Numerical analysis of the unstable phenomenon in different pump turbine at load rejection condition

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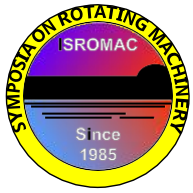

Long Abstract

Introduction

At present, the pump turbine is developing towards to the direction of high head and large capacity, and the key of restricting the design and operation of the large capacity pump turbine runner is the vibration. The unit of pump storage power station is required to switch between pumping and generating modes rapidly and frequently. Once the rotational speed of unit increased to a great extent at load rejection, the flow will decrease sharply, and it caused the vibration and noise [1]. This situation appeared in many plants, such as Tianhuangping, Baoquan in china and Montezic in France, etc. Therefore, the stability of pump turbine has become an important performance index . In order to solve the instability of the pump turbine caused by the “S” characteristics at load rejection, the present study mainly focuses on the optimal design of the runner and the misaligned guide vanes (MGV).

The “S” characteristics can be alleviated to some extent through optimization design, L Yang [2] and N Y Chen [3] designed the runner of pump turbine by using the method of full three-dimensional inverse problem. J L Yin [4] studied the characteristics of internal flow in “S” region and optimized the blade by the method of inverse design. B S Zhu [5] used multi objective optimization method to optimize the runner. The pump turbine of Xilongchi pump storage power station does not appear "S" characteristic at model acceptance test [6]. In addition, the splitter blade runner was adopted in Qingyuan of china and Kanagawa of Japan. The model acceptance test showed that there is higher efficiency and better cavitation performance and smaller pressure fluctuation in the runner, and the "S" curve was basically eliminated [7].

The method to solve the "S" characteristics of the power station has been built is using MGV, such as, Baoquan Tianhuangping etc. J Li [8] simulated the internal flow field distribution and pressure fluctuation in “S” shaped region of Baoquan power station with MGV at different guide vane opening. R F Xiao [9] and T J Chen [10] analysed the influence of MGV on the start-up process and pressure pulsation of the unit. W J Lv [11] studied the influence of the number and open angle and position of MGV on the characteristics of the unit. G H You [12] researched the practical application of MGV device in Tianhuangping pumped storage power station. Through the pre-opening part of the guide vanes, the unit can reach the corresponding flow and speed when the others opening is small, and avoid the "S" unstable region successfully. But this method, as a remedy, will cause greater noise and vibration during the period of MGV input, increase the maintenance cost and reduce the fatigue strength of the unit. J W Li [13] proceeded the load rejection transient experiment of Baoquan pumped storage Unit 1, and found that the MGV can solve the "S" characteristics, but sharpen the vibration of the unit, the swing of the main shaft and the internal pressure pulsation.

Through the obvious research, it is found that at present, the method to control the “S” characteristics is different, there is a lack of effective criteria for the selection of optimal control methods. If considering the selection of control means in the design stage, it will accelerate the process of engineering application. It is urgent to analyse the relationship between the flow characteristics of the unit and the control methods, which lays the foundation for the design of the unit and the selection of the optimal control means.

The numerical simulation of different high head pump turbines was carried out in this paper which taking the weak compressibility of water into consideration. Then the flow field and vibration

characteristics was analysed in load rejection. The law between the flow field and control methods was summarized.

1. Methods

The numerical simulation of the whole flow passage of different pump turbines is carried out in this paper by ANSYS CFX. The geometry model of pump turbine contains spiral case, stay vane, guide vane, runner and draft tube as shown in Figure 1, and the characteristics of parameters are list in table 1. The boundary conditions in generating mode are mass flow inlet and pressure outlet. In the process of calculation, the density of medium is calculated by the weak compressible equation and SST k- ω turbulence model is selected.

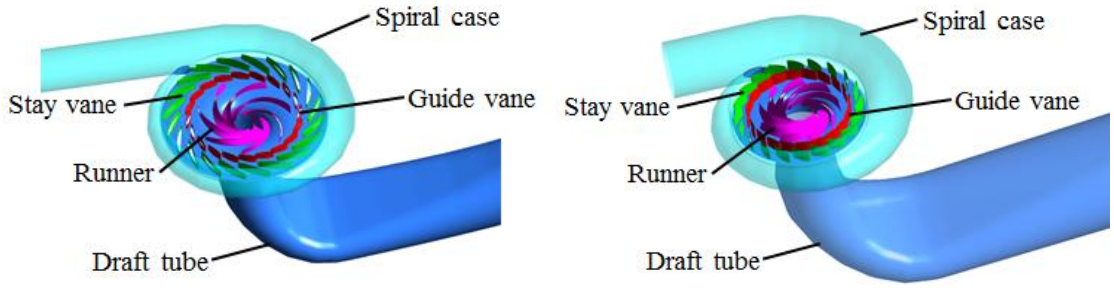

Figure 1. CFD computational domain of the pump turbine

Table 1 Parameters of the pump-turbine

Parameters	value	
	Pump turbine A	Pump turbine B
Runner blade number ZB	7	9
Guide vane number ZG	20	20
Stay vane number ZS	20	20
Rotational speed Rpm	500	500
Runner diameter at inlet D1(mm)	4285	3860
Guide Height D2(mm)	290	338
head H(m)	640	510
MGV	No	Yes

References

[1] Yin, J. L., Wang, D. Z., and Walters, D. K, 2014, “Investigation of the unstable flow phenomenon in a pump turbine,” Science China, 57(6), 1119-1127.

[2] Yang, L., Chen, N. X., and Fan, H. G., 2006, “3-D two- way numerical simulation and performance estimation on the whole flow passage of the reversible pump turbine runner,” Engineering Mechanics, 23(5), 157-162.

[3] Li, L. C., Fan, H. G., and Chen, N. X., 2010, “Optimum design of pump turbine for bidirectional flow control,” Journal of Hydroelectric Engineering, 29(1), 223-228.

[4] Yin, J. L., 2012, “Study on the internal flow and optimum design of pump turbine in the “S” zone,” Zhejiang University.

[5] Zhu, B. S., Wang, X. H., Tan, L., Zhou, D. Y., and Zhao, Y., 2015, “Optimization design of a reversible pump turbine runner with high efficiency and stability,” Renewable Energy , 366-376.

[6] Lv, T., He, Y., Xu, H. Q., Xu, B. P., and Jiang, Z, M., 2007, “Acceptance test results of model pump turbine for Xilongchi pump storage power station project and it’s function analysis,” Construction of Pumped Storage Power Station Project , 85-93.

[7] Du, R. X., Chen, L, N., and Wang, Q., 2015, “Acceptance test results of model pump turbine for Qingyuan pump storage power station project and it’s function analysis,” Mechanical & Electrical Technique of Hydropower Station , 38(2), 12-15.

[8] Li, J., Wang, L., and Liao, W., L., 2014, “Internal flow characteristics analysis on S shaped region of reversible pump turbine,” Transactions of the Chinese society of Agricultural Engineering, 30(15), 106-113.

[9] Xiao, R. F., Liu, W. C., and Wang, F., J., 2012, “analysis of S characteristics and its pressure pulsation of pump turbine under pre-opening guide vanes,” Journal of Mechanical Engineering, 48(8), 174-179.

[10] Chen, T. J., Guo, P. C., and Zuo, Z. G., 2015, “Effect of different openings of pre-opened guide vanes on start op process of pump turbine,” Journal of Hydroelectric Engineering, 34(1), 203-214.

[11] Lv, W. J., 2014, “Research on the influence of the characteristics in pump turbine with misaligned guide vanes,” Lanzhou University of Technology.

[12] You, G. H., Kong, L. H., and Liu, D. Y., 2006, “Pump turbine S zone & its effect at Tianhuangping pump storage power plant,” Journal of Hydroelectric Engineering, 25(6), 136-153.

[13] Li, J. W., Chen, L., and Yu, J. X., 2015, “The research of S characteristics in the Francis pump turbine,” Mechanical & Electrical Technique of Hydropower Station, 38(2), 20-25