SMART SOLUTIONS FOR THE AUXILIARY POWER SUPPLIES SCHEMES IN HYDRO-POWER PLANTS

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The safe operation of a Hydro-Power Plant (HPP) depends on ensuring the necessary power supply to all electric-driven equipment and to other internal consumers. The auxiliary power supply must be qualitative, reliable, sustainable and cheap. The present development of technology offers new possibilities for the improvement of substations. Smart substations are developed by endowing the classical substations with new capabilities. Thus, a better performance and a higher security of the auxiliaries is enabled, besides giving a valuable input for smart grids. The paper describes the principles used in the design of the physical technical structure for the auxiliary power supplies scheme, which is the basis for the development of a smart substation. The study-case is the HPP Lotru-Ciunget (Romania), equipped with 3 units of 170 MW each.

Keywords: auxiliary power supply, Hydro-Power Plants, HPP, smart substation

1. Introduction

The transformer stations of Hydroelectric Power Plants (HPP) contain the following categories of electrical equipment: primary circuits, secondary circuits, units and general auxiliaries (in-house technological consumers) and auxiliary equipment. The alternative current (AC) auxiliary services of a power plant include all the AC equipment that provide the electricity supply to the components used for producing electricity, and also to other auxiliary receivers.

2. AC auxiliaries of a Hydro-Power Plant

To ensure the long-term reliable operation of a modern hydro generator (HG), the auxiliary equipment must allow independent work, from the other outside installations [1]. The auxiliary equipment supplies power to different electric-driven components (electrical valves, electro pumps, rectifiers, breakers etc) [2]. Together they form the auxiliary services of the HG.

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2.1. Hydro Generator auxiliary power supply

Fig. 1 presents the main electrical supply scheme for the auxiliaries of a power plant with Hydro Generator units (HG) and unit's transformers (TB).

For reliability reasons, HG auxiliaries may be powered from two independent sources: (i) the first source (the normal power source) is the generator output, connected to the unit auxiliary transformer for auxiliary consumers (T_{ac}). T_{ac} allows an independent operation from outer networks (see the green line in Fig. 1); (ii) the second source (back-up powering for the HG) is the 0.4 kV substation for general services consumers, through the transformer for general consumers T_{gc} (Fig. 2). Commonly, T_{gc} is used for start-up, shut-down, unit backup and supply of general auxiliaries (see the yellow line in Fig. 1).

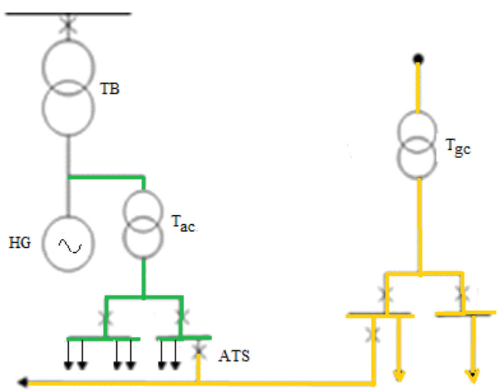

Fig. 1. Power supply of auxiliaries for a Hydro-Power Plant with HG-TB units

Fig. 2. T_{gc} for start-up, shut-down, unit back-up and supply of general auxiliaries

2.2. Powering the back-up of general auxiliaries

The station start-up transformer provides the start-up power and the shut-down power for the power plant. It also back-up's the unit auxiliary transformer (T_{ac}) and ensures the general auxiliaries power supply. The back-up powering of the 0.4 kV consumers from several sources is allowed by the connection of a Diesel group and/or a Micro Hydro-Power Plant (MHPP) to the bus-bars (fig. 3).

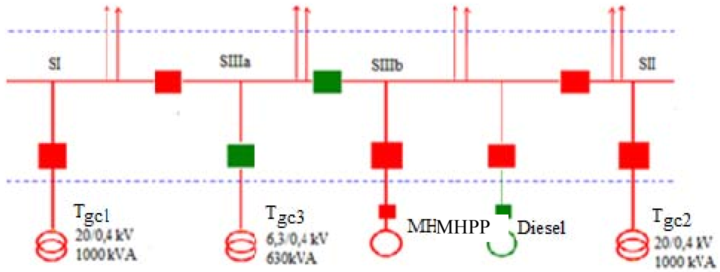

Fig. 3. Detail of the possible ways of powering the back-up of general auxiliaries with a high degree of independence (Diesel, MHPP). Legend: green – connected; red – disconnected

Line disconnection switches split the bus-bar in several subsections (S_I, S_{II}, S_{IIIa}, S_{IIIb}) according to the technological back-up scheme. Thus, continuity in supplying power to the consumers is increased (Fig. 3). The functioning principle consists in decreasing the voltage from the 20 kV electrical lines (through T_{gc1} and T_{gc2}) or from the 6 kV electric lines (through T_{gc3}) to the standard three-phase voltage of 0.4 kV. The minimally needed automation of this substation part and the intended operating procedures already implicitly contains a big part of the functional specification.

2.3. Choice of the nominal power for the auxiliary transformer

The choice of the T_{ac} for the HPP auxiliaries (through the normal or the back-up scheme) is made so that to ensure [1]: the long-term flow of the maximum electrical charge; the start-up of the motor that has the hardest start-up conditions, while the other motors are in operation; the auto run-up of the main motors, in the hardest conditions; the tap of the short circuit current under the limits imposed by the auxiliary equipment.

The maximum power for the auxiliary consumers (T_{ac1}, T_{ac2}, T_{ac3} in Fig. 4) is given by the connected motors taking into account: the load factor, the efficiency, the power factor and the load to the 0.4 kV sections (for example, through the 15.75/0.4kV transformers). For a first approximation, the following relation may be used:

$$S_{M,ac} \approx \frac{K_m}{\eta_m \cdot \cos\varphi_m} \sum_i P_i \qquad (1)$$

where $S_{M,ac}$ is the maximum long-term load required by the auxiliary consumers (in kVA); $\sum P_i$ is the sum of the loads of the i-motors that are connected to the bus-bars of the 0.4kV station (in kW); K_m is the medium load factor of the motors; η_m is the average efficiency of the motors; $\cos \varphi_m$ is the average power factor of the motors.

A first approximation of the nominal power transformer of the auxiliaries is given by the relation:

$$S_{nT,ac} \geq S_{M,ac.} \tag{2}$$

Then, it is verified if this first approximation of the nominal power is enough for the start-up or auto run-up of the high-power auxiliaries motors.

The check-up consists in the predetermination of the homing voltage on the supply bus-bars at start-up/ run-up. The homing voltage depends on the start-up/ run-up input current and on the power level of the three-phase short circuit on the bus-bars from which the motors are powered. The following relation can be used:

$$U_* = \frac{1.05}{1 + \dfrac{S_p}{S_{sc}}} \geq U_{*admissible} \tag{3}$$

where S_p is motor's input electrical power at start-up or run-up; S_{sc} is the short circuit power on the bus bar of the 0.4 kV station that is powered by the transformer and supplies power to the motors (this power is proportional to the transformer nominal power S_{nT}); $U_{*admissible}$ is the relative value of the admissible voltage at start-up or run-up. To assure the tapping of the short circuit currents, S_{nT} is calculated from the relation:

$$\frac{S_{nT} \cdot 100}{\sqrt{3} \cdot U_{n2} \cdot u_{sc\%}} \leq I_{sc.ad.} \tag{4}$$

It is to be noticed that at this point, it is possible to change the solution with a high-power transformer into a solution with two transformers of a lower power or a solution with a transformer that has a divided secondary winding. In case changes are being made, a re-check of the accomplishment of motor's conditions at start-up or run-up is necessary.

The transformer T_{gc} used at the unit start-up, shut-down, back-up and the supply of general auxiliaries is dimensioned according to the relation:

$$S_{nT,gc} \approx 1.5 \cdot S_{nT,ac}\,. \tag{5}$$

3. Normal operation scheme

The normal operation scheme is the one that is approved by the load dispatcher for a determined period of time. Besides the electrical equipment, the scheme includes the protection and control equipment, as their operational status is very important for the manoeuvres. In Fig. 4 we present an example of normal operation scheme for the 0.4 kV substation that powers the auxiliaries of a HPP with 3 units of 170 MW each, derived from the scheme of HPP Lotru-Ciunget (on Lotru River, Romania).

The graph chart representation for the normal operation scheme is made according to the UCTE agreements and to standard specifications. The operation according to a different scheme rather than the normal one presented in Fig. 4 is managed in the operational control room by the dispatcher (who has the decision authority).

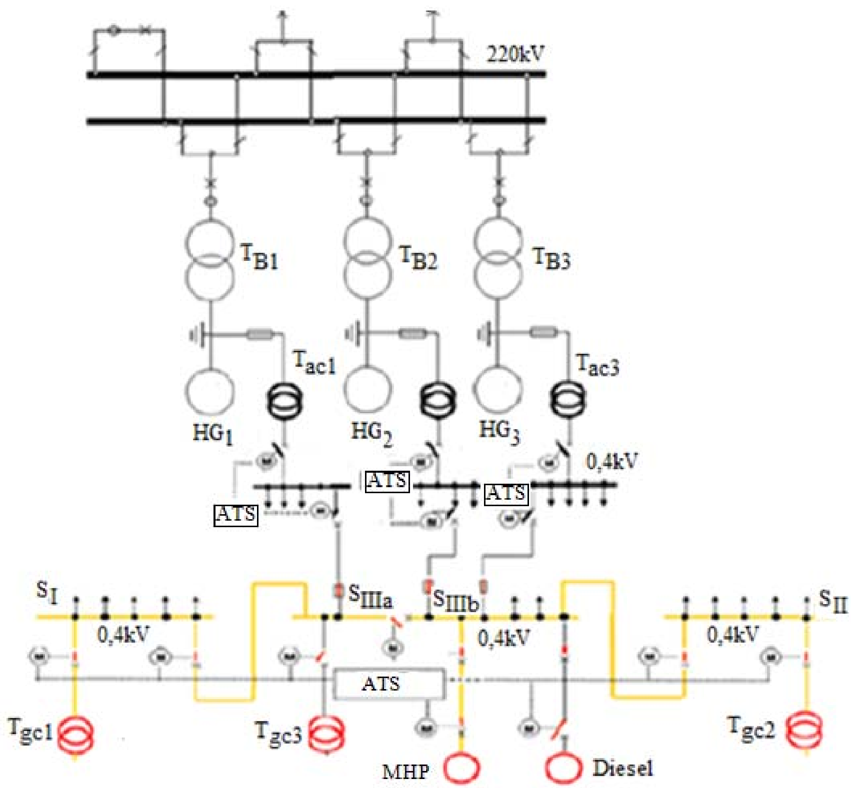

Fig. 4. Example of normal operation scheme for the 0.4 kV substation that powers the auxiliaries of a HPP with 3 units of 170 MW each

4. Smart design and operation to ensure the auxiliaries supply

Abnormal operation (deviation, time period) is recorded. The operation of the Automatic Transfer Switch (ATS) is based on 0.4 kV transformer's voltage and on circuit breaker position. The operation can be manual or automatic. After the voltage returns to any transformer of the general auxiliaries, its circuit breakers re-connect automatically within 30 seconds (Figs. 5–8).

When transformers T_{gc1}, T_{gc2}, T_{gc3} are unavailable, then the Diesel unit starts-up automatically if the following conditions are met: the circuit breakers of the Diesel unit are broached; the Diesel switch cabinet is on the „automatic" position; no malfunctions displayed.

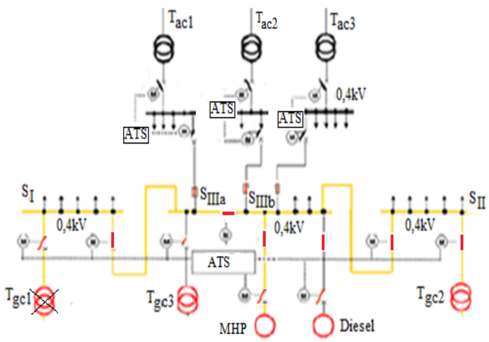

Fig. 5. ATS operation in a scheme with T_{gc1} unavailable

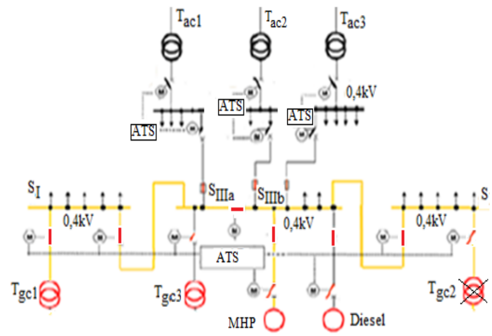

Fig. 6. ATS operation in a scheme with T_{gc2} unavailable

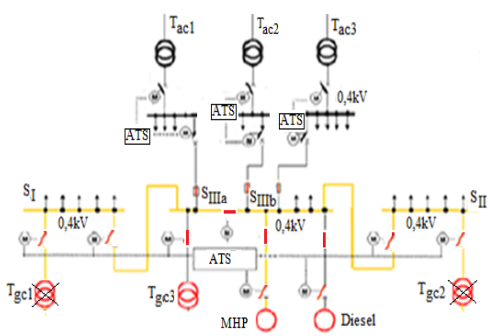

Fig. 7. ATS operation in a scheme with T_{gc1} and T_{gc2} unavailable

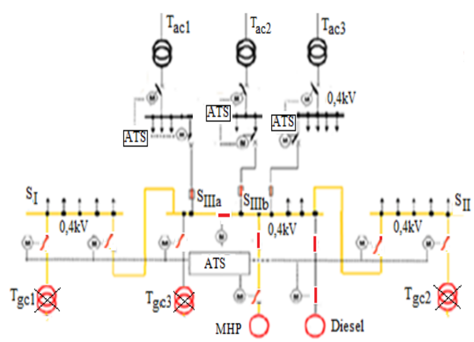

Fig. 8. ATS operation in a scheme with T_{gc1}, T_{gc2} and T_{gc3} unavailable

At the start of the Diesel unit, ventilation units and pumps stop automatically. These components are switched automatically to the manual position. The MHPP is automatically disconnected from the 0.4kV auxiliaries bus-bars, as a protection against failure during operation, along with the automatic transfer switch (passing through zero). After receiving the shut down command, it restarts within 5 minutes.

5. Smart substation

New designs and revolutionary materials and concepts are being incorporated in a modern substation [3]–[6]. A smart substation is actually a digital substation, which has several new functions and communication capabilities [7]. Protection, control, measurement and monitoring functions are integrated within the smart substation, enabling a better performance and higher security. The substation can be monitored and controlled from a central point, thus allowing a better coordination and also lowering the operation costs. The international standard used for the reference architecture is IEC 61850, part of the IEC Technical Committee 57 [8].

Based on Ethernet, the architecture given in the standard, the smart substation enables a high speed protection, interlocking and inter-tripping [9]. Usually, the local operation of the substation is made through control panels and LCD displays, that are connected to a Programmable Logic Controller (PLC). A keyboard is used to give commands, to change set-point and display the desired schemes and reference points. A higher level of monitoring, control and command for auxiliaries substations is given by a Supervisory Control and Data Acquisition (SCADA) system. To operate the substation from the SCADA system, both the central control panel and the local control panel from the 0.4 kV station must be set on the „remote" position.

The automation transfer switch can be set on „manual" or „automatic" operation. If it is set on „automatic", priorities must be assigned to transformers T_{gc1}, T_{gc2}, T_{gc3} (with/without priority). If the automation transfer switch is set on „manual", all connections/disconnections are made manually. For protection, illegal manoeuvres are avoided by electrical interlocking. Fig. 9 summarizes the flowchart of the concept phase for a substation design.

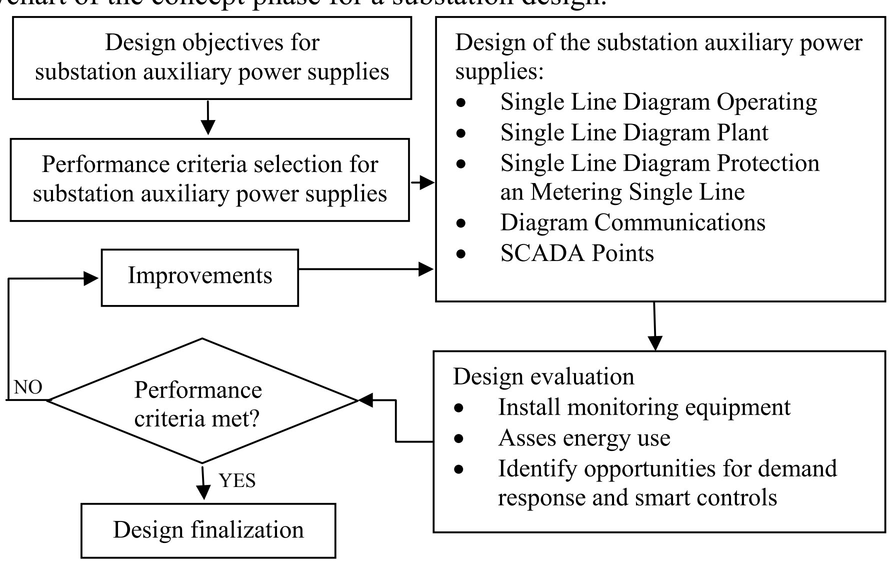

Fig. 9. Flowchart of the concept phase for the substation design

6. Conclusions

The paper describes the principles used in the design of the physical technical structure for the auxiliary power supplies scheme, which is the basis for the development of a smart substation, based on a Romanian study-case, namely the Hydro-Power Plant Lotru-Ciunget (on Lotru River), a HPP equipped with 3 units of 510 MW total installed power.

Nowadays, smartening on the field of measurement, control, transfer and management of data generated a new vision of the whole management processes, bringing important improvements in management, while lowering the operation costs. Auxiliary substations can now benefit from a more complete monitoring and database management system and from an active computer assistance for decision making.

The best decision can be taken in less time and with less human errors. Thus, a higher performance and a higher security of operation are reached with less effort. At the same time, fault detection and outage management are improved, reducing the number of malfunctions. Safety and reliability are increased, and an efficient preventive maintenance of the equipment can be performed. All these, with lower costs.

For highest benefits, the integration of the new technologies must be considered from the very beginning, during the design process. Based on the same principle of ensuring the continuity in power delivery to the consumers, the design of smart substations is based on an open architecture that joins together several applications and can easily include future ones. The design of smart substations aims to take the burden of the operation personnel, by taking over the „rough work", thus leaving the personnel only with a supervising and decision making role. A future step of smartness is the self healing substation.

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