POWER SUPPLY STATION FOR AUXILIARY SERVICES IN PRIMARY SUBSTATIONS

Roberto CALONE
ENEL DIS-IUN – Italy
roberto.calone@enel.com

Giorgio DI LEMBO
ENEL DIS-TRE – Italy
giorgio.dilembo@enel.com

Alessandro FATICA
ENEL DIS-IUN – Italy
alessandro.fatica@enel.com

ABSTRACT
The paper describes a new integrated power supply station for Auxiliary Services (AS) to install in Primary Substation. The new station provides several innovative logic functions to improve the life cycle of the battery. Furthermore, to improve the reliability of device, the new station foreseen a double parallel branch rectifier stage. The costs-benefits analysis shows that the investment return time for each plant in which the new station will be installed is about 5 years.

INTRODUCTION
One of the most critical components in HV/MV transformation plants in Enel Distribuzione is the auxiliary services supply station. All the equipment concerning auxiliary services needs a low voltage supply in order to work; for most of them, as protection, command and remote-control, an absolute continuity of supply is demanded.

Assuring the auxiliary voltage, also in the case of entire plant break down, is one of the primary necessities in order to warrant the activities of all the elements included in a primary substation. Any absence, even temporary, of the auxiliary voltage supply would cause the plant to break down since the transformation machines open immediately. Consequently, the Auxiliary Service (AS) supply is in direct current so that a self-sufficient energy reserve is insured thanks to the accumulators batteries.

HISTORY
In the previous years, the reference technical requirements concerning the realization of supply substation for Power Supply has been deeply modified and, as a consequence, the philosophic approach to the realization of the device itself has changed. There has been a passage from a “double branch” to a “single branch” realization. In fact, the “single branch” realization deletes the switching times in case of an emergency when the supply moves from the network to the battery. The switching times were usually causing the protection and control devices to activate in case of voltage absence.

However, the use of single branch substations in the last years has shown some critical aspects. In particular, an analysis based on the use of app Ma.Re. has shown a high number of interventions in order to repair and/or replace the stations themselves. In brief, the interventions on supply stations turn out to be the most frequent reason for workers to intervene in plants.

In addition, during the analysis, it was determined that the cost incidence related to the batteries’ ordinary maintenance was not a negligible amount of the total cost related to the entire auxiliary services supply system in primary substations.

Finally, the maximum number of elements set up in a battery was limited to 50 for technical reasons. This meant a low battery reliability level since the voltage applied on charges was hardly equal to 100 V when the battery was working.

A NEW APPROACH
In light of what has been shown up to this point, a new technical requirements named DV7078 which takes into account all the above mentioned critical situations has been set up.

The new supply station is conceived as a single branch structure, with an online battery in the AS, but, thanks to the introduction of a voltage regulating stage between the battery and the 110 V charges, the number of accumulators forming the battery has been raised.

In addition, taking into account the problems occurred with the rectifiers, the requirements concerning reliability and safety have been tightened up in order to decrease the fault number.

The introduction of a voltage regulation stage on 110 V allowed the increasing of battery elements number from 50 to 54, referring to a 2 V open vase element.

This change not only assures a wider range of reliability but it also allows the station to be equipped with a wider range of lead acid or VRLA type mono-blocks: 2V, 4V, 6V, 12V. As a consequence any kind of accumulator can be supplied, since they are all compatible with the station and have the same voltage value in the lead out connection (108V).

![Lead Acid, VRLA - GEL, VRLA - AGM](image)

**Figure 1 Different battery elements.**

For any kind of battery it is possible to set and personalize the recharging curve.
FUNCTIONAL ARCHITECTURE

The machine is made up of two parallel working rectifiers, an online configured battery with stationary lead accumulators, a 110V stage on which a step-up/down voltage regulator is interposed and a 24V stage whose regulation is made by two step-down regulators. All the converters have a switching technology with high commutation frequency; as for the rectifiers, they are checked according to the absorbed wave shape in order to reduce the harmonic distortions on the AC side.

The station management and control logic is managed by a microprocessor, whose purpose is the supervision and control of the station, the battery diagnostic and its automatic management and maintenance.

It also manages the double graphic interface, made up of a synoptic panel equipped with a serigraphy showing all the station components and a high resolution graphic display on which are shown: the station condition and its working mode, out 110V and 24V current and voltage measurement and, in case of anomaly, the detailed prompts about the problem occurred and, if necessary, the appropriate steps in order to go back to a normal working stage.

The station interfaces the outside by a RS485 connection with Modbus protocol on DV971 protection and control panel and by a 100 base FX Ethernet connection with SC connector; on this slot a IEC 61850 is implemented.

The service slot is a 100 base TX Ethernet type on RJ45; by the use of this slot the station calibrations and the firmware updating is performed. The supported protocols are TCP/IP-UDP.

BATTERY DIAGNOSTIC

The station includes an advanced diagnostic logic which automatically and periodically performs a complete maintenance of the battery without any workers intervention in site. In particular, voltages, currents and battery temperature can be monitored in order to work out an overall frame of the battery’s health and to evaluate its worsening in advantage.

Different diagnostic solutions are scheduled depending from the working stage of the battery. Each solutions checks the efficiency of the battery by the measurement of all characteristic parameters.

The diagnostic checks: the charge condition status, the stable trickle charge status and generally the absence of any anomaly.

In addition it performs a forecasting analysis of life expectancy by the use of statistical algorithms. Finally, is possible optimize the maintenance procedures. The maintenance will be done only “on demand”.

The diagnostic is performed through three different working modes of the battery:

1. In trickle charge on the AS;
2. With discharge on external power resistor;
3. Discharge on the AS.

The diagnostic function periodically checks:
- the battery efficiency by diagnosing the interruption condition of the accumulators chain. This anomaly condition is recognised on the basis of the voltage and current measurement on the battery itself;
- the battery charge status;
- the stable trickle charge status of the accumulators since 10-30 days (to be set);
- the absence of anomalies.

Discharge on external power resistor mode

By the use of a power resistor it is possible to perform a discharge test in order to diagnose the battery charge level and to induce a suitable ionic exchange among the accumulators boards in order to keep the battery efficient.

The capacity percentage and the test temporal cadence can be set by the PC.

In particular the ranges to be taken into consideration are as follows:

<table>
<thead>
<tr>
<th>% of nominal capacity Cn</th>
<th>Discharge time interval</th>
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<tbody>
<tr>
<td>10 – 30 % of Cn</td>
<td>30 – 180 days</td>
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The default value is set to 15% of Cn with a time interval between two discharge equal to 90 days. During the discharge on R the following measurements are acquired:
- total voltage of the accumulators battery;
- voltage of elements groups of the accumulators battery;
- accumulators battery discharge currents;
- temperature of the accumulators battery elements (2 probes in contact with container vase);

From the above measurements an approximate value of various groups internal resistance is deducted; this value supplies information about anomalous increase compared with an average value of the internal resistance of the accumulators group. The value is acquired only if the battery temperature lies in the 15-30 °C range. The internal resistance of the kth group is obtained as follows:

$$ R_{int}(k) = \frac{V_{med}(k) - V_{scad}(k)}{I_{scad} - I_{med}} $$

where:
- $V_{med}(k)$: is the average maintenance voltage, measured on the kth group after 10 acquisitions before the discharge;
- $V_{scad}(k)$: is the voltage under discharge measured on the kth group, mediated at 10 acquisitions made after 120 s since the beginning of the discharge;
- $I_{med}$: is the average absorbed in maintenance current, measured on 10 acquisitions before the discharge;
- $I_{scad}$: is the current under discharge, mediated at 10 acquisitions made after 120 s since the beginning of the discharge.

Once the resistance measures have been acquired for each group, the algorithm estimates the standard deviation of the above mentioned values:

$$ \sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}} $$

where:
- $\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$

is the arithmetic average.

The station gives an alarm for battery maintenance demand if $\sigma \geq 0.6$.

All the measurements concerning the resistance are saved in a flash memory.

During the discharge phase, the station checks the total voltage stability of the battery.

Ignoring the unavoidable negative gradient, when inserting the load, the station verifies that the battery voltage is constant within the default range 2.08-1.98 V.

The alarm for battery maintenance on demand is generated when the range is surpassed.

**EXSTIMATION OF THE SAVINGS**

The economic evaluations take into account both the cost of the activities for the batteries periodic maintenance and the new equipment presumed cost. Separately the presumed benefit deriving from the reliability of the new component has been considered.

The current in field periodic activity consists on:
- at sight exam and density control;
- assistance battery installation;
- put the battery off duty for maintenance;
- equalizing discharge (only for open vase batteries);
- electrolyte top up (only for open vase batteries);
- deep discharge setting by the use of a load;
- internal resistances measurement using a CELLORDER tool;

The controls are performed by various levels interventions. For superficial controls (at sight exam, densimeter measurement,...) 1h/man with a quarterly periodicity are needed. For the in depth maintenance 6h/man with an annual periodicity are needed. Therefore the plant cost is equal to:

$$ 50€/h \times 1h/man \times 4 \text{ annual int.} + 50€/h \times 6h/man \times 1\text{ annual int.} = 500€/\text{plant/year}. $$

All the logistic costs are included in the 50€.

The current station’s price (old technical requirements) is equal to 6000€. The presumed price increase should fluctuate around 40% so 2400€.

As a consequence the investment return time for each plant in which the new station will be set is about 5 years.

In addition the fixing/replacing interventions cost can vary as a function of the activity to be performed. The extracted from SAP data show that workers interventions for faults in primary substations in 2006 are about 65k€, in all 380 interventions.

The adoption of the new supply station would probably bring this cost down of about one third.

In addition it can be pointed out that the avoided workforce cost for a 100 pieces provision is equal to 1 FTB/year.

In conclusion, the fundamental advantages offered by the new station can be resumed as follows:

- avoid the battery cyclic maintenance, whose cost is 500€/plant/year;
- have the use of weak signals in order to make a preventive maintenance “on demand”;
- insure a battery longer duration thanks to optimum automatic charge/discharge cycles.

All the advantages have not only economic significant impacts but they also allow a better environmental safeguard.