Systems for supervision of substation batteries

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This article discusses the different existing methods for supervising substation battery connectivity and offers a new technical solution based on the measurement of current which permanently passes from the battery to the bus bar or from the chargers to the battery. The results of assessment of various monitoring systems based on the method are presented.

An auxiliary DC power supply substation system, shown in Fig. 1, includes main and reserve auxiliary transformers, power battery, chargers, DC bus bars, and a distribution cabinet. It is an important substation system upon which the reliability of relay protection, automatic system, control and communication depends. According to [1] disturbances in this system may lead to a full power system failure.

A modern charger provides many different internal protective and signaling systems connected to emergency modes, while battery protection boils down, usually, to using a fuse. At the same time the risk of failure in the contacts between the battery and the bus bar is always present; in the links connecting series separate battery banks; failures in internal structure of the accumulators; failures of the battery due to natural disasters, such as earthquakes etc. It is enough to take into account that a 230 V voltage substation battery contains some 106 separate accumulators, connected together in series by means of more than 200 links, the interruption in any one of which can lead to complete battery malfunction.

Existing methods for supervising substation battery connectivity

The Bender company manufactures a device which can be used for monitoring harmonic levels in the DC network [2]. For a serviceable battery connected to the DC bus bar the harmonics level is very low. It was assumed that the disconnection of the battery from the DC bus bar will dramatically increase the harmonic levels produced by the charger which will cause the output relay in the Bender monitoring device to operate. Unfortunately, the harmonics sum generated by charger is high depending on its output current, i.e. from the external load on the DC bus bar.

More to the point, in reality, modern chargers provided with large filter capacitors with a total capacitance in range of 5000 – 5 000 μF in the output circuit result in a very low harmonics level on the DC bus bar even with a disconnected battery. We conclude from this that using harmonics level as the criterion for monitoring substation battery connectivity is not applicable.

Fig.1: Device BA300 type (Areva) for constant monitoring substation battery impedance, voltage and ground insulation levels.

In [3] a device for supervision of substation battery connectivity based on periodical pulsed increase voltage level on battery terminals and measurement of current pulses passing through battery is described.

In [4] a method for supervising the substation battery connectivity by injection of audio frequency signal into the supervised circuit and measurement of voltage drop on the circuit terminals on this frequency is described.

In [5, 6] various devices for measuring the battery impedance as the criterion for supervision battery circuit connectivity are offered, but in [7] it is shown that the conventional methods for measuring battery impedance are ineffective because of the very low value of the impedance in power substation battery and, therefore, very low value of AC voltage which needs to be measured. Measuring such low values of AC voltages in real substation conditions is problematic, as noted in [7]. Nevertheless, Areva offers a special device: "Battery Alarm 300 [8] that is specifically intended for measuring battery impedance, (Fig. 1). This device in parallel with the battery periodically connects a resistor by means of semiconductor switch for short periods of time (50 μs). The resistor produces a short current pulse with a magnitude of 1 A. This current produces a small voltage drop across the battery terminals, which is used for the calculation the battery impedance.

In so far as battery charger contains large filtering capacitors in its output circuits, it is abundantly clear that the current pulse through the measurement resistor in the BA300 device will be formed not only by battery, but also by the discharging of these filtering capacitors. In connection with this Areva suggests inserting a choke, intended on full charger current, in the output circuit of each charger. From where a consumer obtains such a choke for currents of 30 A or 100 A and how much they will cost, Areva is somewhat reticent. Even so, their device itself is expensive (approx €750).

For the sake of justice it is necessary to note that constantly monitoring the impedance of the battery can reveal not only the fact of a full break of the battery circuit, but also the deterioration of the general condition of this circuit even before its full break.

Besides, the Battery Alarm 300 enables supervising additional parameters of the battery, such as voltage and the ground insulation level. However, for the author, the specific goal is limited only to the supervision of the substation battery connectivity, and for this, the suggested solutions should be the most simple, reliable and inexpensive so that it is possible to use a large number of them to cover all the batteries available in a power system.

Suggested method for supervision substation battery connectivity

In distinction to the complexity (and, consequently costliness) of the known methods for supervising substation battery connectivity, we suggest another method, based on the measurement of current which permanently passes from battery to the bus bar or from chargers to the battery, (Fig. 2), in a typical system. Even a fully charged battery continues to consume a small current (referred to as a "floating current") in a range of about 0,5 – 3 A from the charger, depending on the battery power and condition. Therefore, it is reasonable to consider that if the current in a battery circuit is reduced to a level less than 0,1A, this unequivocally testifies to breakage of this circuit.

It is necessary to pick a controller capable of giving the appropriate output signal when decreasing the current in a supervised circuit falls to lower than 100 mA. The problem with the selection of such a controller consists of firstly, the direction in which the current in a supervised circuit can change when reversing, and secondly, change of value of current in the circuit occurs in very wide limits: from 0,1 A up to 100 A, that is by a factor 1000. Therefore a high-sensitivity controller should be reliably protected from the influence of the high current value and should supervise a current in both directions. According to these requirements we constructed various units and tested some different systems for supervising the DC current in the battery circuit, based on different principles.

Device for supervision battery circuit based on nonlinear shunt

Using a nonlinear shunt allows considerable simplified supervision of current which changes in wide limits. The shunt device employs two back-to-back connected Schottky diodes. Forward voltage drop on one of the diodes (depending on the current direction) varies according to the graph shown in Fig.3.

As can be seen from the graph, due to nonlinear diode characteristic the forward voltage drop varies from 0,2 to 0,65 V, i.e., by a factor of three while the current changed by a factor of 100. This feature of the diodes provides proper protection of sensitive input of the controller at high currents. On the other hand, enough high voltage drops on diodes at small currents reduces the requirement of the sensitivity of the controller. To test this idea, a circuit was put together modeled on the controller shown in Fig. 2, using two standard devices produced by the Israeli Conlab company: DCT-3 and DCM-1. First the insulated transducer with high voltage insulation input circuit from output and also the converter from input voltage ±100 mV into a standard output signal of 4-20 mA was connected to them. Then the controller itself with two programmed relay outputs was connected. The controller operated with input signals varying between 4 to 20 mA. For the two back-to-back connected Schottky diodes, STPS200170TV1, manufacturer by STmicroelectronics were used.

Experimental examination of this system indicated that it was thoroughly passable. The output relay picks up at the reduction of the current in the supervised circuit below 50 – 60 mA and releases at current increases up to 130 – 140 mA. The presence a high hysteresis in this case is a positive feature which increases stability of system operation.

At the same time an important deficiency was noted in connection with high heating of the diodes unit at high currents.

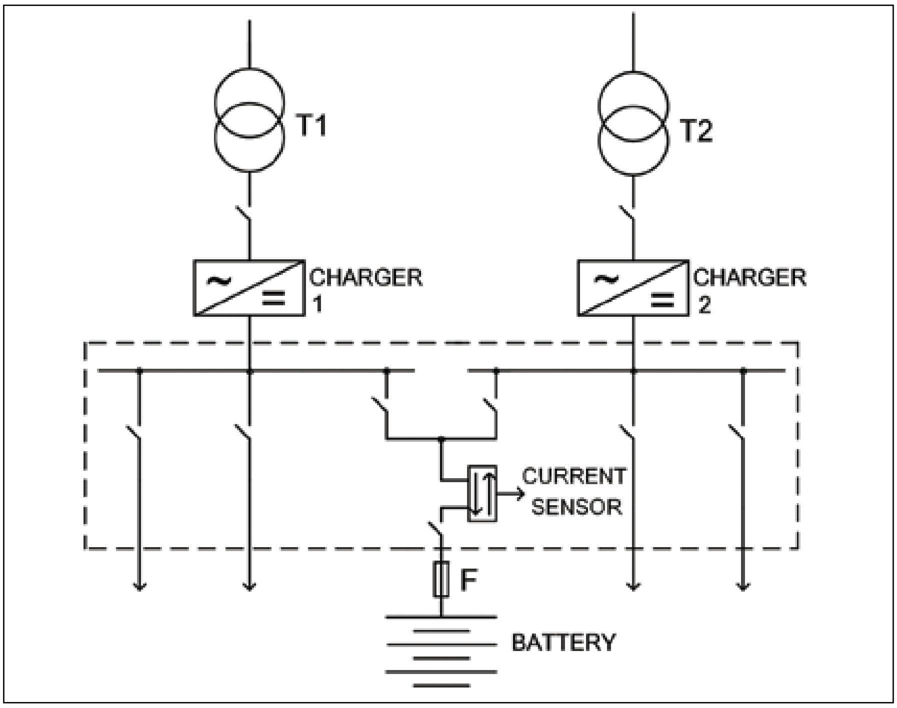

Fig. 2: Typical single-line circuit diagram of substation DC system.

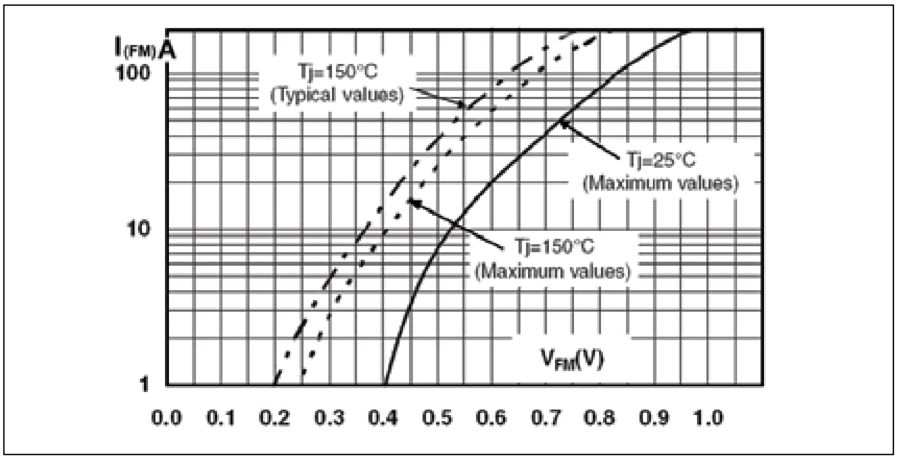

Fig. 3. Dependence forward voltage drops on the Schottky diode STPS200170TV1 type from direct current (for different temperatures of semiconductor structure).

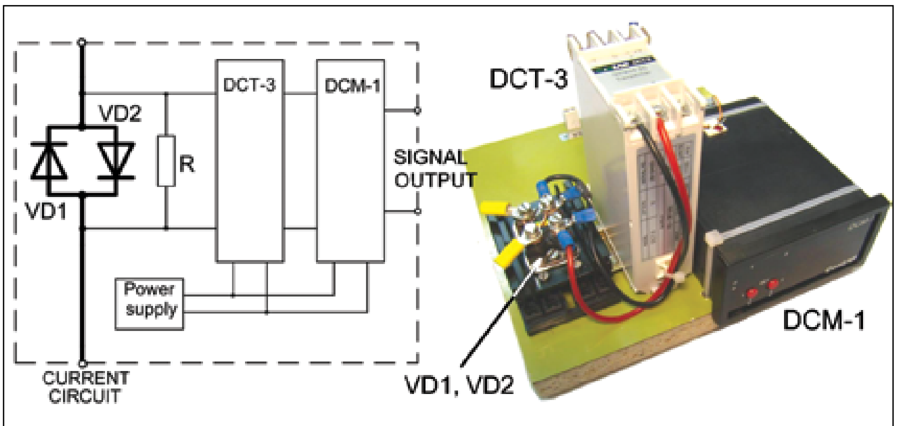

Fig. 4: Model of the system based on nonlinear shunt for supervision battery circuit. DCT-3 and DCM-1 – electronic transducers (Conlab, Israel); VD1-VD2 - unit with back-to-back connected Schottky diodes STPS200170TV1 type (STmicroelectronics)

Installing a small heatsink (Fig. 4) the temperature of the diodes unit achieved about 70°C at 25 A and carried for a period of 15 – 20 min. From this it clear that for operating at currents around 100 A, the diodes unit has to be combined with a large heatsink or a ventilator for forced heatsink blowing has to be used. Another disadvantage of this system is the necessity for using a separate 24 V power supply for feeding the DCT-3 and DCM-1 devices. The cost of this system is about $600.

Using a standard shunt as current sensor

Using a standard linear shunt, for example, 100 A /60 mV or 100 A /100 mV and current pickup level of 0,1 A, the sensitivity of the controller has to be 10 μV (unlike the previous example where the sensitivity of the controller can be as low as hundreds of mV). It is unlikely that a controller available in the market has so high a sensitivity.

At our request, Conlab gave us another system for testing, (Fig. 5) which met the requirements mentioned above for using a standard shunt. During the test this system exhibited the following results: pickup current levels of 60 to 80 mA (through the shunt); release current levels of 120 to 160 mA. The same hysteresis is a positive property of such system because its presence increases the system stability. One of the disadvantages of this system is necessity of using an external 24 V power supply for feeding the transducers. The cost of this system is about $600.

The MSCI-LCD type serial line controller, manufactured by Megatron, Israel, with some slight modifications to meet our requirements appeared as very successful variant and demonstrated very stable operation with high sensitivity. (Fig. 6) This controller practically did not react with the AC component when measuring the input and therefore had a high noise stability, and could feed from the 230 V network.

It was noticed that the controller MSCI-LCD type lacked detecting the polarity of the input signal. In the modified variant of the controller the measuring input is protected against the high voltage applied at high currents carried through the shunt, and also protected against voltage polarity reversals applied to the input during changes of the current direction in the shunt.

A single problem is the necessity of using two identical controllers connected in opposite polarity to the shunt for measuring the currents, proceeding in both directions, and connecting the normally closed contacts of its output relays in series. Thus the output signal will appear only in the case that the current will be lower 0,1 A in both directions. Considering the small cost

Fig. 5: Model of the system based on standard shunt for supervision battery circuit. USD-2 – electronic transducer (input: ±200 μV, output: 4 - 20 mA); DCM-1 – programmed electronic transducer for 4 - 20 mA with relay output (Conlab, Israel).

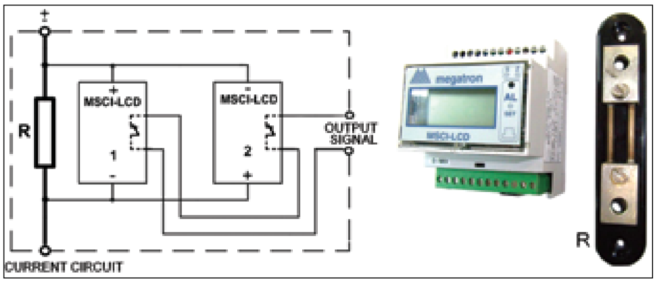

Fig. 6. System for supervision battery circuit based on standard shunt and two universal controllers with relay output MSCI-LCD type (Megatron, Israel)

of single controller (about $130), it turns out that even with two such controllers the total cost is much below that of the second system provided by Conlab.

Usage of the Hall-effect sensor in system for supervision battery circuit

The monitoring systems considered above demand the insertion of additional elements (diodes, shunt) in a power circuit (cable) connecting the battery with DC bus bar. However, there is a variation in which there is no necessity to cut the circuit (cable) and no necessity for inserting additional elements. This variation is based on using a Hall-effect sensor (transducer) in the form of a framework through which the power cable connecting the battery and bus bar is passed (Fig. 7).

Some companies, for example, CR Magnetics [9], have proposed DC current relays with built-in Hall sensors. However, from the answers from the company we received, it seems that such devices cannot provide carrying currents varying between 0,1 A to 100 A and pickups at currents below 0,1 A. We therefore undertook the attempt of developing the current relay of our own design based on separate Hall transducers, such as HAL50-S, manufactured by the Japanese branch of the LEM company and designed for a currents up to 150 A and the AM22D type controller, manufactured Israeli company Amdar Electronics & Controls.

This type of Hall transducer consists of a built-in electronic amplifier and two potentiometers outside for adjusting the amplifier characteristics. The output signal of the transducer is as high as ±4V at nominal current ±50 A. We assumed that such high output signal at nominal current would provide enough high level signal also at current 0,1 A. Unfortunately, even at zero current the output signal level drifted and its instability exceeded the level of the functional output signal at a current of 0,1 A. Thus we would not be successful in receiving the comprehensible signal from such system applicable for use in our supervision system.

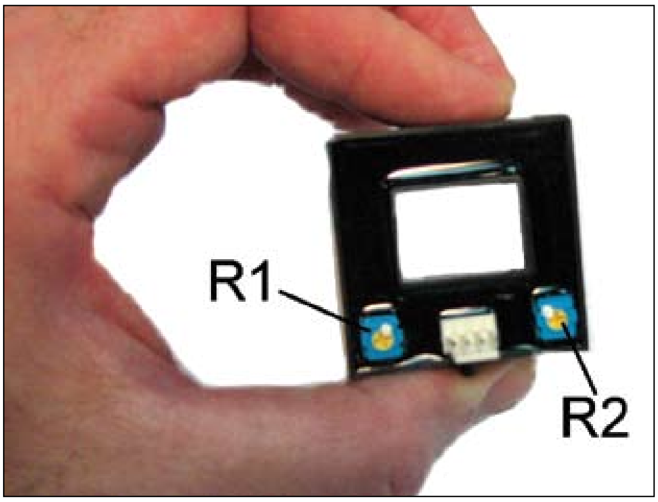

Fig. 7: Hall-effect transducer HAL 50-S type with built-in electronic amplifier for measurement DC current. R1, R2 – potentiometers for amplifier adjusting.

Conclusion

On the basis of a comparative estimation of parameters and test results of the some variations of systems for supervision circuits of the substation battery 230V that were discussed above, we have come to the conclusion that from the standpoint the greatest stability, the greatest reliability and least cost, the system of choice is that based on a standard shunt and two modified MSCI-LCD type controllers, manufactured by Megatron. This is the system that we recommend for wide use in substations and power stations.

References

[1] Skok S., Tesnjak S., and Filipovic M. Risk of Power System Blackout caused by Auxiliary DC Installation Failure. Proceedings of the IASTED International. Conference "PowerCON 2003 - Special Theme: Blackout", New York, December 2003.

[2] Ripple Detector RUG1002Z. Insulation and Voltage Monitoring of DC System RGG804. Operation Manual. Bender GmbH.

[3] Phansalkar B J., Tolakanahalli P. N. Pradeep N. R., Saxena S. K. Method and system for testing battery connectivity. U.S. Pat. 6931332, August 16, 2005.

[4] Russo F. J. High sensitivity battery resistance monitor and method therefore. U.S. Pat. No. 5,969,625, G01R31/36, October 19, 1999.

[5] Wurst J. W., Chester T, Morris C. On-line battery impedance measurement. U.S. Pat. No. 5,281,920, G01R31/36, January 25, 1994.

[6] Burkum M. E., Gabriel C. M. Apparatus and method for measuring battery condition. U. S. Pat. No. 4,697,134, G01R31/36, September 29, 1987.

[7] Kozlowski J.D. A novel online measurement technique for AC impedance of batteries and other electrochemical systems. The Sixteenth Annual Battery Conference on Applications and Advances, 2001.

[8] Battery Alarm 300. User Manual BA300. Areva.

[9] Direct Current Sensing Relay CR5395 Series. Data Sheet. CR Magnetics, Inc.

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