Analysis risk of dynamic stability of power network with multiple small motor groups equivalent to each other

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Abstract. The BPA data of the regional power grid is usually only used for the detailed modeling of the 110kV grid connected substation, and the 35kV and the following grid station generally use the equivalent parameters of the equivalent capacity of the unit, and then be incorporated into the 110kV power grid for simulation analysis. In order to analyze the accuracy of power system stability simulation after equivalence, a detailed model of the grid connected small hydropower units with 35kV and the following is built. The results show that, using a plurality of small hydropower units group area grid equivalence, dynamic stability analysis of differences, there are regional power grid internal oscillation mode equivalent and cannot reflect the regional oscillation modes in small turbine.

1.Introduction

With the strong demand for environmental protection, hydropower, as a clean energy source, has been valued by the state and the localities. Many small hydropower stations have been established in areas with abundant hydropower resources. In the northwestern part of Yunnan, the number of small hydropower units in the municipal-level regional power grid has reached hundreds. The characteristic of these small hydropower units are that the capacity of a single machine is small, the number is large, and the grid voltage level is low. According to the enterprise standard regulations of China Southern Power Grid Corporation [1], the 50MW and above hydro-generator units and pumped-storage power generation/motor units that are integrated into the southern power grid shall be tested and modeled for the parameters of the excitation system, prime mover and its regulating system. However, there is no clear regulation for small hydropower units below 50MW. Usually, considering that if each small hydropower unit established a detailed model, there may be a problem of “dimensionality disaster” in the calculation, so the regional grid BPA data is only used for the detailed modeling of the 110kV grid-connected plant , and grid-connected plants of 35kV and below are generally equivalent to the equal capacity units with typical parameters, which is incorporated in the 110kV power grid to simulate and analyze, or it is equivalent to the regional load. The characteristics of the small power are difficult to fully reflect.

In recent years, research on the equivalent of power system has been increasing [2]~[18]. In [5], it proposes a homology equivalent method, which is generators that oscillate at a similar speed after a large disturbance in the system are classified as a coherent group, and the generators in each group are combined into an equal value machine. Because this method is based on the coherent characteristics of generators after large disturbances, it is generally applied to the external network equivalent in transient stability analysis. The literature [6] combines the characteristics of reginal small hydropower units and the dynamic stability analysis of power systems' requirements to dynamic equivalents. It improves the traditional coherence equivalence, and proposes a dynamic equivalence modeling method for small hydropower groups based on homology aggregation and network simplification. These methods mainly tend to treat the small hydropower unit as a whole, and analyze the influence on the dynamic characteristics of the main network, and it does not take into account the accuracy of the stability analysis of a small number of small hydropower units within a regional power grid.

In this paper, by establishing a detailed model of grid-connected power stations of 35kV and below in a reginal power grid, the simulation and comparative analysis of the dynamic stability and transient stability of the regional power grid before and after modeling are carried out. The results show that in the regional power grids with multiple small hydropower units, there are internal oscillation mode of the regional power grid and regional oscillation mode with small motor groups that are not reflected by the equivalent. The research results of this paper have certain reference significance for the actual power system stability analysis of engineering.

2.Modeling and calculation standards

2.1. Detailed modeling of 35kV power grid

Detailed models are used for all 35kV grid-connected units in the regional grid. Governor model GH, excitation model FV/F+, PSS model SI/SI+/SP, generator model M/MF.

The "Motor Saturation Factor at Rated Voltage" and "Motor Saturation Factor at 1.2x Rated Voltage" in the generator model's MF card are filled in typical values. Fill in the kinetic energy of the generator:

(1) The T_J parameter in the reported data is calculated according to formula (1) to obtain the kinetic energy of the generator.

$$E_{MWS} = \frac{T_J}{2} S_{N\_GEN} \tag{1}$$

(2) There is no T_J parameter. If a power station is split into N equal capacity units, the generator kinetic energy is filled in by the original 1/N.

(3) There is no T_J parameter. Approximate T_J value is 6(Reference book: turbine rotor time constant is 4~8; governor parameter modeling test experience value:1~10MW turbine group, value

4.2~4.5; considering T_J influence on the dynamic stability ,leaving a certain degree of predetermination, value 6).

In the GH card of the governor model, the R adjustment coefficient is filled 4%, the manual dead zone of 20MW or more for a single machine is filled in as 0.001(the value of the standard), and the dead zone below 20MW is filled in as 0.002(the value of the standard). The remaining paraments are filled in according to typical parameters.

Photovoltaic power generation model is updated to PV, BC, BC+ model.

2.2. Stable calculation of relay electrical protection and safety automatic device action time

According to the requirements of the《Guidelines for the Analysis and Analysis of Safety and Stability of China Southern Power Grid》, combined with the actual situation of the regional power grid, the operational time regulation for the stable calculation of relay protection and automatic device are shown in Table 1.

Table 1 Operating times of protection relays and automation devices.

Line fault type	Fault removal time (s)		Reclosing time (s)	Coincidence of trip time after fault (s)
	Proximal	remote		
Three-phase short circuit of 220kV line	0.12	0.12		
Single-phase short circuit of 110kV line (optical fiber differential protection)	0.12	0.12	1.2	-
Single-phase short circuit of 110kV line (distance protection)	-	-	2	-
110kV a line	0.65	0.65	2	-
110kV b line	0.6	0.6	2	-
110kV c line	0.65	0.65	2	-
110kV d line	0.4	0.4	2	-
110kV e line	0.3	0.3	2	-
110kV f line	0.6	0.6	2	-
110kV g line	0.3	0.3	2	-
110kV h line	0.65	0.65	2	-
110kV i line	0.3	0.3	2	-

In the calculation process, considering the 110kV single-phase transient and 220kV three-phase permanent fault. Due to the different 110kV line protection configuration of the power grid in the region, the fault is set according to the specific conditions of the protection: 110kV line configured the fiber-based differential protection as the main protection adopts the fault removal time of 0.12s and the reclosing time of 1.2s; 110kV line configured the distance protection as the main protection adopts that the distance Ⅱ section action time is the fault removal time(mainly considering the distance Ⅱ section protection line length), and the fault removal time is set according to the distance of the specific line distance Ⅱ section setting time + circuit breaker trip time. The fault removal time is the same at the near end and the far end (Due to the distance Ⅰ fault removal time is short and consider the most

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serious situation, the actual fault end is set to be consistent), unified use of reclosing time 2s.

2.3. Stability criterion

According to the《Guidelines for the Analysis and Analysis of Safety and Stability of China Southern Power Grid》, the specific requirements are as follows.

(1) Transient stability: After the system failure, the relative angle rocking curve of any two units in the same system is synchronously decreasing oscillation.

(2) Dynamic stability: If any component in the system fails, the protection and the switch operate correctly. The damping ratio of the oscillation mode related to the small and medium power station group in the system is not less than 3.0%, and the system damping ratio is not less than 4.5% when the system disturbance is small.

2.4. Calculation boundary

Hydropower is as full as possible: the hydropower units of the regional power grid are fully loaded according to the installed capacity.

The ultimate method of abundance: the maximum load limit mode of the abundance according to the stability limit of the section.

Calculate according to the way that hydropower is as full as possible, and check according to the ultimate method of abundance.

3.Dynamic stability analysis results

3.1. Hydropower is as full as possible

In the case where multiple small hydropower units are equivalent in the area, there is an oscillation mode inside the grid. The oscillation mode has an oscillation frequency of 1.342 Hz and a damping ratio of 5.5% (Oscillation mode with damping less than 7%).

Tab. 2 Participation factors and eigenvectors of relevant generators in different system oscillation modes of area A when small hydros are taken as several equivalents

Power plant's name	Right mode value	Right angle	Participation factor
A	0.16	0.00	1.00
B	0.12	12.33	0.56
C	0.14	11.30	0.46
D	0.13	-1.06	0.40
E	0.09	156.45	0.21
F	0.04	148.60	0.07
G	0.04	148.60	0.07
H	0.03	178.87	0.04

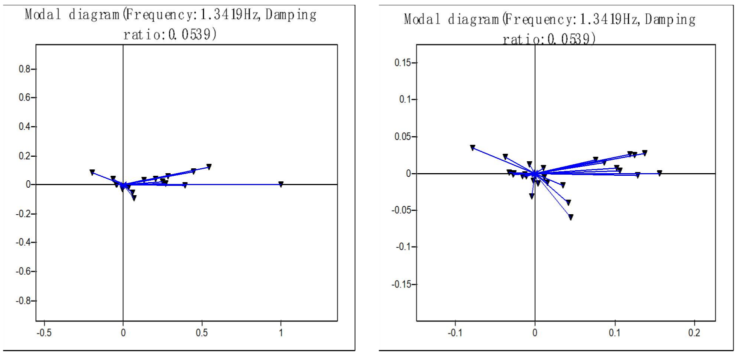
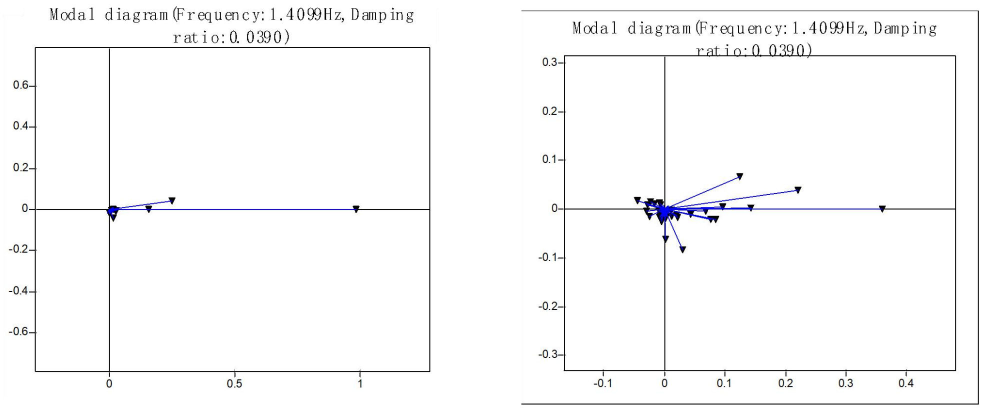


Figure 1. Plots of participation factors and right eigenvectors in different system oscillation modes of area A when small hydros are taken as several equivalents.

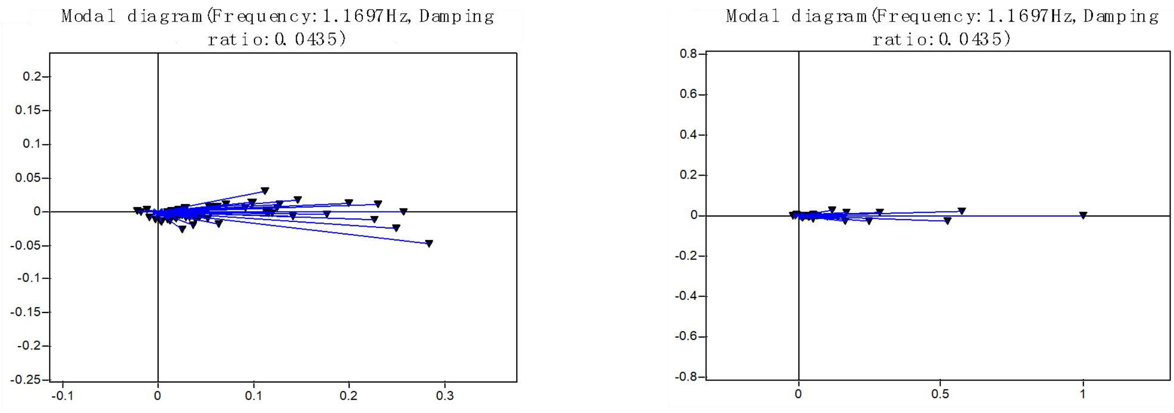
The small disturbance analysis results of the oscillation mode of the hydropower in the full-scale mode of the grid after detailed modeling of the 35kV grid are shown in Table 3. Only the oscillation modes with a damping ratio 7% or less are listed in the Table 3. Each oscillation mode participation factor modal diagram and the right eigenvector modal diagram are shown in Figure 2.

Table 3. Results of small disturbance analyzation in different system oscillation modes when small hyrdos are at their maximum power output.

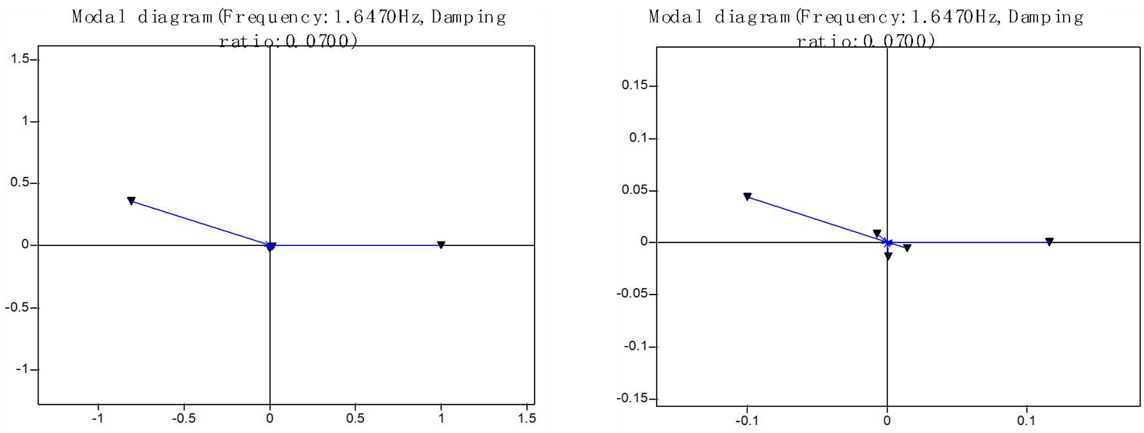
Serial number	Real	Imaginary	Frequency (Hz)	Damping ratio (%)	Oscillation mode
1	-0.346	8.859	1.410	3.9	Mode 1
2	-0.320	7.350	1.170	4.3	Mode 2
3	-0.492	10.016	1.594	4.9	Mode 3
4	-0.726	10.349	1.647	7.0	Mode 4
5	-0.749	10.526	1.675	7.0	Mode 5



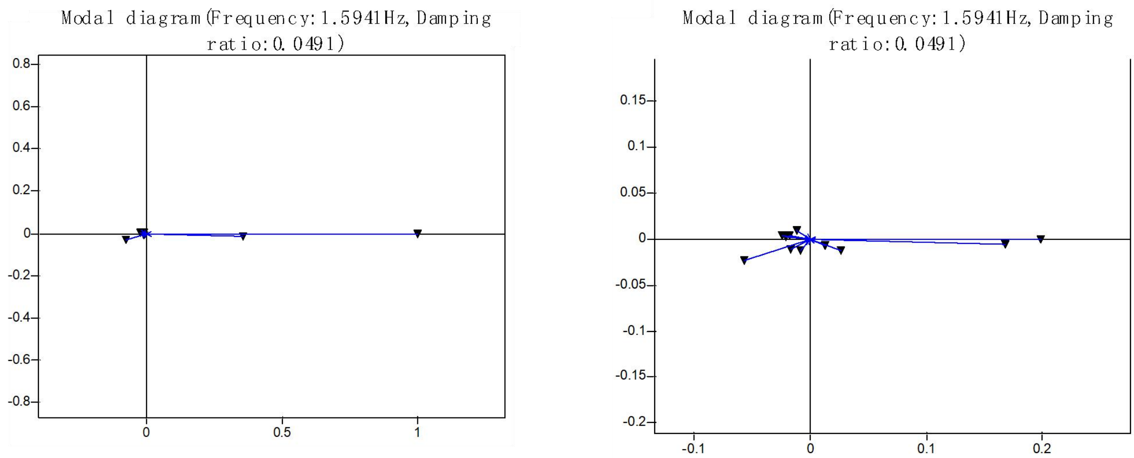
(a) Mode one



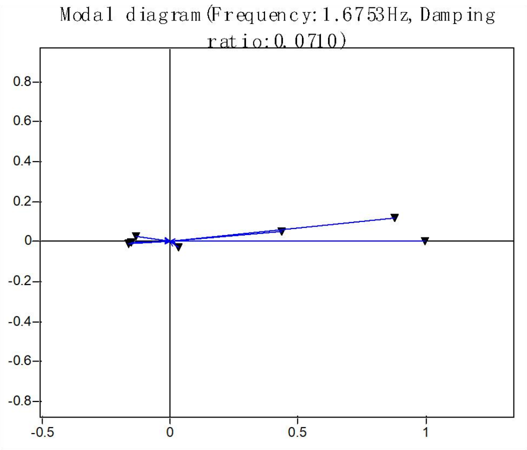
(b) Mode two

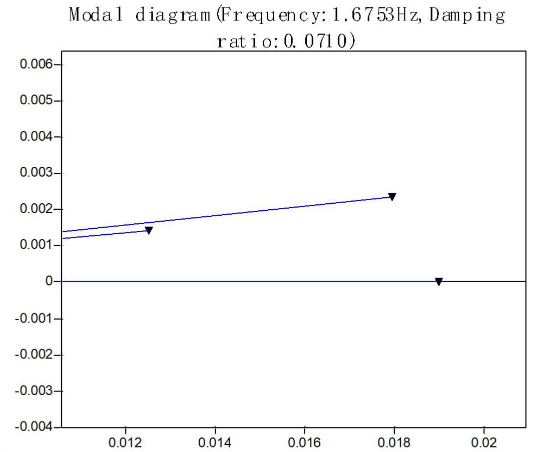


(c) Mode three



(d) Mode four





(e) Mode five

Figure 2. Plots of participation factors and right eigenvectors in different system oscillation modes after building a more accurate mode.

It can be seen from Table 2 that the units with large participation factors in the oscillation mode have A、B、C、D、E、F and so on. The oscillation mode participation factor modal diagram and the right eigenvector modal diagram are shown in Figure 1.

In the full-water mode of hydropower, the 35kV power grid in the region is modeled in detail and compared with the oscillation modes of multiple small hydropower groups. The comparison results are as follows:

(1) There is no 1.342 Hz oscillation mode in detailed model.

(2) Other new oscillation modes appear. After the detailed modeling of the 35kV power grid in the region, mode 1 and mode 2 (the main participating units are C、I、J)and mode 3 , mode 5.

(3) Damping ratio reduction. Before the model of the 35kV power grid in the region, the oscillation mode damping ratio associated with the grid unit was greater than 4.5%, which satisfies the stability standard of the southern grid. However, after the model of the 35kV grid in the region, the oscillation mode with damping ratio less than 4.5% appeared. The model 1 damping ratio is 3.9%. There is an oscillation mode between the regions, which has a damping ratio of 4.3%.

The preliminary analysis produces the above three results for:

(1) Units A, B, C, D, E, F and son on, were split, and the 1.342Hz oscillation mode mainly participated by these equivalent units disappears.

(2) The detailed modeling of the 35kV grid-connected unit has appeared to be accurate to the oscillation mode of each unit. For example, mode 1, it is mainly involved in K, L, M, N power plants. Before the 35kV grid is detailed modeled, the M and N stations are equivalent in O, and the K and N stations are equivalent in P. After the detailed modeling of the 35kV grid, the oscillation mode between the split single units is highlighted.

(3) Compared with the model after the detailed modeling of the 35kV grid, the single unit capacity decreased, and most of the small units were not equipped with PSS, and the damping showed a downward trend.

3.2. The ultimate method of abundance

Under the ultimate method of abundance, after detailed modeling of the 35kV power grid in the region, the oscillation modes of the units participating in the area are shown in Table 4. Only the oscillation modes with a damping ratio of less than 8% are listed in the table.

Table 4. Results of small disturbance analyzation in different system oscillation modes when the system is operating under the limit of high flow period.

Serial number	Real	Imaginary	Frequency (Hz)	Damping ratio (%)	Oscillation mode
1	-0.379	8.859	1.410	4.3	Mode one
2	-0.440	7.085	1.128	6.2	Mode two
3	-0.536	9.946	1.583	5.4	Mode three
4	-0.739	10.298	1.639	7.2	Mode four
5	-0.748	10.518	1.674	7.1	Mode five

Consistent with the conclusion of the full-scale hydropower system, under the ultimate method of abundance, the comparison of the oscillation mode of the 35kV power grid in the region with the equivalent mode has the following three results:

(1) The original 1.342Hz oscillation mode disappears.

(2) Other new oscillation modes appear.

(3) Damping is reduced, and the oscillation mode 1 does not meet the dynamic statbility standard of southern power grid.

4.Transient stability analysis

The transient stability of the grid in this area mainly analyzes the stability of the power angle of the three-phase fault in 220kV line and the single-phase fault in 110kV line (protective correct action), which is consistent with the conclusions of the detailed modeling of the 35kV power grid. Under the ultimate method of abundance and the full power of the hydropower, the power angle can maintain stability.

5.Conclusion

In this paper, the dynamic and transient stability analysis of region power grid before and after the equivalent of several hydropower units in a certain area of Yunnan are analyzed. The results show that the conclusions on the transient stability of multiple small hydropower groups before and after equivalence are consistent; the dynamic stability difference is large, and the oscillation mode inside the regional power grid cannot be highlighted after the equivalence, especially the oscillation before the equivalent small hydropower units, and the oscillation mode between the regions cannot be obtained. The conclusions of this paper have certain warning significance for the stability analysis of power system with multiple small water machine groups.

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