Functional Problems and Maintenance Operations of Hydraulic Turbines

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Abstract : **The exploitation in good conditions of the hydroelectric power plant imposes a rigorous maintenance of equipment and operating facilities, primarily of the turbine. The efficiency of the turbine is strongly affected by any defects which could occur during the operation. The paper makes a synthesis of the most frequent failures which have occurred during the functioning of Kaplan turbines plant and the required maintenance plan that has to be adopted. The maintenance rules for the optimal working of these turbines are also emphasized.**

Keywords: **Hydraulic, maintenance, turbine.**

1. Introduction

The choice of the constructive type of the turbine which equips a hydroelectric power plant is done mainly by following two fundamental criteria: the height of the water fall and the debit of water which passes through the turbine.

Based on these two parameters the Kaplan turbines are utilised for small falls H=10-50 m and large debits reaching to Q =700-800 m^3/s [1]. Such turbines equip hydroelectric plant as Portile de Fier II and on the Bistrita river.

The total efficiency of a turbine is strongly affected by any type of malfunctions which could appear during its operation. The maintenance programs have the role of reducing the number of these incidents and to maintain the operation of a hydro power plant in optimal conditions.

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2. Elements of construction and function of the Kaplan turbine

The classical functional structure of a hydro-generator with a Kaplan turbine is presented schematically in figure 1.

The turbine power is defined by the relation:

$$P = P_h \, \eta = \rho \, g \, Q \, H \, \eta , \tag{1}$$

in which η is the turbine's efficiency and it's calculated as a product between the hydraulic efficiency η_h, the mechanical efficiency η_m and the volumetric efficiency η_v. Any functional defect which affects these efficiencies will reflect in the total efficiency of the turbine and implicitly in the power provided by it.

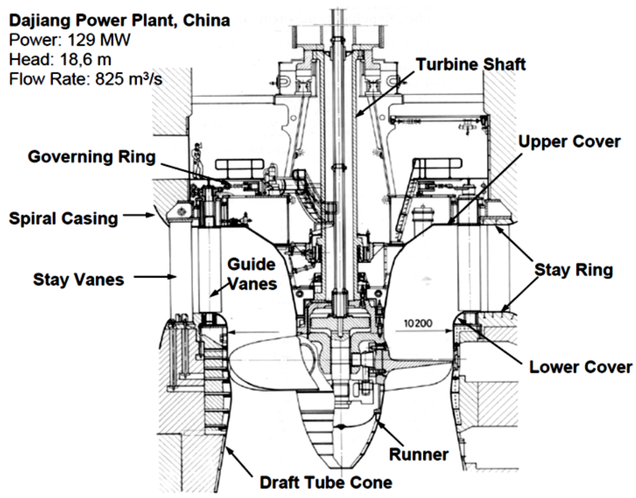

Fig.1. Structure of the Kaplan turbine [3]

The intake of the water in the turbine is carried out through a spiral casing from concrete sheathed with steel plate in the entrance zone in stator (Fig.2). The water's speed when entering the first section of the spiral is of about 4/sec. The stator through its hydrodynamic profile of stay vanes, uniformly leads the water to the guide vanes, imprinting the optimal entrance direction.

Fig.2 Stator

The modification of the entrance of the wicket gate, by changing the position of the blades, allows the possibility of certain different debits in the turbine and implicitly the realization of different powers transmitted to the hydro- aggregate. The actuation of the wicket gate mechanism (Fig. 3.) is made by two classical servomotors.

Fig.3. Turbine cap and the wicket gate control system

The water reaches the runner (Fig. 4.), where the transformation of the hydraulic energy of the water into mechanical energy takes place. For the carrying out of certain efficiencies with high values throughout the entire guaranteed functionary domain, the turbine is provided with a double adjustment. This double adjustment consists in the concomitant rotation in the same orientation of the blades of the wicket gate and of the rotor's pallets, rotation ordered by the speed regulator through the control system and the combinatorial cam. The blades' rotation toward opening and shutting is carried out through the medium of a hydraulic actuator installed in the clump of the runner and a star guidance system with the crank and connecting-rod assembly. The action actuator of the blades is commanded by the speed regulator, through the medium of the cast lid and the distribution column.

Fig.4 Runner hub

To avoid oil losses outside the cap and to avoid water infiltrations inside the turbine, sealing rubber rings have been installed on the circumference of the blades flanges and on the hub openings.

The transition of the torque motor from the turbine's rotor to the hydro generator's hitch is done with the help of the turbine shaft (Fig. 5.). At the cowl level of the turbine, the shaft is guided by a guidance bearing which can assume the eventual radial charges resulted from the imbalance of the rotor masses and the patchy hydraulic forces which can appear on the runner.

Fig.5. Turbine shaft

To avoid the water's penetration in the bearing of the shaft and in the turbine's cap, a service sealing is installed and also a backup one provided with sealing rings of lead and rubber respectively. The avoidance of possible dangerous depressions in the rotor's area and of the aspiration tube, caused from a sudden closing of the wicket gate or of some transitional functionary regimes, is possible through the use of the breaking vacuum valves placed on the top of the turbine. The breaking vacuum valves seal under the influence of the force of a spiral compressing arch and the opening of them is done under the action of the atmospheric pressure, allowing the air to enter the rotor's area.

The access to the spiral casing is done through a visiting window and its emptying is done through a delivery valve. In case one or more shearing bolts break, as a result of a penetration by a foreign object between the pallets of the guide vane, the contacts of safety microswitches, installed on the levers blades, close and the defect is signalled to the control panel of the hydropower system.

In case of revisions or reparations, the clearing out of the oil from the rotor and the distribution column is realized through the medium of the drain valves installed in the rotor hub.

The hydro generator (Fig. 6.) has in its composition two types of bearings, a radial-axial bearing (superior) and a radial bearing (inferior). The radial-axial bearing is a bearing combined axially and radially, installed in the superior star. The axial bearing itself has the role to sustain the rotary parts (rotor generator, shafts, turbine rotor) and assume the hydraulic force created in the turbine's rotor. The radial bearing within the radial-axial bearing has the role of guiding the shaft of the generator's rotor. The inferior radial bearing is a simple bearing having only the role of guiding the shaft of the generator's rotor on the inferior side.

On the hydro generator's shaft, on the superior side the axial hub is s shrink using the help of semi-ringed feathers. Bottom radial bearing hub is made of one piece with the shaft.

Fig.6. The hydro generator (rotor generator and fixed coil generator)

The weight of the rotating parts and the hydraulic axial force of the water are transmitted through the medium of the axial bearing to upper star, then to the generator's hull, and in the end, to the foundation through the assistance of support plates. The upper star has from 4 to 12 arms and the inferior star between 4 and 8 arms which are supported by the foundation. On each arm of the inferior star, a braking mechanism is installed.

The hydro generator is cooled through auto ventilation with air in closed circuit. The guiding of the air is realised with the help of two shields: the superior shield-installed between the arms of the superior star, and the inferior shield-installed on the arms of the inferior star. From the parts which cool the air, to reach the inferior part of the machine, the air passed through channels which go through the foundation on which the hull's hydro generator is set on.

3. Defects which appear in the functioning of the turbines

The complexity of its construction, succinctly presented in the previous paragraphs give points to the possibility of certain malfunctions to appear at the subassembly of the hydro generator [3, 8]. The most frequent are presented in Fig.7.

The cavitation which is avoided by choosing the type of turbine and can be controlled through the use of certain specialised software is not taken into consideration.

The causes for the apparition of such failures and the impact they produce on the normal functioning of the hydro power plant are presented in Table 1.

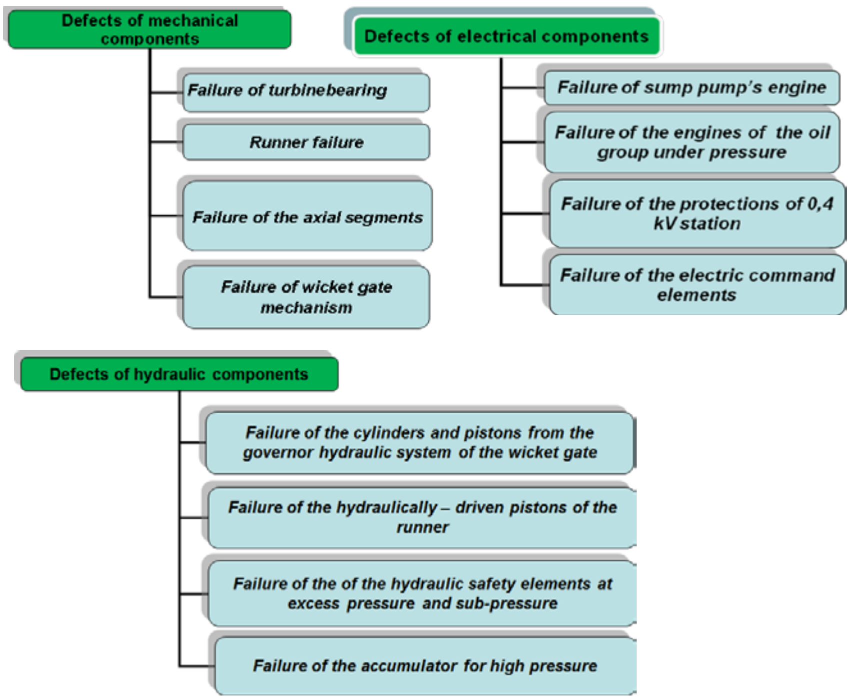

Fig. 7. Defects of mechanical, electrical and hydraulic components

Table 1. Failures of the components of hydro power plant

Flaw designation	Possible causes	Effects
The failure of the turbine bearing	An accidental lack of water in the lubrication and cooling system	The impossibility of turbine functioning The burning of the rubber backings The unavailability for a long period of time which represents financial losses
The failure of the runner	The breaking of a driven mechanism of the blades Oil leaks at the sealing of the rotor's blades	The impossibility to maintain control on the adjustment of the rotor. The unavailability of the turbine for a very long period of time
The malfunction of the axial segments	An antifriction material of poor quality and high temperature of the oil in the axial-radial casing	The depletion of the oil casing The danger of interposing debris, which could lead to an imperfect functioning
The failure of the wicket gate mechanism	The penetration of foreign matters in water hydraulic circuit, which would result in breakage of levers	Unavailability of the turbine for a long time Increasing the clearance in bushing blades, which would lead to replacing them
The failure of sump pump's engine	The burning of winding either as a result of normal wear or as overload	Impossibility of the use of pumps
Failure of the engine of the oil group under pressure	The burning of winding either as a result of normal wear or as overload	Impossibility of the use of pumps
The failure of the electric comand and signaling elements (lamps and buttons)	Depreciation of the contacts Burning of the signaling lamp for resistance operation	Failure aggregates coupling from the control panel Failure to signal operator about the turbine operation.
The failure of the protections of 0,4 kV station	The occurrence of a short circuit Switches failure	Impossibility of station operation Non-operating of the power plant
The failure of the servo-drives of wicket gate	Inappropriate type of sealing elements which lead to the cylinder and piston wear	Non-operating of servo-drives, unavailability of turbines for a very long time
The failure of the hydraulically driven piston of the runner	The line of shafts not made properly and great clearances of bearings (slackness)	Failure of the drive rotor, turbine unavailability for a very long time
The failure of the hydraulic safety elements for overpressure and under pressure	The pressure relief valve adjustment much higher than the pressure provided in the installation Blocking valves due to impurities from hydraulic oil	The occurrence of overpressure that can damage pipes and distribution or control systems
The failure of the accumulator for high pressure	It is due to pressure from installations	Major wear of the compressors

4. Maintenance activities of the hydro generator

To prevent eventual malfunctions which could appear during the operation of the Kaplan hydraulic turbine, the maintenance plan must be realized and respected. This maintenance plan must allow the establishment of all flaws and the way to fix them in the shortest period of time.

A. Maintenance activities for the mechanical components

1. the continuous checking of the lubrication of the bearing - timed control graphics (3 times/12 hours). Transducers will be installed which indicate the debit and the pressure on the water-lubrication installation completed with displaying systems and signalling capabilities for the intervention of the personnel on shift;

2. the breaking of the acting mechanisms of the runner's blades - preventive maintenance is difficult to realize. On account of the sealing spindles from the rotor's blades, they can be prevented through the use of some high quality gaskets. These interventions are done when a capital reparation is being effectuated [9];

3. the depreciation of the antifriction material is owed to the debris from the oil, even from the circulation ducts. These interventions can be prevented when filtering the oil prior to introducing it into the system;

4. the prevention of the levers of the wicket gate breaking is done by thickening the bar grate of the water intakes or supplementing with another bar grate (variant less accepted).

B. Maintenance activities on the electric components.

1. using ohmmeters to measure the values of the resistances;

2. the installing of new protections;

3. the application of protective sheets on the contactors buttons, replacing the lamps which have light bulbs with some which have LEDs

C. Maintenance activities on hydraulic components

1. replacing the old gaskets with new ones - this operation can be done only when a capital reparation is being performed;

2. remaking the line of shafts and the clearances of the bearings - this operation can be done only when a capital reparation is being performed

3. documenting and respecting the utilization prescript of the appropriate pressure for the valves. Periodically filtering the oil based on the number of hours it was in function;

4. installing some traducers which allow the observation of the decrease and growth of pressure from the compressed air system. The choosing and adapting of the compressor appropriate for the respective installations.

According to the definition, maintenance represents the totality of operations done towards maintaining or repairing a technical system. The most important task of maintenance is assuring the long-term functionality of the equipment.

Based on purpose, the following categorisation can be made:

1. preventive maintenance which has as objective to reduce the probabilities of failure or degradation of equipment. It can be systematic (checkouts and current reparations, revisions and capital reparations) or predictive (following the evolution in time of the attrition parameters so that the maintenance interventions can be realized before the defect's apparition).

2. corrective maintenance represents the ensemble of activities realized after the failure of the system or after the degradation of its function in an unforeseen way. These activities consist in localizing and diagnosing the defects in interventions to re-establish a proper operation [4, 6].

The specialty literature [5, 7] defines a system's technical capacity to be restored into function in the shortest possible time, following the remediation of a fault, through the term of maintenance.

Respecting the maintenance plans, also including the assurance of the tools and of the spare parts, the making of reparation charts, etc., assures high maintenance of the hydro-generators [4].

It can be easily observed which category of maintenance, the solutions for repairing the mechanical, electrical and hydraulic flaws presented previously belong to.

The predictive maintenance is very important to be conducted in accordance with the shortest lifetime of composing elements in order to prevent a fault that occurs with important costs in materials and time function. In many situations, considering the differences between theoretical and practical exploitation conditions, the lifetime could be shorter than the estimation time of good function proposed by fabricant and close monitoring of the parameters is very important.

5. Conclusion

At the present day, approximately 26% of the energy consumption worldwide is assured by hydraulic sources.

Romania is energetically exploiting approximately 52% of its hydraulic potential. The preservation in good conditions of the hydro generators which produce energy is conditioned by maintenance programs well put together.

This paper presents the principal defects which could occur when exploiting the Kaplan hydro generators and some prevention measures and solutions to these defects which have to be included in the maintenance programs.

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