

## Analysis of large-scale wind farm operating in transient process

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**Abstract.** The wind power generation capacity of Ganshu grid has exceeded water power and rank the second energy. For the grid, the burden of stable and safe operation caused by wind power increases consequently. Through the testing and transforming the ability of low voltage ride-through for wind turbine, and regulate the operation of SVC, the ability of stable and safe operation .The ability of stable operation under turbulence has been largely enhanced. In order to test the anti-turbulence ability of wind farm, the artificial short circuit test has been taken in Jiuquan area, and the closest real means to test has been taken,too.

### Introduction

In the recent years, the wind power in our country has developed rapidly. Take Ganshu, by the end of 2012, the wind turbine capacity in the whole province grid-connected operation has exceeded 6300MW, account for 21% of the total wind turbine capacity, most of which concentrated in the Jiuquan area. Jiuquan wind power base is established in Ganshu grid terminal, far from the main system and loading center, and relative weak in its net structure. Moreover,because the short circuit characteristic of wind turbines is far different from that of normal hydroelectric and thermal power unit, so large scale grid-connected operation would cause obvious problems of grid stability.Nowadays , there are many researches on the grid-connected operation acceptability, affect on the system reactive sand power quality, wind turbines'influence on distribution net protection,low powe-through problems. But most of the researches on the characteristics of large-scale wind farm, short circuit focus on theory research, emulation analysis and so on. Through data collection and sorting of 330kv Qiaowan collection station line artificial short circuit testing , this paper has analyzed the stable operation ability of wind farm when it suffers huge turbulence,besides , two times crossing ,crossing ability under high voltage and response ability of SVC have also been analyzed in this paper.

### Introduction of Experiment

#### Experiment System.

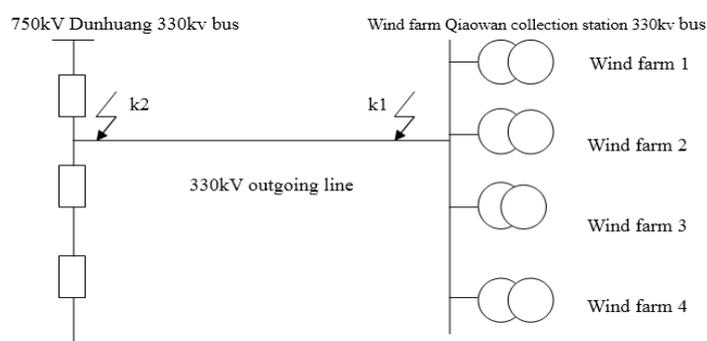


Figure1 Experiment system

As figure1, 330kV wind farm Qiaowan collection works for four huge wind farm,with the total installed gross capacity of 600MW. Each wind farm was accessible to 330kv bus through each own

main transformer(330kv/35kv), and sent to 330kv system of 750kv Dunhuang substation through one 330kV outgoing line. This test was taken on the second wind farm in Qiaowan.

**Testing content.** This paper concerns two artificial short circuit tests, Firstly, the k1 point A of 330kv outgoing line collection station are grounded immediately, the line successfully connects after tripping .Secondly, the K2 point C beside 330kV outgoing line 750kV substation permanently grounded, the line trips, getting connected and then tripping again. This paper has analyzed on the transient process of wind turbine and SVC.

**Transient grounded fault happened to (k1) A phase beside 330kV outgoing line collection station**

A phase beside 330kV line Qiaowan get grounded immediately, after protection,getting rid of A phase, the line auto-reclose successfully after delay.

**Busvoltage variation.** Table1 shows the voltage variation of 750kv Dunhuang substation ,330kv bus voltage, Qiaowan colletion station before and after testing.

Table1 Single phase immediately earthing fault busbar voltage variation

Substation	Voltage	Before Testing	The lowest (phase)		Failure after removal of the highest line voltage
			Faule phase)	Non-fault Phase	
750kV Substation	750 kV	774	362	413	801
	330kV	353	149	182	372
Wind farm collection	330kV	356	8	58	389

**Wind farm SVC transient adjustment.**

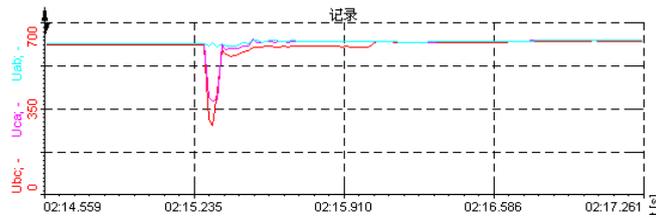


Figure2. Wind farm SVC transient adjustment

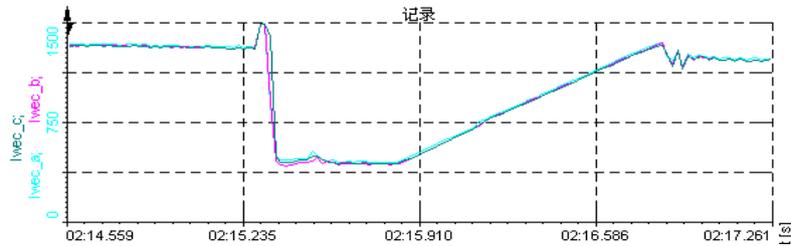
(UAB:: 35kV busbar voltage, UsAB: 330kV busbar voltage, IA SVC current, Q: SVC reactive power)

Shown as figure 2, when 330kv outgoing line is grounded, 330kVbusbar voltage sags. SVC changes with fast and correct operating , and intervene into the support and adjust of busbar voltage, its response time is about 18ms. About 75ms later, the fault is cut off, 330kv busbar voltage recovers, SVC operates with the state before the fault.

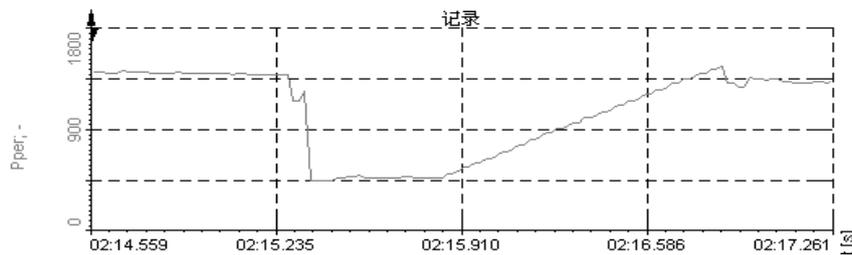
**Testing of wind turbines of Qiaowan second wind farm.** Qiaowan second wind farm adopt the directly driven unit, the unit capacity is 1500Kw, and with the outgoing voltage of 620V.



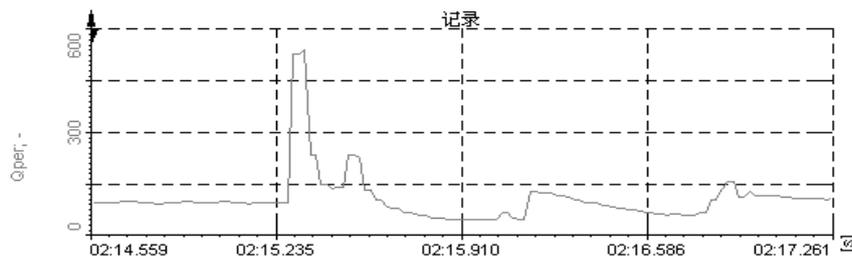
(a) Single phase immediately fault wind turbine outgoing voltage variation curve



(b) Single phase immediately fault wind turbine outgoing current variation curve



(c) single-phase immediately fault wind turbine outgoing active power variation curve



(d) single phase immediately fault wind turbine outgoing reactive power variation curve

Figure 3 Single phase immediately fault wind turbine outgoing electrical parameters

As figure3, when A phase instantaneously earths occurs to the system, the terminal voltage  $U_{bc}$  of wind turbine generator low down to 279V from 608V, the terminal electric current rise to the highest 1320A from 1902A. After troubleshooting the current lowed down to 421A. The active power lows down to 1144KW from 1380kW. After troubleshooting, it reduces to 431kw. After fault, The reactive power rises to 523kVar, after troubleshooting it reduces to 131 kVar.

### Permanent fault of C phase beside 330kv Dunqiao wan

**Busbar voltage variation.** 750kV busbar voltage of Dunhuang substation, 330kv busbar voltage, Qiaowan Dun 750kv busbar voltage variation before and after the test are shown as follows.

Table2. Single phase permanently earthing fault buabar voltage variation

Wind farm	voltage	Before testing(phase)	The lowest ( phase )		The highest ( phase )
			Fault phase (Cphase)	Non fault phase	
Dunhuang substation	750 kV	447	134	374	477
	330kV	204	3	154	217
Qiaowan subatation	330kV	205	0	0	278

**SVC operation.**

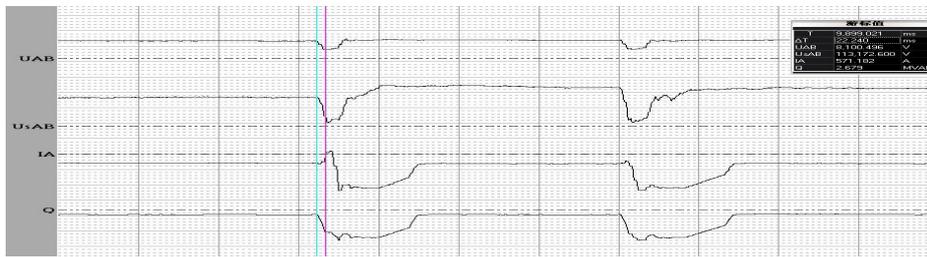


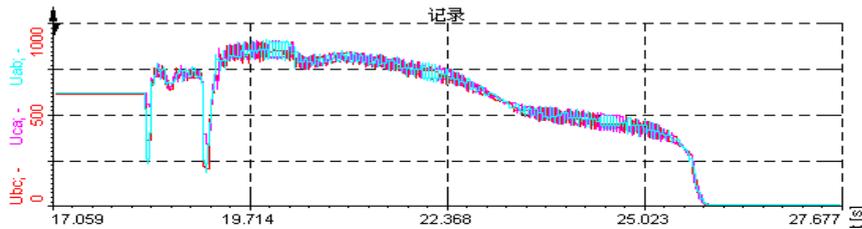
Figure4. Wind farm SVC reactive compensation setting adjustment

(UAB:35kV busbar voltage, UsAB:330kV busbar voltage, IA svc current, Q SVC reactive power)

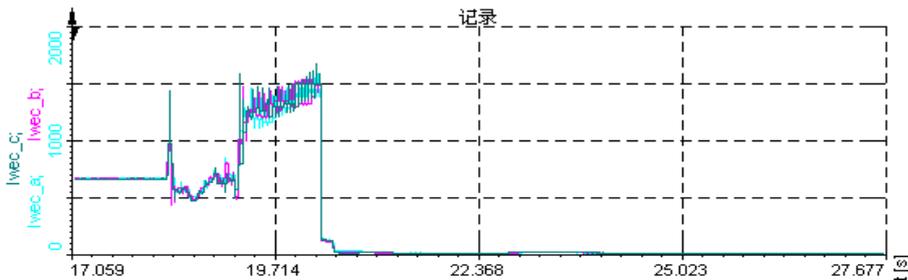
As figure 4, when the line is to earth, 330kV busbar voltage sags, SVC quickly and correctly changes with voltage, and intervene into the support and adjust of busbar voltage, its response time is about 22ms, and the fault is cut off 75ms later, 330kV busbar voltage recovers, SVC reactive power recovers to the original operation state.

When the line reclosing, SVC adjust power quickly support the voltage. When the fault was cut off, 330kv bus recovers its voltage, SVC reactive power remains its original operating state.

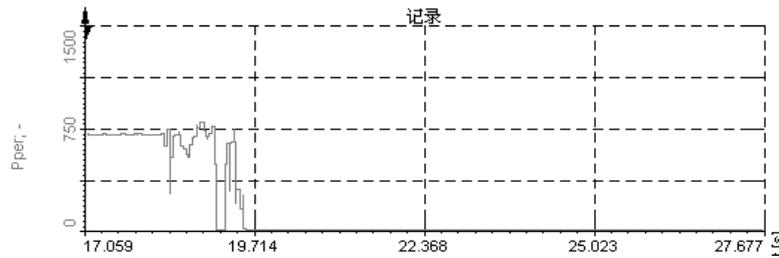
**Test of Qiaowan the second wind turbines on wind farm.**



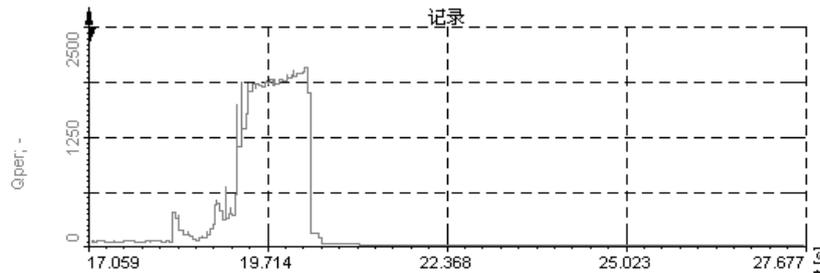
(a)Single phase permanent fault wind turbine outgoing voltage variation curve



(b)Single phase permanent fault wind turbine outgoing current variation curve



(c)Single phase permanent fault wind turbine outgoing active power variation curve



(d)Single phase permanent fault wind turbine outgoing reactive power variation curve

Figure 5 Single-phase permanent fault wind turbines outgoing electrical pre meter

As figure5, after permanent fault occurring to C phase, the wind turbines terminal voltage reduces to the lowest 230V from 611V, the line connects and then trips to the highest 910V, and lows down to 0 after tripping. The terminal current  $I_b$  rises to 1309A FROM 660a, and amounting to the max 1404A after reclosing, when it trips, it lows down to 0. The active power falls from 368kW to 267kW, When the line trips again and falls to 0. The reactive power rises from 54kVar to 388kVar, the line trips again, it rises to 2037kVar, then falls to 0.

In the process of single phase earthing, this unit has relatively obvious reactive support, but in the second crossing, the whole wind farm is off the grid and intensify the busbar voltage dramatically.

### Test result analysis

**Wind turbine reactive power variation analysis when the voltage falls.** Through the wind turbine monitoring, it is found that when the system has earthing fault, the terminal voltage falls, current through the wind turbine increases largely. From the variation curve, it can be found that this current increase mainly provides the reactive outgoing of turbines. Moreover, the larger voltage lowers, the more reactive outgoing, which means that when it is earthing-faulted, the wind turbine reactive outgoing power increases immediately, and support the system voltage. Meanwhile, it increases the overvoltage rate after system recovering to some degree. Especially when the system is permanently faulted, the wind turbine would cross again, the reactive power increases dramatically, and overvoltage will occur to the terminal.

**The static adjustment of SVC in the testing.** In the testing process, it is monitored that the SVC adjustment has right direction, generally, the adjustment starts when the voltage lows down within 5ms, the adjustment degree changes with the voltage variation, which improves the stability of wind farm voltage, and low voltage crossing ability of wind farm.

**Active outgoing power variation analysis when the voltage falls.** The statistics show that most of wind turbines are not off the grid in the testing, but the active power lows down greatly. For example, in the single phase transiently earthing test, the second wind farm in Qiaowan tested wind turbines active power falls to 1144kW from 1380Kw, after the fault is cutting off, it reduces to the lowest 431kW, about 600ms later (amounting to the switch reclosing time), the active power starts to raise slowly. 1S later, the voltage remains nearly 1300kW, which means that when the wind turbines lows down dramatically, the wind turbines regulate the logic steps into low voltage

crossing. At this time, this wind turbine is able to maintain to be on the line, besides, it can provide some supports for system parameter.

## Conclusion

After the testing transform of wind turbines low voltage crossing ability and operation regulation of wind farm SVC in the recent years, the wind farm stable operation ability has improved greatly when there's huge turbulence happening to the wind farm system. In the artificial short circuit testing, most wind turbines are not off the grid because of the low voltage, the wind farm SVC can quickly and correctly trace scheduling and system voltage. To most degree, it guarantees the stable operation of wind farm and the grid.

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