Norwegian University of Science and Technology
Department of Energy and Process Engineering

Condition monitoring of a hydropower plant cooling system

Preliminary project for bachelor's thesis

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Preface

This preliminary project report is written at Voith Hydro in Trondheim. The report is a milestone for a bachelor's thesis in Renewable Energy Engineering at the Department of Energy and Process Engineering at the Norwegian University of Science and Technology(NTNU).

The Norwegian name of this preliminary project is: "Tilstandsovervåking av eit vasskraftverks kjøleanlegg"

This report is a description of the project, and it defines the framework and terms for the work and organization of the forthcoming thesis. It will also serve as a preliminary plan for the execution of the assignment.

I would like to thank everybody at Voith Hydro for opportunity of writing my thesis with them. Furthermore, I want to specially thank my external supervisor Øyvind Holm. Although he is busy, he is always available and shares willingly from his vast hydropower and engineering knowledge. I have gained much knowledge thanks to his outstanding pedagogical skills. Next, I would like to thank my supervisor Felix Kelberlau. His analytic and well-founded advice is nothing but an e-mail away.

Trondheim, April 26th 2019

Marius Lauvland

Marius Lauvland

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1 Project description

1.1 Description of the assignment

The bachelor's thesis is the concluding project work for a Bachelor of Engineering in Renewable Energy at NTNU. Throughout the project, relevant engineering problems shall be identified, formulated and solved. Interdisciplinary theory and skills must be applied to independently acquire extensive knowledge on – or contribute to – the current field of study, while at the same gaining knowledge into project management, implementation and documentation. The current project topics must include elements of innovation, research and development, or entrepreneurship. Besides, will it be necessary to collect data and study relevant literature[1].

1.2 The Voith Group

The thesis is written in cooperation with Voith Hydro Norway. Voith Hydro is a division of the Voith group. The Voith Group is multinational, family-owned, German corporation founded in 1867, and the headquarters are located in Heidenheim, Germany. In 2018 Voith had around 19 500 employees worldwide, throughout it's four divisions; Digital Ventures, Hydro, Paper and Turbo. According to Voith, a quarter of the hydropower energy generated worldwide is produced by turbines and generators they have manufactured[2].

1.2.1 Voith Hydro in Norway

Voith's presence in Norway is mostly observable through their Hydro division. Voith Hydro in Norway is located in Oslo, Trondheim and Fredrikstad, and they deliver automation systems, turbines, generators and electromechanical auxiliary systems for the hydropower industry. Voith has delivered over 100 turbines in Norway and is considered a major player in the industry[3].

1.3 Background

Hydropower plants produce electricity by extracting the kinetic and pressure energy from moving water. When there is a height difference, gravity will force water to flow, or fall, from a higher to a lower point. By leading the moving water onto a turbine the energy induced by gravity can be extracted as electric energy through the use of a generator. Although this process has a very high efficiency, there are, according to Wildi in [4], always losses. These losses are mechanical, like friction in the turbine bearings and windage, and electrical losses, like copper losses and iron losses. Furthermore, Wildi states that the losses reduce the efficiency and increase the temperature.

To avoid accidents or breakdowns, the heated components must be cooled down and the heat must be transported out of the power plant. Most hydropower plants solve this problem by installing a water cooling system – given the fact that water is an effective coolant, and an abundant resource in a hydropower plant. The cooling system plays a crucial part in any hydropower plant. If the system breaks down, it can cause immense material damage, like generator melting and turbine breakdown. A hydropower plant without a functioning cooling system will acquire costs for repairs and may even be forced to let water pass through the plant, without using it for production.

Given the cooling system's importance in hydropower plants, there are several safety and precautionary measures that monitor this system to ensure that it is working as intended. To guarantee the function of the cooling system and its safety measures, maintenance is scheduled regularly, regardless of condition. The maintenance will in itself cost the plant owner money, but it may also require unnecessary stops in production. By monitoring the condition of each component, maintenance can be planned and performed before the component breaks down at scheduled time. This will ensure better and more predictable production and can save costs.

The idea of preventive maintenance was developed in the 1960's and prediction based maintenance in 70's and 80's[5]. Although the ideas and theory behind the concepts are some years old, it is not common to perform this type of maintenance. Recent years advances in computing has made it a lot easier to analyze data to facilitate for condition based maintenance through surveillance and prediction.

1.3.1 Brattset hydropower plant

Brattset hydropower plant in Rennebu is operated by TrønderEnergi. The power plant consists of two identical 40 MW Francis turbines, with a net head of approximately 270 meters[6]. The control system at Brattset – the system that allows for local and remote control of the power plant – is developed by Voith Hydro. This control system is equipped with a data diode that extracts messages, temperatures, alarms and measurement values from the control system, before it makes this data available for off-site access. For security reasons, will the data diode only allow simplex communication, meaning that the communication is only unidirectional. The data that is extracted from the control system is available for analysis and surveillance – which opens up the possibility for condition monitoring.

1.4 Problem definition

The problem definition has been developed in a cooperation between Øyvind Holm at Voith Hydro, Felix Kelberlau at NTNU and the student, Marius Lauvland. It describes the starting point for a variety of possibilities and topics, without limiting the work to a single component or concept. The definition of the problem for this project is:

Condition monitoring of a hydropower plant cooling system

1.5 Scope and methodology

The assignment is limited to analyzing the cooling system at Brattset, with the goal of examining and facilitating for condition monitoring. Voith wants the products or results that are produced, to be easy to reuse in another setting. This implies that no – or at least as little as possible – power plant specific details should be included.

The project requires extensive domain knowledge and will therefore rely on support from Voith and TrønderEnergi. A minimum of one visit to the hydropower plant will be conducted, to fulfill the prerequisite for analyzing and modelling the cooling water system, which is a complete understanding of its operation, configuration and components. Following, will data from the hydropower plant be analyzed and various data science techniques, such as time series analysis, machine learning and modelling, may be applied. Calculations and derivations of signals, or measurement values, will be conducted and tested to analyze the cooling system.

Google Drive, with Google Docs and Google Sheets, will be used as a working space, to prepare and store all documents related to the bachelor thesis. The reports, like the preliminary project and bachelor thesis, will be written in Overleaf. Python, with various libraries, will be used for analysis and scripting purposes. Microsoft Excel and Visio might be used to plot and visualize data.

The project will also rely on extensive literature studies and guidance from the supervisors at NTNU and Voith Hydro. The cooperation with the supervisor from NTNU will be pragmatic, where communication will go through e-mail and meetings will be scheduled when they are needed. The project milestones will have deadlines to ensure project progress, and the supervisor will have access to the Google Drive folders with all documents. These precautions will facilitate a good cooperating environment and full transparency.

The cooperation with the Voith Hydro supervisor is also pragmatic. The supervisor has said that he is willing to guide the student when he has time and is available at the office. Alternatively, will the communication go over e-mail. In addition will meetings be organized, when they are needed.

1.6 Framework and resources

The project workload is 20 ECTS, equivalent to around 500 hours of work.

The project time line has been shifted due to exchange studies. The details and specific dates can be found in section 2.1. This shift will also result in a deviation from the proposed group composition. The project, which is usually completed in a group of two-three students, will be completed in a one student group.

No economic resources or specific equipment will be needed. The software that will be used is mostly open-source and free, like Google Drive and Python with its associated libraries, if not, it is provided by NTNU, like Overleaf, and Excel and Visio from Microsoft. The data will be available from Voith Hydro through their Analyzer and Cockpit tools, which is available over Internet. These tools offer both visualization and exporting of data files.

The student has received an office space at Voith Hydro's location on Sluppen.

In consultation with Voith Hydro it has been determined that the thesis will be blocked from publication for three years.

2 Project plan

2.1 Timeline

As stated in section 1.6, the timeline has been shifted in comparison to the official bachelor's thesis timeline. The revised project period will be more efficient and the delivery will be around six weeks after the official date set by NTNU, namely on the 10^{th} of July instead of the 24^{th} of May. The official and revised timelines, with the tasks defined by NTNU, are given in table 1.

Task name	**Official deadline**	**Revised deadline**
Topic definition	15.12.18	01.03.19
Official start	07.01.19	01.04.19
Preliminary project	15.02.19	26.04.19
Title fixed	15.04.19	03.06.19
Project report	24.05.19	10.07.19
Presentation	27.05.–11.06.19	12.07.19
Graded	14.06.19	02.08.19

Table 1: Timeline of the project

2.2 Schedule

The schedule is an overview of the tasks that are planned, as of now. The tasks defined by NTNU are joined by the task defined in the project and together they represent the project's tasks and events. It is assumed that the project schedule is a subject to change, but the deadlines set in table 1 must be met.

The project will start by defining the topic of the assignment and signing the cooperation agreement before the deadline on the 1^{st} of March. The official start of the assignment is on April 1^{st}, and the first month is mostly about getting settled, set up the required infrastructure and write the preliminary project. During the first timeperiod of the project a lot of time will be spent on getting familiar with the structure and operation of cooling systems generally, and Brattset's cooling system specially. Later, effort will be put into getting access to Brattset data and conduct an excursion to Brattset hydropower plant. Then relevant data sets and signal ids will be identified. The title of the project must be fixed early in June, and this will be done in parallel with the work with the project report. The work with the project report will go over a long period of time, but it will mostly focus on one of the sections at a time. The background theory will provide the knowledge that is required, and it will therefore be implemented first. The analysis and modelling is assumed to be the most time consuming part of the project, and this task is therefore allocated a substantial amount of time. The discussion and conclusion will summarize the report and is the final task before the delivery of the first draft on the 5^{th} of July. After the delivery of the first draft, it is assumed that only minor quibbles is left before the final delivery on the 10^{th} of July. After the report delivery a presentation will be prepared for the 12^{th} of July. The thesis will be graded by the 2^{nd} of August.

For a period of roughly a week at the end of May all work with the project will be put on hold, to work with another subject that has an exam on the 4th of July.

2.3 Gantt chart

Figure 1 illustrates the project schedule graphically using a Gantt chart. If the task name, start and finishing date all are in bold it indicates that it is a summary task that has subordinate tasks. If only the name is in bold it marks that it is a significant task. Subordinate tasks are indented. Each task has a duration, shown to the right in the chart. The summary tasks are recognizable by the triangle which marks the start and the end of the duration. Subordinate tasks are regular bars. A diamond signifies a significant event, that happens at a specific date, rather than a task.

Once an event, task, or a subordinate task, is 100% complete, its color will change to blue, or blue with orange bands, depending on what type of task it is. A purple colored bar indicates that the task is significant for the execution project, but does not belong to the project.

ID	Task Name	Start	Finish	Actual Finish	Duration	% Complete
1	**Topic definition**	**29.01.2019**	**01.03.2019**	**27.02.2019**	**4,8w**	**100%**
2	Sign cooperation agreement	29.01.2019	01.03.2019	27.02.2019	4,8w	100%
3	**Official start**	01.04.2019	01.04.2019	01.04.2019	0w	100%
4	**Preliminary project**	**01.04.2019**	**26.04.2019**	**02.05.2019**	**4w**	**100%**
5	Define project timeline and problem definition	01.04.2019	26.04.2019	26.04.2019	4w	100%
6	Set up cloud infrastructure and routines for backup	01.04.2019	05.04.2019	05.04.2019	1w	100%
7	Transcribe minutes of meetings	01.04.2019	12.04.2019	12.04.2019	2w	100%
8	Coordinate with the other group at Voith	05.04.2019	12.04.2019	12.04.2019	1,2w	100%
9	Determine the structure for, and write, preliminary report	05.04.2019	26.04.2019	26.04.2019	3,2w	100%
10	Deliver preliminary project	26.04.2019	26.04.2019	02.05.2019	0w	100%
11	**Get access to Brattset data**	01.04.2019	26.04.2019	24.04.2019	4w	100%
12	**Excursion to Brattset**	29.04.2019	29.04.2019	29.04.2019	0w	100%
13	**Identify relevant data sets and signal ids**	02.05.2019	20.05.2019	20.05.2019	2,6w	0%
14	**Title for project fixed**	03.06.2019	03.06.2019	03.06.2019	0w	0%
15	**Project report**	**02.05.2019**	**10.07.2019**	**10.07.2019**	**9,8w**	**0%**
16	Background theory and literature studies	02.05.2019	16.05.2019	16.05.2019	2,2w	0%
17	Analysis and modelling	20.05.2019	24.06.2019	24.06.2019	5,2w	0%
18	Discussion and conclusion	24.06.2019	05.07.2019	05.07.2019	2w	0%
19	Deliver first draft	05.07.2019	05.07.2019	05.07.2019	0w	0%
20	Deliver project report	10.07.2019	10.07.2019	10.07.2019	0w	0%
21	**Exam preparation and exam in another subject**	27.05.2019	04.06.2019	04.06.2019	1,4w	0%
22	**Presentation**	**10.07.2019**	**12.07.2019**	**12.07.2019**	**,6w**	**0%**
23	Make presentation	10.07.2019	12.07.2019	12.07.2019	,6w	0%
24	Conduct presentation	12.07.2019	12.07.2019	12.07.2019	0w	0%
25	**Graded**	02.08.2019	02.08.2019	02.08.2019	0w	0%

Figure 1: Gantt chart showing the project schedule

2.4 Timesheets

Timesheets with categories will be used throughout the project. An entry in the timesheets will include the date, the start and end time, and the category of the work that has been done, as shown in figure 2. There are currently seven categories; self-education, research, documentation, programming, modelling and other. The other-category will include a small note, and will be used when the work does not fit into any of the other categories.

The timesheets will keep track of how much time that has been used each day, week and for the entire project.

Date	Start	End	Selfeducation	Research	Documentation	Programming	Modelling	Meeting	Other*	Sum	
1/4/19	8:45	18:45	4	2	3.5			0.5		10	OK!
2/4/19	9:30	19:00	3.5	1	5					9.5	OK!
3/4/19	8:30	16:45	3.25	2	2			1		8.25	OK!
4/4/19	8:30	18:30	3	4	3					10	OK!
5/4/19	8:30	17:00	3	3	2.5					8.5	OK!
Week 14, sum:			16.75	12	16	0	0	1.5	0	46.25	Total for week
8/4/19	8:30	18:30	4	3	3					10	OK!
9/4/19	9:00	19:30	3	3	4.5					10.5	OK!
10/4/19	9:15	17:45	2.25	3	2			1.25		8.5	OK!
11/4/19	11:30	21:00	3.5	3	3					9.5	OK!
12/4/19	8:45	17:45	2	2	2			3		9	OK!
Week 15, sum:			14.75	14	14.5	0	0	4.25	0	47.5	Total for week

Total for each category:	
Selfeducation	36.5
Research	34.5
Documentation	61.25
Programming	0
Modelling	0
Meeting	5.75
Other*	0
Total hours in project	138

Figure 2: Timesheets for the project

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