Application of the theory of double actual power generation in run-of-river hydropower stations’ management

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Abstract. The number of hydropower stations is large in China. The parallel industrial benchmark of run-of-river hydropower stations is not significant, for there are quite different characteristics from each run-of-river hydropower station, so it is necessary to study vertical benchmark of the hydropower station itself. Based on this, the theory of double actual power generation is put forward, and the model of vertical benchmark of run-of-river hydropower station is built after analysing the dynamic and convergent characteristics of the theory. After the model is used actually in Duosongduo hydropower station, the rationality of the theory is verified, and the benchmark management effect is remarkable. The theory of double actual power generation has a wide range of practicability and can be generalized. The theory can be applied in the management of various enterprises, groups and families, and can be extended to the management of many quantitative indicators. It has innovation in management and valuable for further study in economics.

1. Introduction
China is rich in water resources, ranking first in the world in terms of water energy resources [1]. The generating capacity of hydropower stations which has been developed is the largest in the world. According to the utilized mode and adjusting capacity of natural water flow, hydropower stations can be divided into run-of-river hydropower stations and impoundment hydropower stations. Run-of-river hydropower station refers to a hydropower station which has no reservoir or small reservoir capacity and has no adjustment capacity or little adjustment capacity for natural water flow. Run-of-river hydropower stations are generally small hydropower stations. Impoundment hydropower station refers to a hydropower station which has a reservoir with a certain capacity and has different adjustment capacity for natural water flow. This is a huge number that the number of planned hydropower stations with generating capacity of less than 50MW accounts for over 98% of the total number of hydropower stations [2], which is a huge number. For the utilization of water energy, because differences of adjusting ability are different, the utilization efficiency of the impoundment hydropower station is higher than that of the run-of-river hydropower station. Investment in hydropower projects, especially small and medium-sized hydropower projects, is mainly about power generation except for the necessary public welfare functions. The investors of the project are mainly concerned about the economic benefits of hydropower generation [3]. The power generation of small hydropower stations is the decisive factor of
the economic benefit of the project. Therefore, the water energy utilization rate is the key point of hydropower station management.

To improve the utilization rate of water energy of the run-of-river hydropower stations, the generating load can be adjusted at any time according to the incoming water by keeping high water level, so as to keep the generators in an efficient running state as much as possible. Therefore, in the production management, most hydropower stations adopt the industry benchmark to find the gap and improve the operation mode to achieve better business performance, which is also called the parallel benchmark. As each hydropower station is located in different river basins, the hydrological characteristics are diverse, the generators' model is different, and the design and utilization hours differ greatly, the comparison of small run-of-river hydropower stations is unimportant, and the parallel benchmark is not significant. Therefore, it is necessary to study and find the vertical self-benchmark method.

2. Theory of double actual power generation

Being dedicated to hydropower station management for many years, after analyzed and researched the method of benchmark of hydropower stations, the authors put forward the theory of double actual power generation, which can be used for self-benchmark of run-of-river hydropower station, in order to make the benchmark of run-of-river hydropower station scientificity and reasonability, and to find the effective management mode of run-of-river hydropower stations.

2.1. The definition of double actual power generation

The double actual power generation is the actual power generation in the current year add the sum of the actual power generation the remaining period of the last year, which is a dynamically predicted yearly power generation. It's formula as follows:

\[ P_{d} = P + P_{l} \]  

(1)

\( P_{d} \)—double actual generation, kWh; \( P \)—cumulative power generation this year, kWh; \( P_{l} \)— the sum of the actual power generation the remaining period of the last year, kWh.

2.2. The curve and characteristics of double actual power generation

2.2.1. Graph of double actual power generation. We change equation (1) to get equation (2).

\[ P = P_{d} - P_{l} \]  

(2)

Double actual power generation \( P_{d} \) is a dynamic time point value. Although \( P_{l} \) varies over time, it is a fixed value at each time point.
Figure 1. P-T Curves of Double Actual Power Generation

At 0:00 January 1st, formula (1) denotes \( P_{d0} = P_0 + P_{l0}, P_0 = 0, \) and \( P_{d0} = P_{l0} \), that is, the double actual power generation at the beginning of the year is the actual power generation of last year. We named \( P_{d0} \) as the yearly base power generation, that is, the yearly planned power generation is the actual power generation of last year. \( P_0 \) is the power generation at 0:00 January 1st, this year; \( P_{d0} \) is the double actual power generation at 0:00 January 1st, this year; \( P_{l0} \) is actual power generation last year.

Taking power generation \( P \) as the vertical axis and time \( T \) as the horizontal axis, so the curves of \( P, P_d, P_l \) and \( P_{d0} = P_{l0} \) were drawn in the T-P coordinate system, and \( P_{d0} = P_{l0} \) curve was defined as the yearly baseline, as shown in Figure 1.

2.2.2. Curves' characteristics. It can be seen from Figure 1. that the slope of curve \( P, K_P \geq 0 \), and the slope of the curve \( P_l, K_{P_l} \leq 0 \). The curve of \( P_d \) may fluctuate up and down near the yearly baseline \( P_{d0} = P_{l0} \).

When the double actual power generation exceeds the yearly baseline, \( P_d > P_{l0} \), the cumulative power generation \( P \) is greater than that of the same period last year. Meanwhile, the yearly power generation is more likely to exceed that of last year. \( P_d \) has dynamic and convergent characteristics.

The dynamic nature of double actual power generation is conducive to predict the possible power generation in the whole year dynamically and timely. In order to improve the management, accurately predict the power generation, income, profit and other indicators for the whole year, the manager can dynamically grasp the production and operation situation and reasonably arrange the later work.

The convergence shows when \( P = 0 \), \( P_d = P_{l0} \), that is, the double actual generation at the beginning of the year (the actual power generation last year) is the base generation this year; When \( P_d = P, P_l = 0 \), double actual power generation is the cumulative power generation of the whole year, and also is the actual yearly power generation at the time of 24:00 on December 31, this year.

Figure 1 shows that the annual plan adopts the actual power generation of the previous year directly, and adjusts the double actual power generation according to the cumulative power generation of this year. Over time, it gets closer and closer to actual power generation.

3. Application of the theory of double actual power generation

3.1. The diurnal benchmark of double actual power generation
Theory comes from practice, and its correctness must be proved by practice. Only theories that can be applied to practical management can have the value of existing and the possibility of promotion.
Table 1. The actual power generation of Duosongduo hydropower station in 2017 and 2018

| Date       | Jan.2017 | Feb.2017 | Mar.2017 | May 2019 | Aug.2019 |
|------------|----------|----------|----------|----------|----------|
| P           | 8442.55  | 5795.41  | 909.1     | 309.4    | 568.8    |
| Pd          | 4653.25  | 44.4     | 45.7      | 55.9     | 44.2     |
| Pl          | 300      | 45.6     | 30.9      | 45.7     | 44.2     |

On the basis of the theory of double actual power generation and the practical experience of many years of work, we put forward the double actual power generation diurnal benchmark of Duosongduo hydropower station in the upstream of Taobe river in Gansu province, that is, the benchmark of power generation of the same day in 2018 and 2017. It is the vertical self-benchmark of run-of-river hydropower station.The actual power generation of Duosongduo hydropower station in 2017 and 2018 is shown in Table1. The data in Table1 shows that the daily power generation increased significantly in 2018 than that of the previous year.

3.2. Curves of The actual power generation of Duosongduo hydropower station According to the actual power generation of Duosongduo hydropower station in 2017 and 2018, compared the diurnal power generation, for convenient analyzing and mapping, we calculated monthly P, Pd and Pl and showed them in Table 2.
Figure 2. The P-T curves of the double actual power generation of Duosongduo hydropower station in 2018

Compared with Figure 1 and Figure 2, the actual curves are consistent with the theoretical curves, and the practical application fully conforms to the theoretical prediction.

3.3. Results of application of theory of double actual power generation

Based on the system, the management of the diurnal benchmark of double actual power generation of Duosongduo hydropower station motivates every employee. Everyone dedicate to the main task and makes efforts actively. The main achievements are as follows:

(1) The obvious increment of power generation, excluding the influence of incoming water, is mainly reflected in the increase of water head height and the maintenance of water level in the hydropower station, which effectively reduces the water consumption rate of generation and improves the generation efficiency.

(2) With the diurnal benchmark of double actual power generation as the core of their work, all the staff carried out a comprehensive search for problems, increased the self-consciousness to make up for the shortcoming, and the team spirit was fully displayed.

(3) The transparent and open management goal encourages all employees participate in every job actively, so that employees know what they should do and have clear goals.

(4) Through the process management, finally achieve the goal management.

(5) The dynamic double actual power generation is easy to find the gap, which can be analyzed as soon as possible to find the solution or redetermine the reasonable target.

4. Conclusions and prospects

4.1. Conclusions

The proposal and application of the theory of double actual power generation, especially in various benchmark management such as industry and market management, is of great practical significance and has theoretical breakthrough. The following conclusions are mainly drawn:

(1) Dynamic is an important feature of double actual power generation, which can predict the power generation in whole year. It is very suitable to use in dynamic management of the enterprise production.

(2) Convergence defines the range of double actual power generation, which is easy for the manager to grasp the variation range of power generation.

(3) The application of self-benchmark in run-of-river hydropower station provides experience for vertical benchmark of similar power generation enterprises.

(4) The diurnal benchmark of double actual power generation realizes the piecework assessment of electric power products, which it is scientific and can mobilize the enthusiasm of all employees, and also give play to the initiative of the team.
(5) The management of double actual power generation is the method of run-of-river hydropower station refinement management, and it is also the trigger of enterprise refinement management.

4.2. Prospects
Because of the successful application of the theory of double actual power generation in the management of run-of-river hydropower station, and its basis and conditions of the theory, it can be popularized in photovoltaic power generation, wind power generation and other power generation enterprises.

If we change the double actual power generation to double actual production, double actual income, double actual profits, double actual expenditure, and so on, this theory can be applied to any of the various management, for example, enterprise management, group or family management, which has extensive applicability and practicability. The significance of practical application in management is prominent, and the economics significance should be further studied.

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References
[1] Xuzhi, Majing, Jiajinsheng, Zhangying, Wangfei. International comparison of hydropower resources development[J]. Advances in Science and Technology of Water Resources, Vol.38 No.1.2018,63-67.
[2] Yang Hongxing. Theories and Practices of Small and Medium Hydropower Project Management and Post-evaluation in China[D]. Chengdu. Sichuan University, 2012.
[3] Yang Hongxing, Liang Chuan, Jiang yurong, Yang Jilong. Analysis of impact of operating cost change on economic benefits of Dahuang hydropower station[J]. Journal of Water Resources & Water Engineering, 2011, 6:171-173.