Fu-Jian line circuit: the starting point for the 1# main transformer in 220kV substation in Fugong, the ending point is 220kV Jianchuan substation. 220kV Lan-Fu line circuit : the starting point is 220kV Lanping substation, the ending point is No. 2# of main transformer in 220kV Fugong substation; 220kV Jian-Lan Line circuit I: the starting point for the 220kV substation in Jianchuan, the ending point is 220kV Lanping substation; 220kV Dan-Fu line circuit: the starting point for the Danzhu River Hydropower station, the ending point for No. 2# of main transformer in 220kV Fugong substation ; 220kV Gong-Fu line circuit : the starting point for the 2# main transformer in 220kV Gongshan substation , the ending point for No. 1# main transformer in 220kV Fugong substation; 220kV Dan-Gong line circuit: the starting point for the Danzhu River Hydropower station, the ending point for No. 1# main transformer in 220kV Gongshan substation.



**Fig 2.** Operation diagram after splitting of Nu River power grid

**3. Influence of operation on stability**

Although Nujiang power grid operation can improve the economic operation of power grid, the original grid of Nujiang power grid has undergone tremendous changes, and the grid structure of Nujiang will be weaker. When the power grid is disturbed, the stability of Nujiang power grid is shocked.

*3.1. Frequency stability analysis*

When the power system is in normal operation, the whole power system should be kept at the same frequency. The frequency of power grid is an important basis for the balance between power generation and power load. When the power system is in steady state operation, the generator output and system load should be balanced, and the mechanical torque of generator should be equal to the electromagnetic torque. As shown in equation (1):

$$T_m = T_e \tag{1}$$

In the formula:  $T_m$  mechanical torque of the generator;  $T_e$  for electromagnetic torque of the generator.

At the same time, the generator rotates at a constant angular speed. The frequency of the generator is shown in equation (2):

$$f = \frac{\omega_0}{2\pi} \tag{2}$$

In the formula:  $f$  is grid frequency;  $\omega_0$  is angular velocity.

The relation between the power grid frequency and the generator speed change, as shown in equation (3).

$$f = \frac{P \cdot n_0}{60} \tag{3}$$

Among them:  $P$  is the generator's extreme logarithm;  $n_0$  is generator speed;  $f$  is grid frequency.

When the system is disturbed, the output power of the generator is not balanced with the load absorbed power, mechanical torque is not equal to electromagnetic torque. This results in a corresponding change in the angular velocity and revolution of the generator, which results in frequency fluctuations of the power system. As shown in equation (4).

$$\left\{ \begin{array}{l} \Delta T = T_m - T_e \\ \Delta \omega = \omega - \omega_0 \\ \Delta n = n - n_0 \\ \Delta f = \frac{\Delta \omega}{2\pi} \\ \Delta f = \frac{p \cdot \Delta n}{60} \end{array} \right. \quad (4)$$

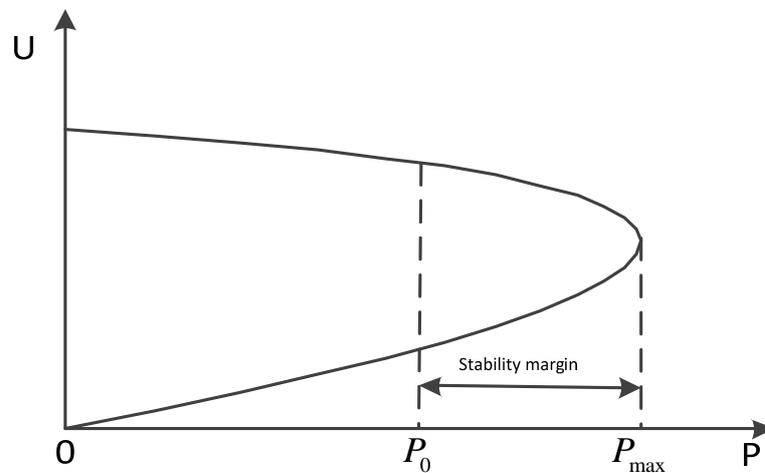
Formula:  $\Delta T$  torque deviation;  $\Delta\omega$  angular velocity deviation;  $\Delta n$  is speed deviation;  $\Delta f$  is frequency deviation.

The frequency mainly reflects the balance between the injection of the mechanical power and output of the electromagnetic power. When the system is out of balance, the frequency of the power grid fluctuates. When Nujiang power grid operation may lead to a regional sub power grid and China Southern Power Grid contact becomes weak when the system fails, it is prone to system frequency instability. In the region, regional and regional power grid and Lanping-Fugong main contact is the single track between Lanping and the Jianchuan. When the tie line fails, the frequency stability of the power grid is inevitable.

### 3.2. Influence of voltage stability

Voltage stability is that when the power system is subjected to large and small disturbances, the system voltage can still be maintained or returned to the extent that the system can withstand, without voltage collapse. Voltage instability is the result of the interaction of system characteristics and load characteristics. The premise of stable operation of power system is that there must be a stable equilibrium point. When a large disturbance occurs, the maximum power delivered by the transmission line after disturbance will decrease as compared with the maximum power before disturbance, and then the voltage instability will occur. The PV curve is usually used to determine the stability of the system voltage and to determine the degree to which the system voltage approaches the voltage collapse point. The PV curve is shown in Figure 3 :

The vertex of the PV curve is the critical point of voltage stability. The upper part of the PV curve is the equilibrium point that the system can run stably, and the lower half of the PV curve is the unstable equilibrium point of the system. In the actual system, as the load increases, the system will move from the upper part of the PV curve to the lower half of the PV curve, so the PV curve will be beneficial to the analysis of the system voltage stability. With the independent operation of Nujiang power grid, power grid structure is changed. It is necessary to analyze the voltage stability after the operation of Nujiang power grid.



**Figure.3** PV diagram

#### 4. The problem of voltage exceeding limit after operation

The over voltage limit refers to the grid voltage exceeding the rated value. Voltage quality is an important index to reflect the quality of power system. The reactive power level and its regulating capability of the network directly affect the voltage level of the whole power grid. Reasonable reactive power compensation and effective voltage control can not only ensure the quality of voltage, but also improve the safety and economy of power system operation.

After the split operation of Nujiang power grid, the original transmission line pattern has been changed. As the Nujiang power grid is an external power supply network, the local load is less. Due to geographical factors, the power and load distribution is unbalanced. The reactive power of each node in the power grid should first meet the principle of local balancing, and cannot rely solely on the reactive power injection provided by the system. If a large number of reactive power cannot be balanced locally, then long-distance reactive power transmission will not only increase network losses, but also lead to greater voltage drop, and eventually lead to low voltage operation of the system.

For reactive power and voltage optimal control, the influence of the sequence of control actions is mainly reflected in the change of the control effect after the control action. Due to the adjustment of transformer OLTC voltage regulating measures do not generate reactive power, reactive power can only change. In the reactive power shortage and lower voltage, load switch does not provide complementary reactive power transformer, but the reactive power shortage on to the high side power grid. If the transformer load tap is adjusted under the condition of reactive power shortage, the voltage of the main grid will be seriously reduced and the voltage collapse accident will happen. When the voltage of the accident is reduced, the reactive power supply should be first put into use, the transformer is automatically loaded, and the response of the tap changer should be slower.

We can take the following measures in view of the voltage limit:

Putting into the reactive power compensation device. Capacitors are reactive power sources which can generate reactive power. The shunt capacitor can be used to compensate reactive power locally or separately; Making the generator late phase or phase operation, change the generator terminal voltage;

Adjust transformer tap, select transformer ratio. Adjusting the tap of a loaded transformer can change the distribution of reactive power, and does not produce reactive power perse. In the case of reactive power adequacy, the voltage can be effectively adjusted.

Through the above adjustment, as far as possible to reduce the dependence of the reactive power resources of each node, so that the voltage of the Nujiang grid is maintained within the normal range.

## 5. Analysis and regulation of over limit voltage of limit outward delivery

### 5.1. Analysis of exceeding limit voltage

Table 1 is the part of the node voltage limit of the Nujiang power grid under the limit transmission mode. The voltage limit is as high as 46 nodes. When the voltage exceeds the limit in the grid, the system enters a state of emergency. Unless effective measures are taken, the operation will deteriorate further and even cause a system crash. When the voltage in power system exceeds the limit, safety correction measures should be taken immediately. By controlling certain voltage adjustments, the voltage of the monitored node in the system is corrected to a predetermined range of operations or a predetermined target value.

According to the results of the operation of the tide, it can be analyzed that the nodes with low voltage are concentrated in the Chongren area. Chongren, the center of main transformer and the voltage variable Liuku part load node and the generator nodes is low. Chongren area node voltage did not appear high, the overall lack of reactive power. Gongshan, Fugong and part of voltage node in Lanping area is high, part of the node voltage is low, the overall present situation of uneven distribution of reactive power.

**Table 1.** Part of the node voltage limit table

node	Voltage level	The actual value of voltage	Voltage unitary value	Limit voltage value
CR11	115	108.46	0.9431	-0.0069
CR12	115	108.47	0.9432	-0.0068
CR2	230	211.36	0.9189	-0.0311
CR351	37.5	34.56	0.9216	-0.0284
CR352	37.5	32.92	0.8779	-0.0721
FG352	37.5	33.87	0.9032	-0.0468
LANP35	37.5	34.69	0.9251	-0.0249

### 5.2. Control measures of the limit outward voltage

According to the low voltage and over voltage node data list observation voltage limit results can be found in Pianma substation, power plant and other Liuku are concentrated in Chongren area. These nodes are nodes with lower voltage limits. The main cause of low voltage is reactive power, so the main adjustment strategy is to increase reactive power compensation in this area. As shown in the following table2:

**Table 2.** Compensation reconciliation

Adjustment compensation place	Pre adjustment compensation capacity (MVar)	Adjusted back compensation capacity (MVar)
Chongren becomes 2# main transformer	0	45
Chongren becomes 1# main transformer	0	15
The centre of 1# main transformer Liuku	0	3.6
The centre of 2# main transformer Liuku	0	3.6
Pianma substation	0	7.2

Through the above adjustment strategy, we can get the results as follows:

**Table 3.** List of nodes, low voltage and over voltage node data

node	Reference voltage	Voltage		Range of voltage		Gross boundary voltage
	(kV)	(kV)	(pu)	min(pu)	max(pu)	(pu)
CR2	230	216.11	0.9396	0.95	1.052	-0.0104
CR351	37.5	35.4	0.944	0.95	1.052	-0.006
CR352	37.5	34.12	0.9099	0.95	1.052	-0.0401
FG352	37.5	33.88	0.9034	0.95	1.052	-0.0466
LANP35	37.5	34.7	0.9254	0.95	1.052	-0.0246
Huang mu L	10.5	11.59	1.1041	0.95	1.052	0.0521
Huang mu S	37	40.17	1.0856	0.95	1.052	0.0336

The results show that through reactive power compensation, the voltage of Chongren district is basically adjusted to the normal range, and the low voltage limit is still appearing in a few power stations.

## 6. Overload limit transformer and line overload analysis

Transformer equipment and line overload will lead to transformer loss increase, transformer output voltage reduction and reduce transformer life, and even lead to large-scale blackouts. Regarding the transformer equipment and the overload of the line, the power flow transfer is the best measure. The Nujiang power grid is a radial network of power supply, and the load of power supply, outlet transformer and line and 220kV main transformer is heavier. Transferring power is difficult to achieve for Nujiang power grid. According to the actual situation of power flow, equipment capacity or cutting machine to reduce the tide, to solve the long-term heavy load on the equipment hazards. The limit line overload and transformer overload are shown in the following table 4:

**Table 4.** line load rate is greater than 80%

line circuit	Electric current	The rated current	Proportion	Apparent power	Rated apparent power	Ratio
	(A)	(A)	(%)	(MVA)	(MVA)	(%)
CR12~LiukuY	664.1	700	94.9	129.5	139.4	92.9
FG12~Majikai	494.9	610	81.1	102.6	121.5	84.5
Xiyuege2G~ XiyuegeL	522.6	515	101.5	5.7	5.6	101.5
Xiyuege3G~ XiyuegeL	522.6	515	101.5	5.7	5.6	101.5

**Table 5.** The transformer load exceeds the rated value of 80% of the data list

The transformer branch				Apparent power	Rated capacity	Proportion	power factor
				(MVA)	(MVA)	(%)	
CR2	230	CR352	37.5	106	90	117.8	0.9434
FG1	230	FG11	115	150.2	180	83.4	0.9946
FG1	230	FG221	230	152.3	180	84.6	0.9786
FG12	115	FG2	230	193.8	180	107.7	0.9756
FG2	230	FG222	230	200.9	180	111.6	0.938
GS12	115	GS2	230	163.1	180	90.6	0.9996
GS2	230	GS222	230	163.2	180	90.7	0.9962

## 7. Analysis and regulation of voltage over limit

### 7.1. Voltage adjustment strategy in Chongren District

According to the low voltage and overvoltage data list, the voltage limit is observed, and it can be found that the voltage in Chongren area is lower. The minimum voltage is mainly concentrated in: Chongren substation, Laowo river power station, Liuku hydropower station and so on. The main reason for the low voltage is the lack of reactive power, so for the low voltage phenomenon in this area, the first adjustment strategy is to put in capacitors and increase reactive power compensation.

Specific strategies are as follows:

NO.2# main transformer in 220kV Chongren substation low voltage side put in all four groups of 15MVar capacitors (total compensation reactive power 60MVar);

110kV 1# and 2# center in Liuku substation low voltage side of main transformer of each input a set of 3.6MVar capacitors (total reactive power compensation 7.2MVar);

A 3.6MVar capacitor is placed on the 10.5kV side of the 110kV chip substation.

**Table 6.** compensation reconciliation

Adjust the compensation place	Pre adjustment compensation capacity (MVar)	Adjusted back compensation capacity (MVar)
Chongren 2# substation main transformer	15	60
Chongren 1# substation main transformer	15	0
Pian masubstation	0	7.2

Through the above adjustment strategy, we can get the following results:

The results show that the voltage of Chongren district can be adjusted to the normal range by adding reactive power compensation into the capacitor. In the 220kV substation, 35kV Chongren 1# transformer with low voltage side and 220kV Chongren 2# transformer with high voltage side appears low voltage over limit phenomenon. At the same time, Yinpo River power plant, Laowo river power plant also continued to show a low voltage crossing phenomenon. At the same time, YinPo River power plant, power plant Laowo river power plant, Liuku substation also continued to show a low voltage crossing phenomenon.

**Table 7.** List of partial low voltage and over voltage node data

nodes	Reference voltage	The voltage		Voltage range		Over voltage values
	(kV)	(kV)	(pu)	min (pu)	max (pu)	(pu)
Shangpa 2L	10.5	11.87	1.13	0.95	1.052	0.078
Shangpa 2S	37	41.54	1.1228	0.95	1.052	0.0708
Huangmu L	10.5	11.57	1.102	0.95	1.052	0.05
FG352	37.5	33.78	0.9008	0.95	1.052	-0.0492
CR352	37.5	34.18	0.9114	0.95	1.052	-0.0386
Yinpo river 2G	6.3	5.78	0.9182	0.95	1.052	-0.0318
Yinpo river 1G	6.3	5.78	0.9182	0.95	1.052	-0.0318
Huangmu S	37	40.1	1.0837	0.95	1.052	0.0317
Zi lijia 2G	6.3	5.82	0.9238	0.95	1.052	-0.0262
Zi lijia 1G	6.3	5.82	0.9238	0.95	1.052	-0.0262
Langping 35	37.5	34.73	0.9262	0.95	1.052	-0.0238
Langping S	37	39.79	1.0755	0.95	1.052	0.0235

### 7.2. Voltage adjustment strategy of Nu River north area

Chongren area has been adjusted to a reasonable range. North of the Nu Jiang area, and Lanping area, Fugong, Gongshan still exist the limit voltage problem. The low voltage side of main transformer substation, Fugong Gongshan substation and Lanping substation has low voltage limit phenomenon. In the Zi Lijia power station, the phenomenon of low voltage over limit occurs, and the rest of the site is over voltage, and the overall distribution of reactive power is uneven. Fugong, Gongshan and Lanping area appear low voltage phenomenon. The 48MVar capacitor can be put into the Lanping substation on the basis of the original. In Fugong substation was put into 30MVar reactor. In Shangpa substation was put into 1.8MVar capacitor and reactor 4MVar.

**Table 8.** Compensation reconciliation

Regulation of compensation place	Pre adjustment compensation capacity (MVar)	After adjusting compensation capability (MVar)
Lanping substation	0	48
Fugong substation	0	-30
Shangpa1#	0	1.8
Shangpa2# low-pressure side	0	-2
Shangpa 2# medium-pressure	0	-2

**Table 9.** Transformer regulation meter

Transformer type	Pre regulation ratio	Ratio of regulation to change
Shangpa2T/2S/2L	110/38.5/11	121/38.5/11
Langping1T/S/L	110/38.5/10.5	116/38.5/10.5
Huangmu1T/S/L	110/38.5/11	121.3/38.5/11
Zi LijiaY/1G/2G	121/6.3/6.3	116.8/6.3/6.3
GS2/GS12/GS352	235/115/35	230/115/35

Through the above adjustment, results in the following table:

**Table 10.** List of nodes, low voltage and over voltage node data

nodes	Reference voltage	Voltage		Voltage range		Over voltage value
	(kV)	(kV)	(pu)	min (pu)	max (pu)	(pu)
FG352	37.5	34.6	0.9227	0.95	1.052	-0.0273
LANP35	37.5	34.71	0.9257	0.95	1.052	-0.0243
CR352	37.5	34.89	0.9304	0.95	1.052	-0.0196
FG351	37.5	35.17	0.9379	0.95	1.052	-0.0121

For these main transformers, the low-voltage side is low voltage. The main transformer Fugong not install capacitors, capacitors have been put into Chongren. Although the Lanping has changed the main capacitor sets, all the inputs still can not make the voltage limit to improve to a reasonable range. Fugong, Chongren and Lanping area, due to the capacity of reactive power compensation device can not meet the requirements, the reactive power compensation and generator input into late phase operation, still can not be all the more node limit voltage to pass. Through the above adjustment, draw conclusions as follows: in the extreme mode of operation, The capacitor can improve the Chongren area border node voltage is too low and the Nu River north part of this node reactive uneven distribution. Finally, the node voltage can be basically adjusted to the eligible range.

## 8. Summary

Nu River power grid power grid from typical area, power grid and China Southern power grid fault disconnection, high frequency problem is very prominent. When the power delivery system is solved as an isolated network system, the system power is surplus. The excess of active power will accelerate the generator rotor and cause the system frequency to rise. In order to solve the problem of the stability of the regional power grid from paralleling operation to isolated network, the power imbalance must be eliminated as soon as possible. The safety and stability of the isolated network system are analyzed in detail. Taking necessary control measures according to the requirements of safety and stability of power system. As far as possible, the isolated power grid is restored from the emergency state to the running state.

Operation strategy can improve the stability of NuJiang power grid. The power grid divides a portion of the power supply for power transmission, improving the economic reliability of Nu River power grid. Independent operation of Nu Jiang power grid is presented to solve the serious Nu River hydropower plant waste water problems, it will be part of the hydropower resources through network

breakdown, transported to the main network. Some accidents, such as local power network fault, natural disaster or human error, lead to the disconnection of grid tie line to form isolated network operation, and the frequency of power grid fluctuates greatly. Later, the trend recovery strategy of the isolated network will be further studied.

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