An analysis of the burning accident of the tower bottom cabinet of G58-850KW wind turbine group

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Abstract. In March 2020, an accident happened in a wind farm in Jilin Province, which caused huge economic losses. Based on the investigation of the operation process at the scene of the accident, the burning condition of the equipment and the historical data of the relevant faults, it is found that the cause of this accident was the insulation aging between the low-voltage side turns of the transformer in the power converter cabinet.In the process of opening the main circuit of the equipment, the over-voltage phenomenon of the transformer occurs, which leads to the phenomenon of electric spark explosion.Through the accident analysis, a series of rectification measures are obtained, which will play a reference role for the subsequent maintenance and operation of wind turbines.

1. Introduction
In recent years, with the rapid development of industrial systems in the world, people's demand for resources is increasing. With the increasing depletion of traditional fossil energy reserves and the improvement of environmental protection awareness in various countries. The new energy technology represented by wind power has been rapidly developed, and the installed capacity has grown rapidly. At the same time, it has also accompanied the outstanding failure of unit operation, which has greatly threatened the wind turbine's safe and stable operation[1-2]. Especially in the early-stage wind turbines, the technology is relatively backward, and wind turbines are generally faced with many problems, such as aging of components, replacement and update of components, maintenance difficulties, etc, resulting in the decline of generating capacity and frequent safety accidents[3-4]. In this regard, the major machine manufacturers have also taken a lot of technical transformation measures, however, the means of confidentiality are rarely disclosed. Most of the research on wind turbine technology in universities and research institutions is based on advanced theory and lack of practical case support[5-6]. If there are enough fault solving cases related to the operation of wind turbines as a reference for the maintenance of active duty wind turbines and for theoretical research in scientific research institutions, on the one hand, it can greatly enrich the troubleshooting means of unit faults and improve
the stability of old wind turbines, on the other hand, the research institutions can take more targeted research according to the common problems of the existing wind turbines, and provide more technical means for the wind turbine fault resolution.

2. Accident process and loss
On March 22, 2020, the weather is clear, the site ambient temperature is 10.55 °C, and the average wind speed of the fan is 4.62 m/s. The person A in charge of the work issued a work ticket and team member B went to the wind power site to inspect the control cabinet at the bottom of the wind turbine.

At 15:17, the staff on duty in the central control room stopped the fan and switched to maintenance.

At 15:21, the operator entered the wind turbine tower and heard an abnormal "buzzing" sound in the power inverter distribution cabinet.

At 15:21:46-50, when the operators disconnected FG5 circuit breaker and fg8 circuit breaker in turn according to the safety measures, they heard the explosion sound from the power distribution cabinet of the frequency converter and the arc light generated inside, and then ran out of the tower. About 10 seconds after the first explosion, the converter distribution cabinet makes a second loud noise. The operator shall immediately use the operating rod to disconnect the load switch at the high voltage side of the box transformer.

At 15:23, the operator inspected the converter at the bottom of the tower and found that some components of the converter distribution cabinet were burnt without obvious fire.

At 15:32, the operator used the joystick to pull open the 35kV line drop fuse of the wind turbine, and disengage the fan from its line.

After preliminary inspection, some parts of the fan converter distribution cabinet were burnt, and the specific losses are shown in Table 1 below.

| Name of spare parts     | Number | Unit Price (RMB) | sum of money (RMB) |
|-------------------------|--------|------------------|--------------------|
| Transformer             | 1      | 12182.9          | 12182.9            |
| AC contactor            | 1      | 8987.01          | 8987.01            |
| FG8 breaker             | 1      | 10092            | 10092              |
| Air switch              | 2      | 1813             | 3626               |
| F400 Wave filter        | 1      | 3914             | 3914               |
| Molded case circuit breaker | 1  | 3521             | 3521               |
| Current transformer     | 6      | 584.06           | 3504.36            |

The economic loss of the device caused by the accident is as high as more than 40,000 yuan, which does not include the loss of power during the shutdown and subsequent manual repair costs.

3. Wind turbine main circuit diagram and fault record data
The fired G58-850KW doubly fed generator set was installed in December 2007 and has been in safe operation for 12 years. The wind turbine has 9 failures in 2019, no failures in 2020 and no similar situation in two years. Because the wind turbine was in a maintenance state when there was a failure, various operating data were not abnormal, and other types of units installed during the same period did not have such an accident, so the accident was judged to be a single incident.

By referring to the wind turbine drawing, the electrical schematic diagram of the main circuit is drawn as shown in Figure 1 below.
The data records before and after the accident are extracted, as shown in Table 2 after deletion.

| Time    | Wind speed | Grid frequency (HZ) | Grid-side voltage (V) | Grid-side current (A) | Generator speed (RPM) | Pitch angle setting value | Total active power (KW) | Bus voltage (V) |
|---------|------------|---------------------|-----------------------|-----------------------|------------------------|--------------------------|------------------------|----------------|
| 15:21:42| 4.75       | 49.98               | 681.06                | 0.3                   | 5.6                    | 83.01                    | -2.56                  | 804.83         |
| 15:21:43| 4.74       | 49.98               | 681.01                | 0.3                   | 5.6                    | 83.01                    | -2.56                  | 804.73         |
| 15:21:44| 4.74       | 49.97               | 680.97                | 0.3                   | 5.6                    | 83.01                    | -2.56                  | 804.64         |
| 15:21:45| 4.73       | 49.97               | 680.92                | 0.3                   | 4.67                   | 83.01                    | -2.56                  | 804.54         |
| 15:21:46| 4.72       | 49.96               | 680.67                | 0.2                   | 3.73                   | 86.5                     | -1.47                  | 792.99         |
| 15:21:47| 4.72       | 49.95               | 680.42                | 0.1                   | 2.8                    | 90                       | -0.37                  | 781.44         |
| 15:21:48| 4.75       | 49.95               | 680.18                | 0.1                   | 0.93                   | 90                       | -0.37                  | 746.25         |
| 15:21:49| 4.73       | 49.95               | 340.27                | 0.1                   | 0.93                   | 90                       | -0.37                  | 739.42         |
| 15:21:50| 4.72       | 0                   | 0.37                  | 0.1                   | 0                      | 90                       | 0                      | 732.6          |
| 15:21:51| 4.67       | 0                   | 0.37                  | 0.1                   | 0                      | 90                       | 0                      | 718.94         |
| 15:21:52| 4.62       | 0                   | 0.37                  | 0.1                   | 0                      | 90                       | 0                      | 705.29         |
| 15:21:53| 4.62       | 0                   | 0.37                  | 0.1                   | 0                      | 90                       | 0                      | 705.29         |
| 15:21:54| 4.62       | 0                   | 0.37                  | 0.1                   | 0                      | 90                       | 0                      | 705.29         |
| 15:21:55| 4.62       | 0                   | 0.37                  | 0.1                   | 0                      | 90                       | 0                      | 705.29         |

As can be seen from Table 2 above, before 15:21:46, the wind turbine was in a maintenance shutdown state, and the wind turbine operation data was normal. At 15:21:46, the G5 circuit breaker in Figure 1 was opened, the converter power supply was disconnected, and the bus voltage began to drop. When the FG8 circuit breaker is opened at 15:21:50, the grid side line of the generator stator is disconnected and the grid side current is 0. Then the wind turbine failed at 15:21:52, and the recorded fan data will not change. From the above data, it can be known that the wind turbine is in the normal operating range before the FG5 circuit breaker and FG8 circuit breaker are opened in sequence, and there is no failure phenomenon. The communication failure of the wind turbine occurred after about 2s, so it can be determined that the bottom cabinet was burnt out due to this operation.

4. Accident cause analysis
Through field inspection, it was found that the FD1 switch on the low-voltage side of the TT2 transformer tripped, the FG 2 on the high-voltage side did not trip, and the fuses on the low-voltage
side A and C of the 35KV box were blown. The TT2 transformer was severely damaged. The detailed damage is shown in Figures 2 ~ 5 below.

Figure 2 shows the damage effect caused by the short circuit explosion of the TT2 transformer. It can be seen that the silicon steel sheet of the transformer is cracked and deformed, and some of the transformer's windings are fused and bead is generated, accompanied by spraying. Figure 3 is the position of the wire nose under the TT2 transformer and FG8, It can be seen that the wire nose under FG8 has a melting phenomenon; Figure 4 is a three-phase bronze medal burnout effect diagram under FG8, in which phases A and C are more serious. Figure 5 shows the breakdown of the bronze medal A and C backplane under FG8.

![Figure 2. TT2 transformer damage effect chart](image)

![Figure 3. Location of the wire nose under the TT2 transformer and FG8](image)

![Figure 4. Three-phase bronze medal burnout under FG8](image)
According to the Gamesa G58-850kW wind turbine control electrical circuit diagram, and combined with the actual site inspection, the following analysis conclusions can be drawn.

The TT2 transformer (220V power supply transformer 690/230V in the nacelle) of the tower bottom converter has an abnormal “humming” sound due to the aging of the interturn insulation. When the operator disconnects FG5 and FG8, a "opening occurs" The "voltage" phenomenon has an impact on the 690V bus, which causes the voltage on the low-voltage side of the TT2 transformer to rise, causing insulation breakdown. The high-temperature gas and arc generated by the short circuit blast the external insulation layer of the transformer, causing the first explosion sound.

Because the short-circuit point of the TT2 transformer is directly facing the copper bar under the main circuit breaker FG8 (the low-voltage side of the box transformer to the connection between the unit's main cable and the copper bar), the arc, high-temperature gas and melt generated by the short circuit of the TT2 transformer cause the copper bar A under the FG8, C, and backplane discharge and phase-to-phase discharge (A, C copper bars are significantly closer to the backplane than B), a second explosion occurred, causing the fuses on the low voltage side of the box transformer to fuse A and C (800A).

5. Conclusion

Through the analysis of the accident, it can be seen that the cause of the accident is the aging of insulation on the low-voltage side of the transformer inside the converter distribution cabinet. When the circuit breaker is disconnected, the over-voltage impact on the line where the transformer is located will cause the fire phenomenon and lead to the expansion of the accident. Through this accident, the following preventive measures can be obtained for the unit early warning in the future.

1) Regular maintenance, especially insulation test, shall be carried out for each operating equipment of the wind turbine;
2) All the baffles of the busbar under fg8 must be installed in place, and interphase insulation baffles shall be installed at the busbar to prevent short circuit;
3) For the equipment with potential safety hazards, it is not allowed to disconnect the circuit breaker on its series line without hesitation. It is necessary to judge whether there are multiple parallel branches, and whether the breaking of the circuit breaker will cause opening overvoltage. If necessary, the general circuit breaker on the convergence bus of multiple branches can be disconnected.

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