Labor-Saving Initiatives in Basic Design of Hydropower Generator

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Keywords Hydropower generator, Business improvement, Optimization, Active use of AI

Abstract

The hydropower generation market is booming in Japan thanks to the Feed-in Tariff (FIT) system, and the burden on designers continues to be high. The specifications of hydropower generators vary depending on local installation conditions and operation methods, and the basic design stage is burdensome because optimal power generation is required. To reduce the burden on designers during this estimation work, we evaluated basic design methods that use design optimization support tools and Artificial Intelligence (AI).

For the electrical design, we evaluated the design optimization support tool because the estimation work process can proceed in a sequential manner. Although some adjustments are still required, the system was confirmed to exhibit high accuracy in electrical design. Since structural design requires experience and knowledge, we evaluated a design method using AI and found that there was still an error of about 15%, so on-going improvements are being made in the structural design.

1 Preface

In the business of typical hydropower generator design, it is expected that inquiries for hydropower projects will continue to increase in the future while it takes time to train designers and pass on technology. Furthermore, the basic design of a hydropower generator requires multiple internal review processes including alternative estimates and efficiency improvement studies, which are a heavy burden on the designer.

To reduce this burden, we need to build an efficient basic design flow, compile a database of the know-hows of well-experienced designers, and supplement it with the latest technology such as Artificial Intelligence (AI). In doing so, it is necessary to build a design system that can be handled by even new designers.

The conventional design method that forms the basis of estimation work is a design based on past track records and experiences of designers. Measures to address new issues such as increasing efficiency are also required.

New efforts were made, including the use of design optimization tools and AI technology. The design was optimized and the efficiency of the design was verified. In this paper, we present the results of verifying whether basic design using optimization support tool and AI technology can reduce the burden on designers.

2 Application of New Technologies to Basic Design

Fig. 1 shows a basic design flow. In the basic design, various constants are calculated using electrical design based on the input of customer specifications, and design values are determined using a design sheet. Based on this design sheet, the final generator structural design document will be created through structural design.

Fig. 2 shows an overview of the design optimization support tool. Electrical design work uses multiple tools and each parameter is adjusted to achieve an optimal design. The design optimization support tool integrates these design tools and automatically and repeatedly calculates parameter adjustments. The system is, therefore, designed so that the designer can automatically calculate candidates for an optimal solution by simply inputting basic information about the specifications. This calculation takes time, but during this time the designer

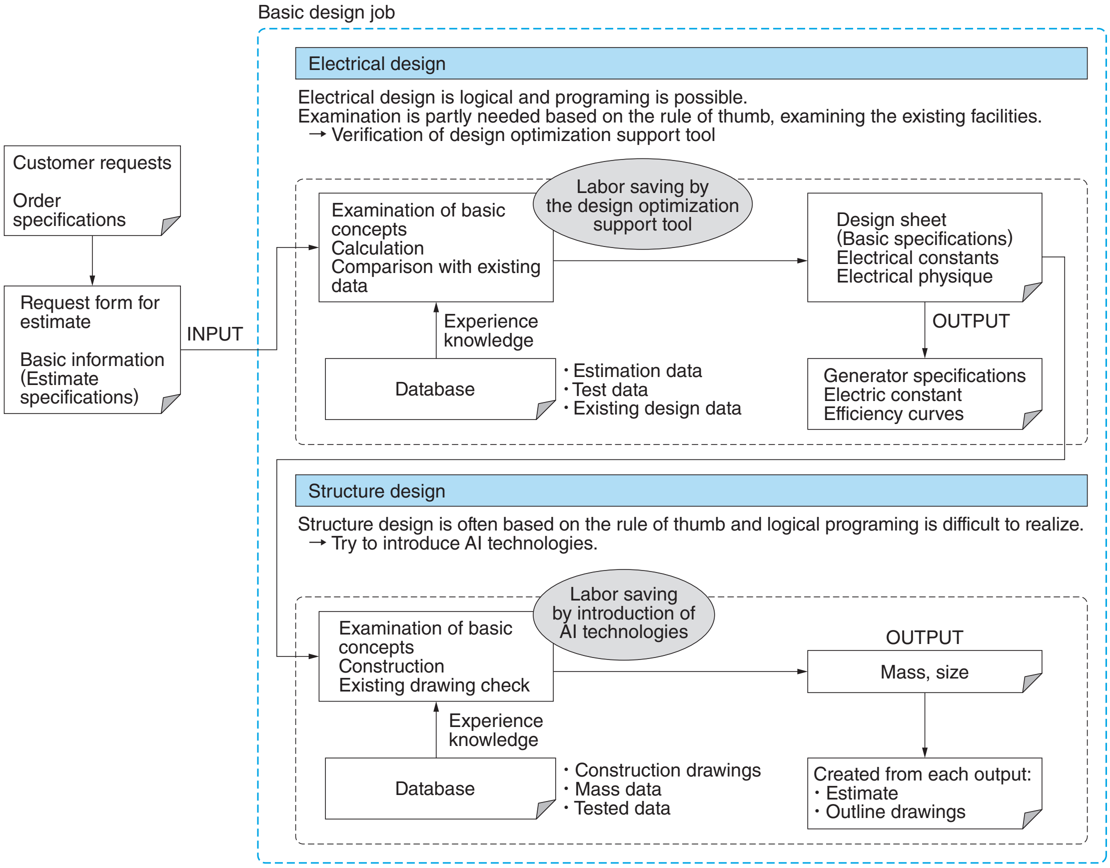


Fig. 1 **Basic Design Flow**

Basic design flow is shown.

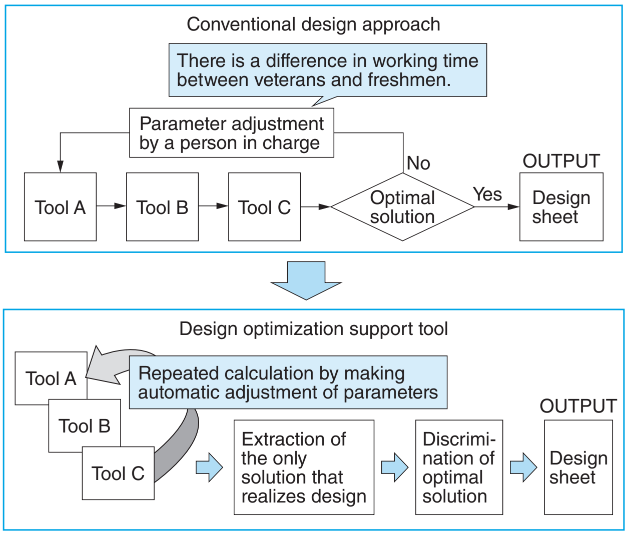


Fig. 2 **Overview of Design Optimization Support Tool**

A difference between a conventional design approach and the adoption of the design optimization support tool is shown.

can handle other tasks, greatly improving work efficiency.

The structural design of the generator is designed based on the design sheet created by an electrical design, but there are areas where knowledge and design expertise are strongly involved, and like electrical design, it cannot be designed with current tools. This kind of knowledge and expertise can be used effectively to derive optimal solutions by having AI learn from a database of previous results. Since the type of bearing (pedestal bearing, rolling bearing, etc.) greatly affects the AI machine learning results, we examined pedestal type bearings, which are often used in horizontal shaft generators.

3 Design Optimization Support Tool

In electrical design, we use various tools to create design sheets based on customer specifications. Comparing the time required for this work between experienced and new designers, it was found that new workers require nearly twice as much time as experts. One reason for this is that novel designers lack design work experience and require time to adjust parameters to obtain an optimal solution.

A design optimization support tool uses various tools to refine parameters and automatically repeat calculations for optimal solutions. It is, therefore, expected that even inexperienced workers can accomplish tasks in the same amount of time as experienced workers.

This optimization design support tool also has the advantage of being able to select between single-objective optimization and multi-objective optimization, allowing calculation results to be obtained in accordance with the design objective.

This time, we used "generator efficiency" as the objective function for a single objective and verified "generator efficiency" and "output coefficient (Ku ≒ output ÷ volume)" as objective functions for multi-objective optimization.

The optimal solution is searched from the results of one set of calculations (200 times), and the results determine the initial values for the next set. The next set of initial values can, therefore, start from conditions closer to the optimal values. Rather than calculating 6000 times continuously, it is better to divide the calculation into a certain number of times. Because this allows us to efficiently reach the optimal solution, we adopted a method that divides the calculation into a fixed number of times, and in this development, we decided to repeat the calculation 200 times/set × 30 set.

4 Calculation Accuracy of Design Optimization Support Tool

Fig. 3 through **5** show the results of model case calculations using the design optimization support tool. It is a diagram plotting the results designed by the designer and the results are calculated using the optimal design tool. Note that the gray plot is valid as a generator design, but the calculation results cannot be said to be superior to the optimal solution in terms of efficiency and output coefficient.

In addition, when calculating with the design optimization support tool, the following calculations were made using the following conditions.

(1) In designing using AI on the structural design side, (which will be later described), existing design conditions were set as constraints on the design optimization support tool for AI machine learning on the existing design database.

(2) In order to confirm the relationship between the number of generator poles and the number of calculations, the number of calculations was kept constant during evaluation.

Fig. 3 shows the calculation result for a 12-pole generator and is based on actual result. In contrast, calculation results have been obtained that are superior to existing designs in both single-purpose and multi-purpose designs in terms of efficiency and power as an output coefficient.

Fig. 4 shows the calculation result for a six-pole generator, and like **Fig. 3**, the calculation result is superior, but in some areas the calculation result is not obtained.

Fig. 5 shows the calculation result for a 12-pole generator with different specifications from those in

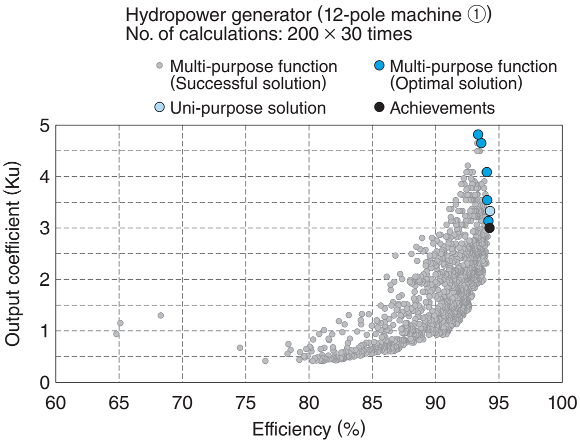


Fig. 3 **Design Optimization Support Tool: 12-Pole Generator Calculation Result ①**

The calculation result of efficiency and output coefficient by a conventional approach was compared with the method done by the design optimization support tool. The result of the calculation with the design optimization support tool is superior to the conventional approach.

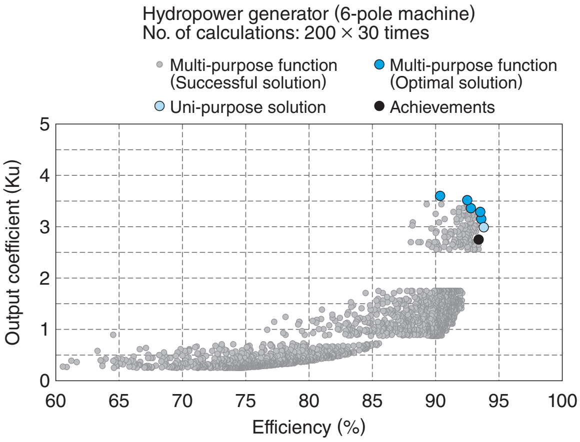


Fig. 4 **Design Optimization Support Tool: 6-Pole Generator Calculation Result**

Similarly, as for **Fig. 3**, the result of the calculation by the design optimization support tool is superior to the one done by conventional approach. There is, however, no result in some part of the domain. This suggests a fact that the number of calculations is insufficient.

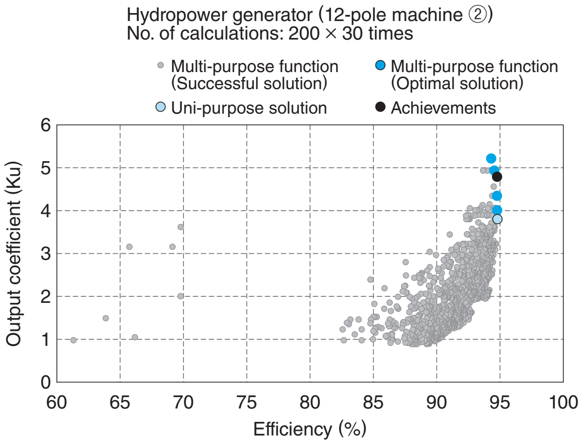


Fig. 5 Design Optimization Support Tool: 12-Pole Generator Calculation Result ②

Similarly as for **Fig. 3**, a 12-pole machine was used for the calculation, but different specifications were applied. Unlike **Fig. 3**, the result cannot be said to be more significant than the design values. It can, however, be said that it is superior in terms of individual parameters. It is possible to conclude that the result was superior to the design values through the concentration of the calculation on parameters close to the optimal solution.

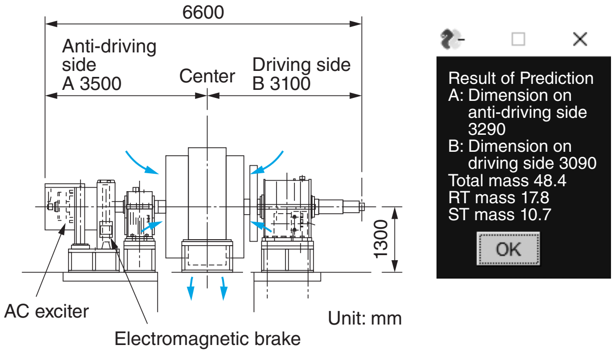
Fig. 3. Even for the same 12-pole machine, the result of the calculation in **Fig. 5** indicates that the goal functions of both efficiency and output coefficient are not significant for the design values of the designer. For individual items such as efficiency and output coefficient, however, results were obtained that were superior to the design values.

The reason why there are areas where no calculation results are obtained in **Fig. 4** and why optimization is not achieved in **Fig. 5**, is thought to be due to the insufficient number of calculations because the number of calculations was kept constant. Although we did not narrow down the range of parameters this time, it is necessary to consider parameter convergence so that the number of calculations close to the optimal solution increases.

Based on the above, it is necessary to improve and verify the constraints and number of calculations to further improve accuracy, but we confirmed that the burden on designers can be reduced by using the design optimization support tool.

5 Utilizing AI for Structural Design

We verified the validity of man-hours and costs using a tool that quickly predicts dimensions and mass based on specifications and electrical design information for hydropower generators. In this verification, we built an AI-based prediction model using a hydropower generator database, and produced an AI-based prediction software.



Result of Prediction
A: Dimension on anti-driving side 3290
B: Dimension on driving side 3090
Total mass 48.4
RT mass 17.8
ST mass 10.7

Fig. 6 AI Tool Output Parameters

An explanatory drawing of parameter output from the AI tool is shown.

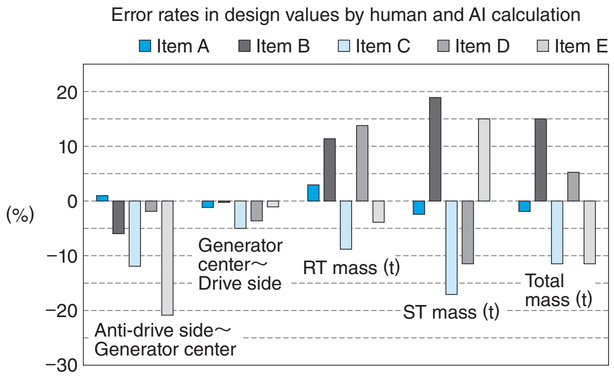


Fig. 7 Comparison of Human Design Values and AI Design Values

The result of a parameter calculation by an AI tool is shown. There is a great divergence according to conditions. The error range, however, is suppressed to approximately 15%.

Since product specifications for hydropower generators are not standardized, they must be designed and manufactured for each project case. The basic design also needs to be examined in accordance with the specifications each time. Similar existing hydropower projects exist, and AI-based basic design methods that make predictions from statistical information from existing data are effective in increasing efficiency. This method allows AI to learn a database of generators and output representative parameters of the generator. **Fig. 6** shows the AI tool output parameters.

Furthermore, the results of the AI learning are converted into software and can read the data sheets created in the electrical design process mentioned above, so there is no need to input data and the calculations take only a few minutes.

Fig. 7 shows a comparison of human design values and AI design values. In case Item E, there is a large deviation in the dimensions from the non-drive side to the center of the generator. This is due to the presence or absence of a brake ring. As suggested, it is necessary to adjust part of database and AI learning. Despite this, we confirmed that the error range was approximately 15% or less compared to the designer's design values.

It is at a level that is sufficiently useful preventing design errors for through rough estimation and comparison of design results.

In addition, since the learning database contains a mixture of design values and actual results, it is thought that accuracy can be further improved by enriching the database based on actual results.

6 Postscript

We tested the design optimization support tool and tools that utilize AI to reduce the burden on designers and confirmed the efficiency of the basic design and accuracy of the optimization tools. Although the accuracy is still at the verification stage, we will continue to improve the design in the future. We intend to use this system as a tool to further improve accuracy.