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VARIABLE SPEED PUMPED STORAGE HYDROPOWER GENERATION

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OUTLINE

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Abstract: -

The potential advantages of variable speed hydroelectric generation are discussed in this paper. Some general aspects concerning the efficiency gains in turbines and the improvements in plants operation are analysed. The main results of measurements done on a test loop with an axial-flow turbine are reported. Also is described the control scheme implemented, which is based on artificial neural nets (ANN). The conclusions encourage the realisation of more detailed studies, especially for low head plants, in order to confirm the practical interest of this technology.

Keywords: - *Variable Head Hydro Plants, Operation limits of Hydro Turbines, Variablespeed generation, generative Frequency Converters, Artificial Neural Networks*

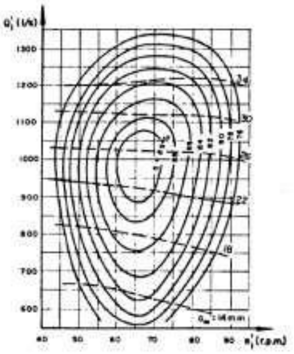
INTRODUCTION

In variable-speed turbines the allowable range of variation of the hydraulic magnitudes would be enlarged, giving rise to significant advantages in the plant operation. This gives improvements in environmental, energy and hydraulic conditions are reported. Variable-speed technologies are presently well introduced in wind generation, where appreciable advantages have been found. In general a static frequency converter is needed and is worth to mention the recent advances in Power Electronics that enhance the performance of these devices. Of course the power converters increase the cost of the generating facility, but the improvements in operation that may result, and the potential net benefits that can be obtained make this option reasonably attractive. The aim of this paper is to discuss the possible advantages of using these techniques in hydro generation, considering the main aspects related with the turbine, generator, control system and operational conditions.

Variable Speed Hydraulic Turbines

Francis turbine

The potential advantages of variable speed operation are especially found in Francis turbines with high specific speed as well as in Kaplan or propeller turbines



$$n = n_1 \sqrt{H} / D_1$$

$$Q = Q_1 D_1^2 \sqrt{H}$$

$$P = P_1 D_2^1 H^{2/3} = 9.81 \eta Q_1 D_1^2 H^{3/2} \quad \text{(kW)}$$

Fig. efficiency hill of a Francis turbine

From the figure is clear that the efficiency drops appreciably if Nideviates from the optimal values. In a constant speed turbine this occurs when the net head, H, changes. But if it were possible to modify the speed, n, the changes in the unit speed, nI , could be reduced or even suppressed, maintaining the high values of efficiency. Moreover, the speed adjustment would avoid other problems which arise when the head deviations are excessive, namely: draft tube pressure oscillations and cavitations

- **Kaplan turbine**

In a Kaplan turbine the efficiency drops dramatically for load values out of a narrow range in the neighborhood of rated power. As before, variable-speed operation of a propeller turbine improves substantially its performance, although keeping it below that of a Kaplan one. Moreover, in some power plant configurations it would be possible to operate without wicket gates, with the regulation provided by the speed. It could be said that variable-speed propeller turbine may be a good alternative to a Kaplan turbine, because of its greater simplicity and robustness, while still maintaining good performance. The counterpart comes from the extra equipment needed for variable-speed operation on a fixed-frequency grid.

Converting An Existing Plant to Variable Speed

Although the design for converting synchronous unit to a variable speed unit is quite simple yet it requires due consideration when it comes to actually implementing the design. In this regard what we do firstly is we upgrade the turbine this has to be considered because the power variation in pump mode and the potential speed variation depend on the hydraulic design.as a result, setting a new hydraulic profile within an existing machine structure requires requalification of the mechanical structure, as well as verification of the hydraulic transients. New constraints has to be decided which keep track of the changes in speed and the other changes relating to functioning of unit. Second, the choice between a synchronous generator with full convertor and a double-fed induction generator with converter in the rotor circuit must be evaluated. The constraints of upgrading the motor-generator into a variable speed induction machine within an existing powerhouse and its effect on the plant must be taken into account. Also the structure should be checked for increased stresses due to changes in the structure. Variable speed units lead to higher loads on civil structures. However, modifying the civil works in the plant is not cost-effective. Thus, all existing concrete structures must be checked to ensure they can bear the foundation loads of the stator (loads and torques, under static and dynamic conditions) and thrust bearing load transfer. Ultimately, local reinforcement may be necessary or variable speed machine size must be limited to match civil structure bearable loads.

Hydraulic design insight

Hydraulic design should be able to adapt to the power and flow changes as power mode in pumping mode relies heavily on it. Because the older designs are not set to these conditions, an upgrade is recommended to get the most benefit. Upgrading the hydraulic design could affect:

— Hydraulic transients considering the existing waterway;
— Integration of the new hydraulic components within existing contours; and
— Cavitation-free operation with the available runner setting. This is one of the main parameters that could affect the pump power range.

Control Of The Turbine Speed

The axial-flow turbine installed has no wicket gates, so the only control variable is the turbine speed. Hydraulic operational conditions are defined by the pump speed, which determines the gross head for the turbine. A controller has been designed and implemented that selects the optimum speed for the actual conditions. The operation points included in Table I are used for this task that is carried out in two steps:

• The first step is to estimate the state of the system, given by the speed of the pump. This Variable should be obtained from the measured values of turbine speed and generated power.
• The second step is to find the optimal turbine speed that corresponds to the actual system state. Such value determines the desired frequency in the machine side of the regenerative converter

Key Benefits

- Energy storage could be achieved when power levels are below the normal level also it reduces number of starts and stops which helps in regulating the network frequency and voltage in the pumping mode.
- Global plant efficiency increases immensely due toOperating close to the turbines optimal efficiency point.
- Smoother operating (for example at partial load), elimination of operation modes prone to hydraulic instability or cavitation, resulting in improved reliability, reduced maintenance and increased lifetime. It also results in a reduction in the Pump turbine submergence level, reducing civil engineering costs
- The operations are now done at a wider head range which considerably increases the availability of the plant characterized by wide head variations.
- It helps to rectify sudden voltage disruptions which are resulted due to instantaneous power output adjustment.

Variable speed pumped-storage plants use asynchronous motor-generators that allow the Pump turbine rotation speed to be adjusted.

Conclusion

It is clear from above given information on different functions of various turbines that indeed the varying speed hydro power generation is the need of the hour and it could effectively eradicate several difficulties posed in the generation of power.

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