Analysis of Equipment Maintenance for Terminal Storage Batteries of the Distribution Network

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Abstract: The passage analyzes maintenance and management plan for terminal storage battery of the distribution network; it analyses causes for increasingly declining of bearing performance for currently applied storage batteries of the distribution network; it proposes and analyzes technological plan for storage battery maintenance, data collection and uploading and collective management and regulation plan for storage batteries.

1. Introduction

Automation construction has been gradually promoted with construction scale gradually expanding yearly since automation construction implementation of the distribution network carried out by the state grid. While storage batteries which guarantee automation control, unattended operation and various automatic terminals still apply traditional Maintenance procedures[1]. It has become major hidden dangers for safe operation as capacity of storage batteries under distribution network operation decreases significantly with insufficient supporting capability. What’s more, it makes the major issue invisible with no grasps for maintenance and management of storage batteries and no data to support. The passage proposes online treatment plans for increasingly declining of storage battery capacity of the distribution network and further analyzes the issue.

2. Performance and Maintenance for Storage Batteries of the Distribution Network

As per requirements of Terminal Technical Specifications for Power Distribution Automation[2] and general technical regulations for material procurement: it should be guaranteed with storage batteries supplying power ①three times opening and closing of the circuit breaker after power off shall be guaranteed and at least eight hours operation for terminals and communication modules shall be maintained; three remote terminals: one closing and opening of the circuit breaker operation shall be guaranteed and at least four hours operation shall be maintained for the power distribution terminals and communication modules; two remote terminals: at least thirty minutes operation for the power distribution terminals and communication modules shall be maintained; ②service life for the plumbic acid storage batteries controlled by valves free from maintenance shall be at least three years.

During actual work, assessment for performance of storage batteries only carries out at equipment testing period and equipment delivery testing period[3] with no assessment for performance of storage batteries after putting into operation. As a result, it is not common for storage batteries of newly procured equipment which satisfy technical requirement while performance of storage batteries fails significantly with technical regulations after one to two years operation. Operation and maintenance for distribution network rely largely on manual inspection and maintenance, which cannot observe decreasing of performance of storage batteries and equipment failures in time. It will lead to protection exiting, tripping of the switch cabinet, failure for remote control, super tripping and other results with failures of the operation power supply of the storage batteries, what’s worse, damage on primary equipment may also be resulted in.

3. Analysis of Failures and Maintenance Methods for Storage Batteries of Distribution Network
Failures of storage batteries may be caused by various reasons, such as exceedingly high/low ambient temperature, long-term under or over charging, long-term float charging, out of service for a long term, over current for float charging, over voltage for float charging and so on. Partial causes can be removed by strict management and working parameters for charging modules, for example issues such as under or over charging, long-term float charging, out of service for a long term, over current for float charging, over voltage for float charging shall be resolved by strict regulation for charging module working index setting, increasing automatic routine charging and discharging and temperature compensation. And influence of exceedingly high or low temperature of the environment can be eased by adding temperature protection measurement at power distribution terminals.

Through analysis of 51 sets (136 pieces) of scrapped storage batteries of the distribution network, severe sulfuration accounts for 68.38% of battery failures, among which imbalance of battery set accounts for 64.71% (severe individual sulfuration is the main cause for imbalance of batteries). Thus, sulfuration is the main factor that causes failures of storage batteries. It shall be discussed further that how to reduce sulfuration and remove sulfuration crystallization to maintain storage batteries within rated capacity and how to notice storage batteries with damaged performance and recover them to original status the soonest time possible. Currently, mature online maintenance equipment cannot be found in the market with only maintenance equipment for storage batteries of only online monitoring or balancing, which possesses limited capability for battery capacity. While some of the methods to rectify storage batteries, such as major current impact, electrolyte filling and other methods need to be conducted offline. Following are two technologies fit for online maintenance:

Online balancing[4]: it is beneficial supplement for ills of the charging machine, which can efficiently resolve the issue of imbalance charging between individual batteries. Through micro computer control, it will perform online balancing control and regulation for individual battery of the storage battery set, making voltage, capacity and internal resistance of each battery balanced to avoid under and over charging and perform supplement charging for batteries with inferior performance to maintain performance of the whole set.

Pulse desulphuration: plumbic acid crystallization with different size will be impacted with continuous pulse current output with specified frequency and range. Resonance will be formed between the pulse and harmonic frequency of lead sulfate crystallization which is crushed and dissolved in the lead sulfate electrolyte that will join the chemical reaction to recover capacity[5]. It is practical for pulse desulphuration to adjust and realize online operation for low voltage and small capacity storage batteries of the distribution network. It is the most practicable methods currently to combine the above-mentioned method with online monitoring, to adjust output parameters of online balance and pulse desulphuration as per dynamic change of storage batteries by establishing dynamic analysis modeling to analyze monitored and collected data, adapting actual condition of dynamic change of batteries.

4. Online Maintenance Device Design for Storage Batteries
We have designed an online maintenance device for terminal storage batteries of the distribution network considering capacity deduction of the storage batteries of the distribution network and the resolution. The device is integrated with online monitoring, dynamic balancing and harmonic pulse through time-sharing control mechanism, forming an organic whole. The device is installed with MODBUS agreement to communicate with the host machine.

Main functions: online monitoring, dynamic balancing, harmonic pulse desulphuration.

4.1 Device Hardware Design
It is applied with micro handling chips as the controlling core to integrate battery online monitoring technology, online balancing technology, online desulphuration excitation technology, data collection and uploading, controlling instruction assignment to realize voltage, current and temperature monitoring of the battery set and individual battery. To satisfy voltage collection and active maintenance output of individual battery of the battery set, collection and output unit is designed to complete voltage collection, balanced charging output and pulse desulphuration output. The amount for collection and output units can be configured as per amount of individual battery of the battery set. Uploading and assignment of controlling instructions of collected data can be achieved through connection of the general data line with multiple collection and output units. Besides, current collection circuit, working temperature collection circuit, municipal power on and off collection circuit shall be set to complete collection for monitored data under battery set working environment and communication unit circuit is set to communicate with the host machine.
As shown in the detailed hardware design:

**Diagram 1: Online Maintenance Device Design for Storage Batteries**

Due to difference of each battery of the battery set, collection and output module for individual battery shall be considered for the equipment design program to realize different outputs. Collection and output module is connected with the central processor through the general data line to receive its instructions and operate as instructed. Isolation voltage will be produced by internal transformer and pulse current will be produced by MOS pipe controlled by MCU. Through this method, collection and output functions can be integrated into one circuit with higher reliability than the relay. Through general line technology and module design, maintenance device for different battery sets suitable for series connection will be formed.

**Diagram 2: Design Theory for Collection and Output Module.**

4.2 Working mechanism of the device
In view of the fact that main functions of the device are both measurement and collection as well as differential output aiming at individual batteries, time sharing controlling mechanism is applied to realize coordination work for different functions. Firstly, data from measurement and collection for individual battery performance shall be summarized to the processor where working status and performance assessment for individual battery will be judged by calculation pattern to realize online monitoring function and dynamic balance, online desulphration output parameters as per calculation modeling to conduct time sharing output for individual battery one by one, realizing circulation working mechanism from monitoring to performance judgement and to positive output maintenance. Considering safety for working and avoiding output disturbance, output pattern shall be set under the condition of float charging and output with voltage a little more than that of float charging and small current.

**Diagram 3: Circulation Working Mechanism**

4.3 *Communication mechanism with the host machine*
MODBUS agreement is applied for communication with the host machine, uploading quantity of states includes municipal power on and off status, working status for storage batteries (charging/discharging/float charging/testing), working temperature, float charging voltage, terminal voltage, current, storage battery capacity, discharging period, power off alarm signal, discharging stopping signal and other information as well as degraded individual battery numbers.

**5. Applicable Design for Harmonic Pulse Desulphuration**
Crystal harmonic frequency is related with size of crystals that the larger size the crystal is, the lower its frequency is and the smaller size the crystal is, the higher its frequency is. Pulse harmonic desulphuration equipment is applied with sweep frequency technology, producing positive pulse peaking to input for the battery sets which generate harmonic effect with sulfate lead crystals. In view of the fact that pulse with steep rising edge contains abundant harmonic which has high amplitude at low frequency area and low amplitude at high frequency area, making large sulfate lead crystal acquire more energy and small sulfate lead crystal receive less energy that large sulfate lead crystal shall be more easy to be crushed than the smaller ones.

Currently, desulphration devices with high frequency harmonic pulse vibration technology are applied in the market, whose high frequency pulse generating circuit are hardware circuit of which pulse frequency and width cannot be adjusted in real time with storage battery status for desulphration so that the circuit will be working with fixed frequency and width regardless of status of storage batteries and optimal desulphration can not be achieved especially under the condition of inferior storage battery balance degree. With one damaged battery of four storage batteries being modified online, the voltage of the damaged one will increase rapidly with external charging being performed since total voltage of four storage batteries are fixed that a virtual voltage with less current will be formed which will stop absorbing of modification energy, resulting unsatisfied storage battery modification effect.

The design and modification of this program can be performed through building controlling model that the central processor will control output parameters of all collection and output units to adjust desulphration pulse frequency and pulse width automatically, realizing real time intelligent management. What’s more, calculation modeling control also realizes fixation for frequency pulse, sweep pulse, combination pulse and other working patterns, to adapt maintenance requirement for storage batteries of different specifications and status.
6. Assessment of Working Performance Measurement
To verify actual working efficiency of the designed equipment, contrast tests for terminals of power distribution in operation have been conducted under actual operating environment.

6.1 Practical operating environment tests
Actual operating environment for ring main units will be selected as the tested environment. Stations with storage battery sets after operating for 1-2 years and 2-3 battery sets with the same specification shall be selected as samples to confirm typicality and validity of tested samples. Basic data for tested samples indicates as table 1.

| Serial No. | Site name                  | Nominal capacity | Battery unit configuration | Operating years |
|------------|----------------------------|-----------------|---------------------------|----------------|
| 1          | Chengjian ring main unit   | 18AH            | 12V*2 pieces              | 1 Year         |
| 2          | Jiarui A ring main unit    | 18AH            | 12V*2 pieces              | 1 Years        |
| 3          | Jiarui B ring main unit    | 18AH            | 12V*2 pieces              | 2 Years        |
| 4          | Jiarui C ring main unit    | 18AH            | 12V*2 pieces              | 2 Years        |
| 5          | Jiuhua ring main unit      | 20AH            | 12V*2 pieces              | 1 Year         |
| 6          | Ouge ring main unit        | 20AH            | 12V*2 pieces              | 2 Years        |
| 7          | Huabin 01 ring main unit   | 12AH            | 12V*2 pieces              | 1 Year         |
| 8          | Huabin 02 ring main unit   | 12AH            | 12V*2 pieces              | 1 Year         |
| 9          | Huagong FTU                | 12AH            | 12V*2 pieces              | 2 Years        |
| 10         | Huajie ring main unit      | 12AH            | 12V*2 pieces              | 2 Years        |
| 11         | Haishi ring main unit      | 17AH            | 12V*2 pieces              | 1 Year         |
| 12         | Guanyin ring main unit     | 17AH            | 12V*2 pieces              | 2 Year         |
| 13         | Coupling 33 Switch         | 7.2AH           | 12V*2 pieces              | 1 Year         |
| 14         | Coupling 32 switch         | 7.2AH           | 12V*2 pieces              | 1 Year         |
| 15         | Stone 1503 switch          | 7.2AH           | 12V*2 pieces              | 2 Years        |
| 16         | Coupling 004 switch        | 7.2AH           | 12V*2 pieces              | 2 Years        |
| 17         | Stone 1401 switch          | 7.2AH           | 12V*2 pieces              | 2 Years        |

6.2 Testing methods
Choose 17 sets terminal batteries as testing samples for distribution power and conduct twice full capacity discharging tests before and after installation of the online maintenance equipment for storage batteries to contrast performance promotion function for storage battery sets. The equipment will be operated for one month and the primary and secondary tests will apply the same testing methods and parameters.

Parameters for full capacity discharging tests are set as following:
1) Charging current: 0.1C (A)
2) Charging capacity: nominal capacity (AH)
3) Expiration terminal voltage: 21.6V;
4) Expiration individual terminal voltage: 10.8V;
5) Expiration charging period: 10 hours;
The discharging test can be ended with any of the above-mentioned conditions satisfied.

6.3 Contrast of tested data
Testing data records under actual environment indicate in table 2.

| Serial No. | Site name       | Nominal capacity | Primary testing capacity | Actual capacity ratio | Secondary testing capacity | Actual capacity ratio | Rising capacity ratio |
|------------|-----------------|------------------|--------------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| 1          | Chengjian ring main | 18AH             | 15.4AH                   | 85.6%                 | 17AH                      | 94.4%                 | 8.80%                 |
|   | Unit                        | Capacity (AH) | Percentage | Capacity (AH) | Percentage | Capacity (AH) | Percentage |
|---|----------------------------|---------------|------------|---------------|------------|---------------|------------|
| 2 | Jiarui A ring main unit    | 18AH          | 57.8%      | 13.5AH        | 75.0%      | 17.20%        |
| 3 | Jiarui B ring main unit    | 18AH          | 80.0%      | 15.8AH        | 87.8%      | 7.80%         |
| 4 | Jiarui C ring main unit    | 18AH          | 55.6%      | 15.1AH        | 83.9%      | 28.30%        |
| 5 | Jiuhua ring main unit      | 20AH          | 62.5%      | 17.2AH        | 86.0%      | 23.50%        |
| 6 | Ouge ring main unit        | 20AH          | 41.0%      | 13.9AH        | 69.5%      | 28.50%        |
| 7 | Huabin 01 ring main unit   | 12AH          | 36.7%      | 5.7AH         | 47.5%      | 10.80%        |
| 8 | Huabin 02 ring main unit   | 12AH          | 57.5%      | 7.2AH         | 60.0%      | 2.50%         |
| 9 | Huagong FTU                | 12AH          | 38.3%      | 5.2AH         | 43.3%      | 5.00%         |
| 10| Huajian ring main unit     | 12AH          | 50.0%      | 7.3AH         | 60.8%      | 10.80%        |
| 11| Haishi ring main unit      | 17AH          | 76.5%      | 14.7AH        | 86.5%      | 10.00%        |
| 12| Guanyin ring main unit     | 17AH          | 52.9%      | 14.1AH        | 82.9%      | 30.00%        |
| 13| Coupling 33 switch         | 7.2AH         | 27.8%      | 4.4AH         | 61.1%      | 33.30%        |
| 14| Coupling 32 switch         | 7.2AH         | 41.7%      | 3.9AH         | 54.2%      | 12.50%        |
| 15| Stone 1503 switch          | 7.2AH         | 69.4%      | 6AH           | 83.3%      | 13.90%        |
| 16| Coupling 004 switch        | 7.2AH         | 83.3%      | 6.6AH         | 91.7%      | 8.40%         |
| 17| Stone 1407 switch          | 7.2AH         | 55.6%      | 5.1AH         | 70.8%      | 15.20%        |

### 6.3.1 Analysis of primary testing

The primary test for actual capacity indicates that capacity of 14 tested samples is below 80% (as per GB, capacity lower than 80% can be determined as unqualified). Qualified battery ratio of tested samples is only 17.65%.

### 6.3.2 Analysis of secondary test results

Actual capacity of the secondary test indicates that all actual capacity ratios of tested battery sets have been increased significantly only one month after installation of the online maintenance equipment for storage batteries, among which five sets of capacity ratio of the failed tested batteries in the primary test turn to qualified (>80%). Qualified battery set ratio of the tested samples in the secondary test increases to 47.06%.

It can be concluded from contrast for discharging curve of primary and secondary tests that discharging curves for tested storage batteries after installation of the online maintenance equipment for storage batteries decrease significantly with performance for storage batteries promoted significantly.
6.3.3 Data contrast
Compared with primary testing data of 17 sets ring main unit, data of secondary test one month after installation of online maintenance device for storage batteries indicate that qualified battery unit ratio increases by 29.4%, individual storage battery capacity increases by maximum of 33.30% and average capacity ratio increases by 15.68%.

It can be concluded from above actual tested data that all capacity ratios for storage batteries increase significantly after installation of online maintenance equipment for only one month. Obviously, online maintenance equipment for storage batteries is capable of recovering battery capacity significantly. Through real-time monitoring and immediate modification for storage batteries, normal operation for storage batteries can be better maintained.

7. Conclusion
As per analysis of online maintenance resolution program for terminal storage batteries of power distribution and verification through tests, it can be fully proved feasibility and necessity for online maintenance equipment of storage batteries. It provides new concept for operation and maintenance of terminal storage batteries of the distribution network, enabling precaution management for operation and maintenance of the distribution network to avoid failures caused by failures of storage batteries efficiently, safeguard backup supporting capability and make intelligent power distribution more stable.

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