

Research on scheme of pumping energy-saving based on computer control technology

Li Chuan-Lin, Ma Shi-lei, Liu Hua, Wu Hai-yun, Gao Ping, Yang Fan

College of Engineering and Technology, Tianjin Agricultural University in Tianjin, CHINA

Abstract. Energy conservation of pump station has attracted more and more attention. The scheme of pumping energy-saving based on computer control technology was explored in this study by taking the example of Da Zhang Zhuang pump station in Tianjin. The results showed that when efficient was improved by 1%, the 170,000 kWh power would be saved annually. This method was applicable for the other pump stations with same style. What's more, for the pump stations which have already been controlled by computer program, it would be much more convenience that might be easy conducted in the near future.

1 Introduction

The importance and urgency of energy conservation and emission reduction is more and more recognized by our world [1-3]. To reduce costs, reduce energy consumption, and raise economic benefits is the goal of every business.

Energy conservation of pump station has attracted more attention; especially in the energy saving has become a national strategy today. There are a large and adjustable power consumption for the large fully regulated axial flow pump unit, which provide 1the necessity and possibility for the energy saving. However, there is not a better way to reduce the power consumption for pumping station effectively until now.

Computer technology has been widely used in the operation of automatic control, which provides a broad platform for the energy conservation scheme[4-5]. In this paper, the method to reduce power consumption in the process of the water delivery was explored based on computer control technology. 13502093313

2 Program analysis

2.1 Positioning principle of centroid localization algorithm

The power consumption in the process of the water delivery was showed in expression 1 and expression 2. Where h_1 was the water level of front pool of pumping station; h_2 was the water level of tail pool of pumping station; v_1 was the water velocity of front pool of pumping station; v_2 was the water velocity of tail pool of pumping station; η_1 was the motor efficiency; η_2 was the pump efficiency; E was the electric energy consumed per second; m was the amount of water flowing through

the pump; E_L was the channel loss; E_s was the channel potential energy of water flowing through the pump; and E_M was the work-energy of water flowing through the pump.

$$E = \frac{\left(\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2\right) + (mgh_2 - mgh_1) + E_L}{\eta_1\eta_2} \quad (1)$$

$$E = \frac{\Delta E_M + \Delta E_s + \Delta E_L}{\eta_1\eta_2} \quad (2)$$

In the long-term operation of pumping station, energy consumption was reduced by improving η_1 and η_2 by technical personnel usually. But for running management personnel, it has been impossible to adjust the internal parameters of the motor and the pump to achieve the purpose of improving efficiency. What we could do was to adjust its external parameters to make the unit as efficient as possible. In addition to external parameters, the efficiency of the motor was related to the ratio of the output power to the rated power. And the more the output power closed to the rated power, the higher for the efficiency.

The aim of optimal energy saving scheme was to get the least power consumption based on the premise of the completion of the water delivery task. According to the model of the experiment, the performance curve of 18CJ-63 pump was showed in Figure 1.

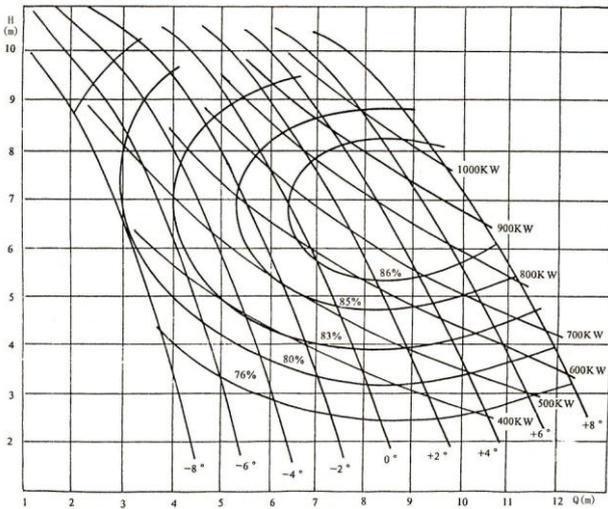


Figure 1. 18CJ-63-type pump performance curve

The flow rate Q and the head H were showed in the horizontal axis and the vertical axis respectively. Axial flow pump blade angle was from -8° to $+8^\circ$. There were nine equal blade angle curves and equal power curves. The most significant group of egg shaped curves was the equal efficiency line. The most inside circle was the most efficient area where can achieve the highest efficiency for water pump. Generally speaking, the pump was expected to run in high efficiency so that to get the most energy-efficient. But it was often impossible in fact. Because of the pursuit of high efficiency by only increasing the pump head would increase the pump power. In fact, what we pursuit was to achieve the same purpose (dispatching order) with the least consumption of electricity. It was also the most reliable and direct method that might be considered as the final energy saving program.

In order to improve this, Tianjin water diversion project was used as an example to analyze. This station was equipped with five 18CJ-63 type water pump and a TL900-24/2150 motor. The design flow rate was 30M³/s. The design level of the front pool was from -1.78m to -1.10m, and the water level was from +2.90m to +2.30m. The actual head was between 3.40m and 4.68m. From the pump performance curve, the head should be increased in order to improve the efficiency (reducing the level of the former pool, and raising the level of the tail pool).

From the previous analysis, there was almost no change for ΔE_m , but a increase for ΔE_s . If the actual head increased 1m, ΔE_s would increase 9.8×10^4 J of energy consumption per second when the flow was 10 M³/s. The efficiency η_2 could increase 1% ~ 4% from the figure. As to the motor efficiency η_1 , the rated value was 93.5%. Mechanical loss was accounted for about 70% ~ 80% of the total loss. And there was litter change basic iron loss, stimulate loss and additional loss. There was only slightly increased for the total loss of the motor with the increase of the input power. Since pump supporting motor generally would not reach the rated maximum value, the total loss of the motor was setted 6% of the rated power. The efficiency was expressed in the

equation 3. Then when the output power of the motor was 500 KW, the motor efficiency η_1 was 90.3% according to equation 3.

$$\eta_1 = \left(1 - \frac{\sum p}{P + \sum p}\right) \times 100\% \quad (3)$$

$$\eta_{\max} = \eta_{1\max} \times \eta_{2\max} \quad (4)$$

Thus it assumed that when the flow rate was 10m³/s, the total efficiency increased by 6 percentage points and achieved the highest after the lift raised 1 m, which could be expressed in the equation 4.

At the highest efficiency the input power per second can be up to 963J. The total loss was 774 x 10³ J. While before the head increased, the total efficiency was 74.4%, and the loss was 676 J. And 909 J input power per second was needed. So it could be find that although the overall efficiency of the unit could be improved with the lift increased, the input power was increased by 54 J. On the other hand, if the total efficiency was reduced after the lift decreased, the total energy consumption was reduced too. Of course, it was depend on whether the raised of lift was necessary for the water transfer or not [6].

The pump unit included the pump and the motor. In this study the pump unit was took as a whole, and the power consumption for the unit to achieve the same purpose was used as the index to select the measure of energy saving program. For multi-unit pumping station, the power consumption for the whole pumping station to achieve the same task was used as the index to select the measure of energy saving program.

Based on this idea, the actual consumption for all the pumping station of each program at all possible operating conditions were measured. In order to achieve the purpose of saving electricity, all the programs were compared, and the least power consumption program was used to complete a task.

2.2 Computer control technology for Luan River

There was no better way to complete the works by taking use of computer. We took the example of Da Zhang Zhuang pump station, part of Luanhe-Tianjin Water Diversion Project to explain. This pump station was composed of 5 pump units, with design flow 30 m³/s, and its target was to transport the water from Er Wang Zhuang upstream to down stream. In another word, it should guarantee the water quality free from influence under certain flow and keep the water level of former and rear pond and blade angle in a certain adjustable range.

The blade angle was separated from +80 to -80 by 17 operation point with one point for 10, in which 11 points for former pond water level from -1.78m to 0.78m with one point every 10 CM, and 8 points for rear pond water level from 2.2m to 2.9m with one point every 10 CM. Then three parameters were combined. The input power and flow rate of each unit were recorded. Two three-dimensional array could be established based on the leaf angle, the front and the back pool water level as the index variable, the corresponding flow and power for the array values. For the whole pumping station (up to three units), the leaf angle of other two units were taken as the index variable (when only one set was on, the other two sets of leaves was -100). Thus two three-dimensional array could be established. When there was a certain flow of water from the upstream pumping station, the computer would be able to compare the power at the various operation of this traffic, and found the best way to run.

Firstly, the reference flow of every operation point as mentioned above was measured with flow gauge and standard section, and then the possible flow was divided into many flow points with equal distance by using the method above. Next the stable was test for every flow point under the premise of same upstream flow and same flow for each point. As for the unstable point, we could upgrade or degrade to guarantee the flow provided for each point for every operation method on every flow point is equal. Then the power in every operation method at the same flow point was compared to find out the optimal operation point. While if the flow was accurate or not will not affect the result. Besides, we could confirm the optimal operation flow to provide reference for water maneuver by comparing every flow point with the method and the reference flow above.

3 Application of computer control technology

3.1 Control technology plan

In the actual operation, with computer governing program, the stable running could be achieved by adjusting water level of former and rear pond、blade angle and numbers of pump started, and then the optimal operation method could be confirmed in accordance with the certain reference flow concluded in the stable operation by Flow Digital Module [7-9]. If the stable operation was disturbed by changing of flow, it could be re-stabilized by governing the blade angle or numbers of pump started. The new optimal operation point could be confirmed in

accordance with the new flow concluded in the re-stabilized operation. The specific flow was showed in Figure 2.

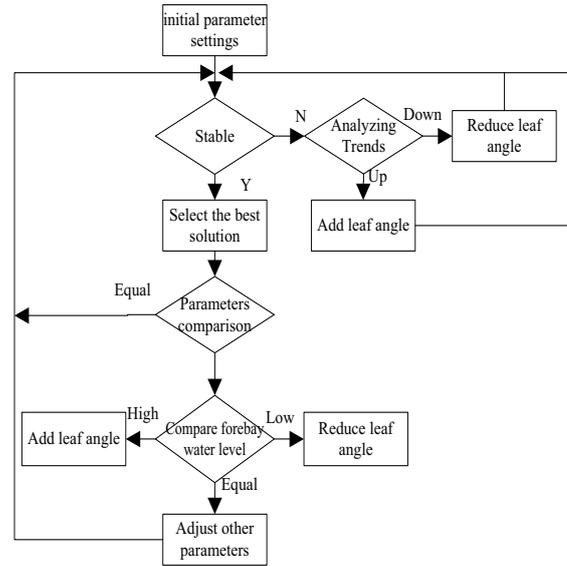


Figure 2. Specific flow

3.2 Application of Da Zhang Zhuang

As mentioned above, the computer program should be capable of data-collection of water level of former and rear pond\blade angle and running power etc. and of adjustment these data except the running power. Da Zhang Zhuang pump station have achieve the requirement above. The blade angle\water level\running power\numbers of pump started and its tag could be inputted into computer by transmitter and blade angle as well as water level could be adjusted automatically. If the flow (or related parameters) was inputted in to computer too by adding an experimental program, the operation above could be performed and gated the experiment data by computer itself which would be much better. Because it would take much more time and man power by mankind to perform the experiment with so many points. While by computer program, the data collection and storage could be taken by the computer after adjustment of these parameters. And it could collect another group of data soon and store them again.

Meanwhile, it could capable of experiment with big and small flow alternatively, as so to keep the general water volume same with upstream input water volume in a certain period of time. In the experiment, either with big or small flow could be decided by the high or low water level of former canal before the pump station and the gate valve, so that the experiments with so many operational points could be competed in a short time, with getting all the possible operational data of pump station. Obviously, it was also a challenge for equipment and facilities involved that operation parameters and flow during experiment would be changed so frequently. However it was acceptable during the emergency water transporting mission and non-full-load water transporting mission.

Due to the adjustable precise of the blade angle/water level of former and rear pond and flow was limited, the interval of operational point was big. As a result, the data measured in the actual operation should be dealt with to be equals to approximate operational points. Although it would not be precise, the power changing would not be tremendous if data altering was not big, and the operational points would be near the optimal points eventually. If the optimal operation method could not be feasible due to some reason, such as the water level of downstream was so high that rear pond water level could not be lower than a certain value, the best operation method could be selected in all the feasible methods, which shall guarantee the pump station could be running in the power saving status all the time.

4 Summary

Pumping station was an important water conservancy infrastructure. It played a key role in the cross basin water transfer project, farmland and regional drought resistance, urban flood control and drainage, urban water supply, and sewage discharge. With the development of the national economy and the national energy consumption, the performance of the pump device was took more and more attention. In order to meet the needs of the society and promote the further development of the pump device, the key technologies of the water dynamic characteristics and multi objective optimization of pump device was studied by theoretical analysis, numerical simulation and physical model experiment.

By taking the example of Da Zhang Zhuang pump station as above, one of the methods of computer using in the energy conservation of pump station was discussed. As for the large-scale pump station as Da Zhang Zhuang, whose power could be more than 2000kW during all three units operation at the same time, if its efficient was improved by 1%, the 170,000 kWh power would be saved annually. As for the other pump station with same style, this method was applicable too, only if the related parameters could be adjusted specifically in accordance with actual status. Especially, for these pump stations which have already been controlled by computer program, it will be more convenience. The method above was necessary to be completed and improved in the actual practice.

Acknowledgements

The research work was supported by Innovation and Entrepreneurship Training Program of Tianjin(201510061070 and 201510061140) and College students of science and technology innovation projects of Tianjin Agricultural University

References

1. J. P. Wu. Xi'an University of Technology. (2005)
2. Y. P. Zhu. Hunan University. (2005)
3. J. K. Fu. Hefei University of Technology. (2009)
4. W. Zhang. Zhejiang University. (2010)
5. Z. J. Zhang. Chongqing University. (2012)
6. S. Wei. University of Science And Technology. (2007)
7. C. H. Xiao. Hunan University. (2014)
8. A. H. Zhang. Xian University of Architecture and Technology. (2004)
9. X. X. Liu. Tianjin University. (2012)