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SUMMARY

OF PH.D. THESIS

Research on the Francis turbine from Rueni Hydropower Plant operating in system services, transient regimes and in regime with cavitation erosion. The influence of these operating regimes on the spiral chamber resistance

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Summary: The thesis consists of 7 chapters preceded by the preface, table of contents, list of figures, list of tables, list of abbreviations and list of notations, ending with personal contributions, future research directions, dissemination of results and refrences.

Chapter 1 presents general information about the Francis hydraulic turbine, the current state of research in the field and the objectives of the thesis.

Chapter 2 makes a general presentation and a history of the Ruieni hydroelectric power plant, presentation with reference to the Bistra - Poiana Mărului hydropower development. The component parts of a hydro unit were described and the functional role. The Francis hydraulic turbine (FVM 78 - 326) and certain recommendations related to the operation of the Francis turbine were highlighted. Also, the operation diagram of the turbine from CHE Ruieni and various hydropower exploitation regimes were shown, which could be highlighted in the SCADA program from the summer of 2020, in secondary regulation and without secondary regulation.

Chapter 3 is dedicated to System Service. It feature ensures the stability of the frequency, the stability of the voltage, the restoration of the functioning of the national energy system (SEN), the availability of SEN consumers and the requirements regarding the teleinformation system. In this context, explanations were given about the frequency-power regulation, the equipment for achieving the frequency-power regulation being described in detail and the main system services offered as a supplier for SEN by CHE Ruieni were presented. In the subchapter on certification measurements for the provision of system services - CHE Ruieni, the digital speed controller for the Francis turbine was highlighted, the results of the certification measurements for the f-P adjustment of both hydro units (HA1 and HA2) were presented in graphical form at different time intervals , respective at different power levels. Also, depending on the results of the measurements, a calculation model for the statistic was shown, respectively the characteristic of the statistic was drawn.

In **chapter 4** the results of measurements in secondary adjustment and transient discharge regimes in three cases, are presented, as follows:

- discharging HA1, at maximum active power Pa = 76.5 MW and falling H = 339.39 m, with HA 2 stopped;
- the hydro aggregate HA1 operates at maximum power when HA2 is discharged from the load at maximum power;
- simultaneous discharge of HA1 and HA2 from the active power Pa = 70 MW and fall H = 300 m.

Based on these measurements, the nominal pressures of the spiral chamber were established., the adjustment guarantees and from tests performed in transient load discharging regimes.

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Chapter 5 is dedicated to the presentation of the cavitation behavior of the turbine rotor at CHE Ruieni, the pressure pulsations in the cone of the suction tube and the operating regimes of the turbines. The operation diagram of the turbine with a marked range of flows and falls at which cavitational erosion occurs has been prepared. This has involved:

- transposing the results from model to prototype;
- determining the equation of the servomotor stroke depending on the opening of the steering apparatus;
- calculation of the exploitation diagram.

The analysis of the pressures in the cone of the suction tube enabeled following observations:

- at high powers, over 70 MW, the pressure under the rotor measured by the transducer P1 has negative values, correlated with the suction load and the cavitation behavior of the Francis turbine;
- for the pulsating phenomena in the suction tube, the values of the fundamental harmonic frequency below 48 MW are important. At 44 MW and 38 MW, the frequencies of the fundamental harmonics are between 1.667 Hz and 1.949 Hz. These frequencies are in the band 20 - 30% of the

rotation frequency (7.14 Hz), being generated by the central vortex that appears after the rotor. The amplitude of the fundamental harmonic measured in mbar is also increased to powers below 48 MW, due to the central vortex;

- no noise and vibrations specific to the existence of a developed central vortex were reported in the operation of the turbine. Under these conditions it can be considered that the vortex motion in the cone of the suction tube associated with the central vortex is of low intensity and does not affect the turbine performance.

It was concluded that the vortex motion in the cone of the suction tube associated with the central vortex, which is low intensity and with the cavitation phenomenon, at powers over 70 MW, does not generate pressure pulsations in the spiral chamber.

Chapter 6 presented the structural analysis of the spiral chamber and the stator performed with Simulation module from SolidWorks program. The following were concluded:

- The equivalent von Mises voltages, for all calculation regimes relative to the allowable voltage, give safety coefficients higher than 1 or by reference to the flow limit of the spiral chamber material, safety coefficients exceeding 1.5;

- The fatigue limit (σ-1) of the material from which the spiral chamber is made is about 220 MPa. By reporting the calculated von Mises stresses, at this fatigue limit, safety coefficients lower than 1.5 were obtained. For turbine components of major importance, such as the spiral chamber, current design standards recommend fatigue safety coefficients greater than 1.5. Under these conditions, for the analyzed spiral chamber, measurements on the hydro aggregate are required in the future, in order to determine the fatigue cycles and to prevent any crack propagation.

Finally, **Chapter 7** presents the personal contributions, future research directions and dissemination of results

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