BORN TO ENGINEER

Application of Design Automation to Reduce Cycle Time of Hydro Turbine Design

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Introduction

Hydropower is the largest renewable source of electricity and there is lot of focus in upgrading existing hydel Power plants in India, or set up new ones. With the rapid growth in the demand for electricity and increased credit risks in the financial markets, there is a strong business driver to reduce the design to commission cycle time of hydel power plant projects. Hydro turbine design depends on the physical condition where the power plant needs to be set up (Head available, Discharge Volume etc) there by making every unit a unique design. In a typical Hydro turbine assembly more than 10000 components goes in and some 1000 plus drawings (manufacturing drawings, process drawings etc) and 3D CAD models needs to be created. Adding on to this the other challenge is non availability of many experienced hydro designers. Under such circumstances key to the success would be to integrate the design process and CAD process and automate the same. The concept of knowledge based engineering and design automation can help the major Hydro OEM's in reducing the engineering cycle time considerably. Hydro Turbine design process can be automated from the concept design stage, through layout design and detailed design phase, culminating in the automatic updation of manufacturing (or machine shop) drawings.

Bulb Turbine Design

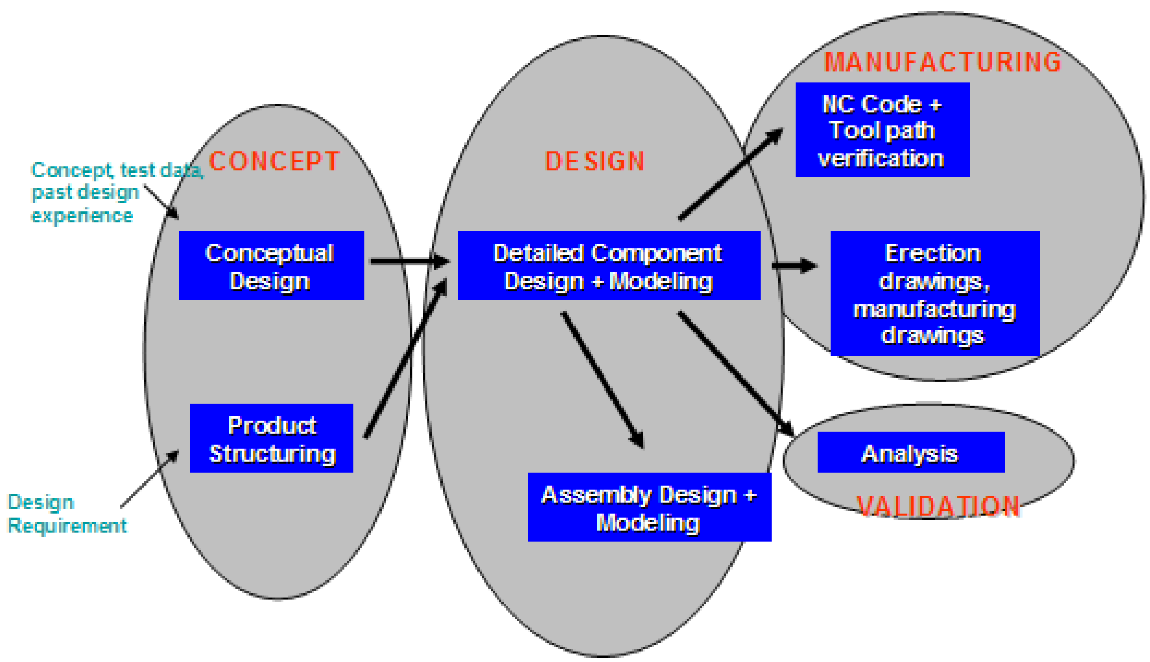
Bulb Turbine, a reaction type of Kaplan Hydro Turbine, is considered to be one of the most appropriate solutions for getting maximum output at lower heads. It is characterized by having the essential turbine components along with the generator inside a bulb like enclosure.
A typical bulb turbine excluding the generator would comprise of:

- Foundation Ring & Draft Tube
- Discharge Ring
- Runner Assembly
- Wicket Gate & Operating Mechanism
- Stay Cone
- Shaft & Oil Supply pipes
- Packing and Packing Box
- Bearing and Bearing Casing

The bulb turbine design begins with generation of a homologous model of the hydraulic passage from intake to the tailrace. This water passage is designed based on computational fluid dynamic calculations together with consideration of civil structure. After doing this, the profile of the upstream passage, the approach to the turbine casing and the tailrace leaving the draft tube is optimized and designed. Before the design and manufacture of the prototype machine, various types of model tests on hydraulic performance model are carried out. Based on the outcome, the final prototype of the Bulb turbine is defined. Using this prototype, the detail design and assembly of the complete turbine is done. In the process assembly and sub assembly drawings, component and hardware drawings, bill of material and the process drawings are generated. Any hydro turbine designer needs to spend considerable amount of time during the bidding stage where the initial calculations are done to calculate the weight of material required and cost along with cross section drawings of the proposed turbine. Then after the project approval CAD models for carrying out FEM calculations and other engineering calculations are created and developed. While doing the detailed design thousands of drawings with multiple iterations are required to be generated. Sometimes because of some manufacturing faults, some assembly drawings or component drawings need to be redone. These are typical of the challenges faced by any Hydro Turbine OEM.

Description of CAD & Design Automation Model

With the influx of highly sophisticated CAD and PDM, PLM software, automation has become relatively simpler. Most CAD software used by designers is based on the concept of Knowledge Based Engineering (KBE). Using KBE, the CAD models can now be made smart to retain the design rules and criteria and also automate them. The diagram below gives a graphical illustration of a generic design process.



The bulb turbine design also follows a similar design path starting with conceptual design of the water passage, followed by the development of the prototype, detailed design and finally the creation of erection and process drawings.

1) The design automation system starts with a parametric hydraulic passage drawing for the Bulb Turbine. This is obtained through extensive model tests in the past.
2) The parameter of the master model of the individual components is decided based on the pre-determined hydraulic passage and detail component level design.
3) The assembly model of the complete bulb turbine has parameters linked from the hydraulic passage drawing and also the component level models. The assembly model also has some additional parameters like positional dimensions which are calculated at the assembly level.
4) The standard hardware details are selected from a lookup table developed in Microsoft Excel and these hardware details are captured in the bill of material. The non standard hardwares are developed parameterized master model and the individual parameters are updated based on the design calculations.

The hydraulic passage drawing, the master models and the associated drafting sheets are all developed based on the concept of knowledge based engineering.

The following figure explains the automation flow:

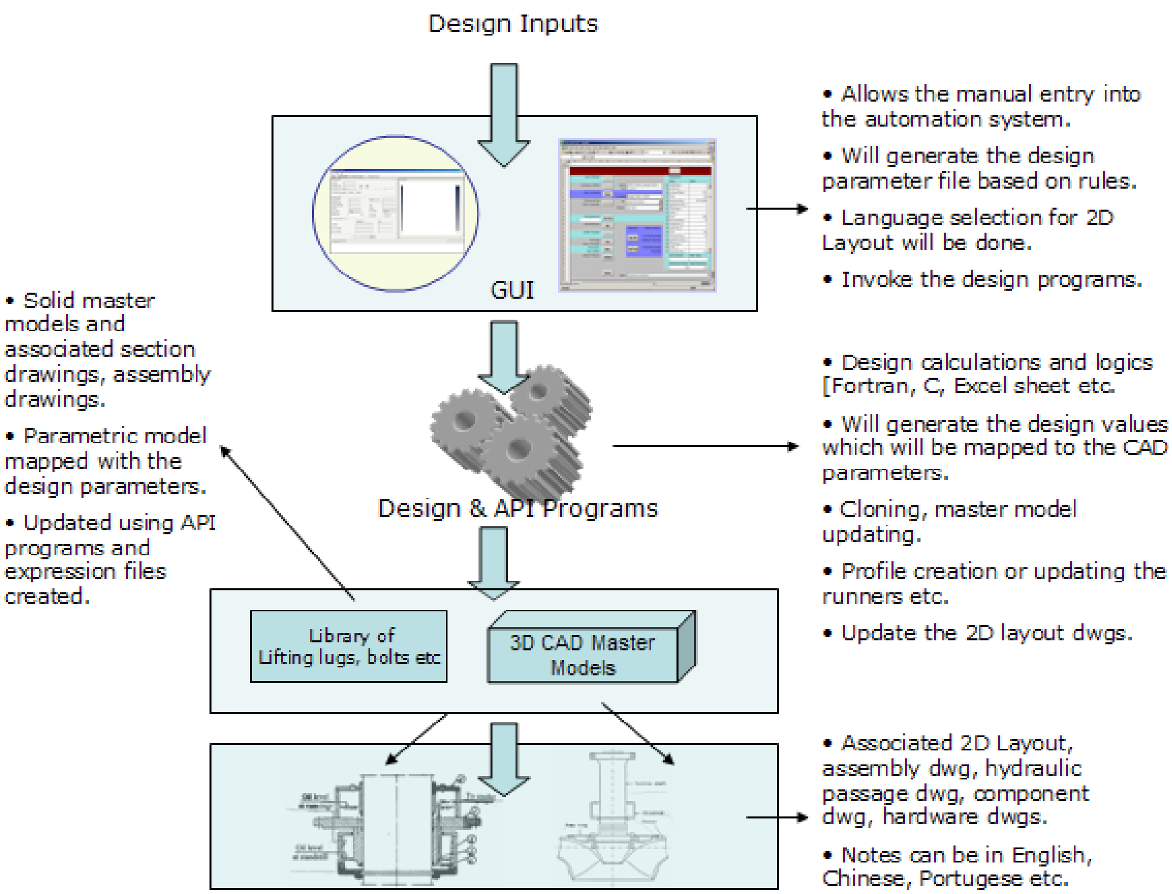


Figure: Automation System High Level Concept

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The user interface for this design automation system is Microsoft Excel workbook. The CAD master model handles different design configurations and topology of the bulb turbine like 3, 4 and 5 blade runner type. These master models are parameterized and the CAD parameters are named according to the design parameters of the bulb turbine. These CAD 3D master models also have linked drawings that contain notes and annotations in multiple languages in different layers. Based on the language selected by the user the corresponding layer is selected and the note is updated in the drafting sheet. The design sheet and the CAD master models are integrated using API programs. The API programs are used to clone the master models, update the parameters, update the drafting views and save the updated files with the new names. They are also used for creating vane profiles from XYR data, weight calculation of the components and assemblies, creation of BOM, updating notes and annotations and drafting details.

Description of Development Model

1st Step – Standardization & Defining the design rules

The key to success for any design automation project is standardization. The design process and the final product which needs to be automated should be standardized. After the standardization is done, it's time to define the design rules. Some parameters may be calculated by strength calculation. Others might be determined by empirical rules. Initially all the reference input drawings capturing the different variations of the Bulb turbine assembly and its components are studied and analyzed. Then the dimensions in these drawing sheets are marked. These dimensions are marked based on whether they are calculated dimensions, standard dimensions (like chamfer angle, fillet radius etc) or manually entered dimensions. After categorization of the dimensions the different topological variation of the bulb turbine components are analyzed. Based on this analysis a preliminary excel sheet is prepared capturing the design flexibilities, topological variations in individual components and these are directly mapped with the reference input drawings used for developing the automation tool.

Sl.No.	Component Name	Design Automation Flexibility	Requirements / Output from DA	Reference Drawings		
				Casting	Fabricated	Machining
1	Main Assembly	Variation in the components to be assembled, positional variations, variation in the topology of the assembly are captured here	Assembly drawing capturing the notes and annotations, BOM, updation of the views automaticaly		Availale	Availale
2	Sub Assembly - 1	Variation in the topology based on design conditions, presence of the sub assembly in the main assembly depending on design critierias, positional variations, cross sectional variations are captured here	Sub assembly drawing with the BOM	Availale		Availale
3	Component -1	DifferentTopology variations of the same component are captured here	Casting drawing maching drawing, cladding drawings	Availale		Availale

Then these topological variations are linked with design criteria and design requirements. After the study is completed, the standard 2D templates capturing the different variations in the geometrical shape of the components are prepared and mathematical rules defining these shapes are defined.

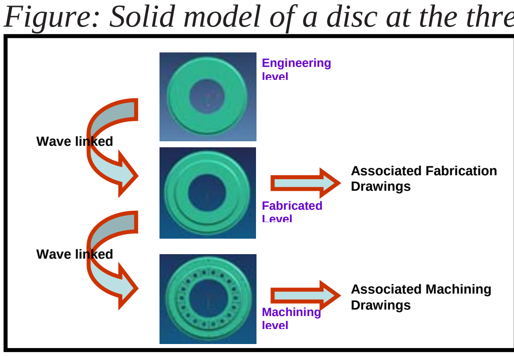
2nd Step – Building the design program

The second step is to develop the design programs. The design programs include strength calculation programs, program for calculating the runner and wicket gate vane profile etc. Based on the 2D templates developed in the first step, the CAD parameters required for defining the geometry of a component are listed down in the excel sheet and named properly. Then these parameters are mapped with the actual design parameters of the Bulb Turbine. The design logics or calculations to determine the design parameters are inserted into excel using excel formulas, look up tables etc.

3rd Step – Developing the Master Model and linked drawings

Master modeling is a concept where the 3D CAD model and the linked drawings are parameterized to accommodate the different design configurations and flexibilities. The design templates developed during the first step are used for developing sketch based parametric model in the CAD package and the parameters are interlinked or linked with some design calculations based on design requirements. The Bulb Turbine components are predominantly cast and fabricated components. The CAD models are developed in three levels and the concept of WAVE linking is used to link the parameters at each of the levels. The first level of model is the engineering level, followed by casting or fabrication level and the final level is the machining level. The parameters are interlinked and follow a top down approach.

Figure: Solid model of a disc at the three levels



The engineering level model is the first level of the system, which is based on approximations of the geometrical features like the fillets and chamfers which are not required for the FEM calculations are avoided in this level. Based on the outcome of the FEM calculations the parameters are updated automatically in the levels below.

The second level is the pre machining level or the fabrication / casting level. For fabricated components (like discharge ring, draft tubes, stay cones etc), a single part file approach has been adopted to keep the model simpler and easy to use. In the single part file all small components (like ribs, reinforcement plates, etc) will be modeled inside the part as solids. Hence there will be multiple solids present in the single part file. The drafting sheets at each of these levels are linked with the corresponding 3D models. The sectional details are extracted and referred from the solid model. So any update in the solid model will get reflected in the drafting views also. Another feature that is provided in the tool is the automatic creation of the plate development curves. The weldments for the fabricated components are created as parametric solids in the same part file and the weight of the same are calculated using API programs. The final level is the machining level showing the machining operations like holes, bolts etc. These are developed as sketches and parameterized. These three levels of master models are developed and referred as master model templates. The notes and annotations for the drafting sheets are prepared specific to different languages in individual layers and based on the user selection the appropriate layer is selected and updated in the drafting sheet.

The API programs are developed to update these master model templates based on the actual design calculations. The Bill of material and drafting view updation is also done automatically using API programs. An excel based GUI is developed to integrate the design programs and the master models. In this era of sophisticated software technology being available, the excel based GUI was preferred keeping in mind the end users and the cost of development. Simple excel based GUI makes the usage of the tool simpler.

Next Steps of Automation

The overall architecture of the tool is developed taking into consideration the future needs and requirements of the user. The tool can be easily migrated to web based application, using client-server architecture. The front end GUI can be developed using .NET or JAVA allowing the tool to be used by multiple users (sales person, designer, vendors) at the same time across the globe. This tool can be upgraded and linked with PDM / PLM software. The master model templates can be stored in the PDM database and retrieved. The final output of this automation tool can be directly uploaded into the PDM. This is possible only after a proper product structuring is accomplished and established in the PDM. The master models developed can be extended to accommodate the manufacturing logics and can facilitate automatic generation of NC codes and tool path details. This tool can also be extended to accommodate automatic FEM calculations.

Conclusion

The automation tool has helped the user in reducing the design cycle time considerably. Using this tool the user can now bid for completing a Bulb Turbine project in a shorter span of time with more accurate and detailed information. All the design rules and logics are now incorporated inside the master models which help in better knowledge management. The migration from 2D to 3D CAD platform has helped the user in reducing design errors and provides better visualization of the product. The standardization of the product structure and design practice and automating the same has given the user an edge over its competitors.

About the author

Somnath Kundu is PMP certified Program Manager for the design automation team at QuEST, India. He has more than 8 years of experience in Design Automation in Energy domain, ranging from design automation of steam turbine, hydro and turbo generators, centrifugal compressors and hydro turbines. In his current role he is also responsible for business development and customer interfacing for the Asia Pacific and European Energy customers.