Public summary of workshop 2

HydroFlex

Increasing the value of hydropower through increased flexibility

Deliverable D6.15 Public summary of workshop 2

Work package	WP6 Communication, dissemination and exploitation
Task	Task 6.3 Dissemination events
Lead beneficiary	Multiconsult
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Dissemination level	Public

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Summary of the HydroFlex public workshop no 2

Due to public health restrictions the planned public workshop had to be replaced by a series of digital events. The following report gives a brief summary of the content and discussions in the webinars. In a collaborative research project, it is important for researchers to meet, discuss and establish connections and social relations. Digital events are a meagre replacement for the physical meetings. On the other hand, the accessibility of online events has led to a more diverse and international audience than could have been expected for a public meeting in Uppsala, Sweden.

Preamble

The HydroFlex project, much as the rest of the world, has been severely affected by the SARS-CoV-2 virus and the COVID-19 pandemic. As part of the dissemination activities, a public workshop in Uppsala was planned for April 22 and 23, 2020. The event was planned to be organized in collaboration with the Swedish Hydropower Centre (Svensk Vattenkraft Centrum, SVC). Soon after the emergence of the virus in Europe and subsequent travel restrictions and lockdown in early March 2020, it was decided to move the event to the autumn of 2020. At the time, it was still foreseen to be a physical event. In the coming months it became obvious that the plans had to change again and that the physical event should be replaced by a digital event.

Overview

The digital events that replaced the public workshop is summarized in the table below. The planned workshop for PhD students and post docs affiliated with the project was also held as an online event. This was not a public event but is included in the table for completeness. In addition, an executive board meeting for the project was held in the same time period.

All the public events were recorded. The recordings are posted online and promoted on the HydroFlex website and in social media. Accordingly, it is expected that in future, the actual audience of the events will be larger. The number of participants is based on the registration to the events. An analysis of the list of participants shows that the total number of participants is 270 and unique participants is 168. Participants from at least 17 countries were present. This is based the registration address. It is interesting to note that participants from countries such as Buthan, Nepal, India, Iran and Turkey were attending the webinars. If the public workshop had been held in Uppsala, Sweden it is less likely that such a varied audience would have had the opportunity to attend.

Event no	Date, time	Descriptions	No of participants
1	September 24, 13:00-16:00	WP2 webinar: Hydropower in the European energy system: Future flexibility requirement.	94

2	September 30, 10:00—12:00	WP3 webinar: Flexible turbines	69
3	October 13, 13:00-16:00	WP 4 webinar: Flexibility of generator and converter	33
4	October 21, 09:00-12:00	Workshop: How to write popular science articles	18
5	October 22, 10:00-12:00	WP5 webinar: Environmental impacts and their mitigation	56
		Total	**270**

Table 1 – Summary of the digital events that replaced the HydroFlex public workshop no 2, originally planned to be held in Uppsala, Sweden.

WP2 webinar: Hydropower in the European energy system: Future flexibility requirement

Time	Description	Name
13:00	Introduction to HydroFlex WP2	Marius Siemonsmeier (RWTH)
13:15	Hydropower as flexibility provider for Europe's future energy markets	Peter Wirtz (RWTH)
14:15	Highly flexible water turbines – Essential solution to future stability challenges?	Maik Schönefeld (RWTH)
15:15	Panel discussion: Nordic/Swedish hydropower in the future European energy system panellist: • J. Bladh, Swedenergy • F. Engström, Vattenfall moderator: • B. Børresen, Multiconsult	

Table 2 - Program for WP2 webinar held on September 24, 2020

The research goal of work package 2 is to improve the understanding of future development of the European and Nordic power system, and how this development drives the need for flexibility in the power system. The research approach is development and extension of an existing market model of the European power system, developed at RWTH. At the starting of the HydroFlex project the market model did not include sufficient details of the Nordic power system and power market to accurately answer the key research questions. As part of the introductory session of the webinar, Marius Siemonsmeier (RWTH), WP-leader introduced the background and motivation for the HydroFlex project. He also gave an overview of the specific tasks in the work package and the current progress.

At the departure, the RWTH-model did not include a detailed description of the Nordic installed fleet. Furthermore, the model was not able to predict the detailed production schedule for an individual hydropower plant in the Nordic system, In the first keynote, Peter Wirtz, RWTH presented the extension of the RWTH-model and in particular the work required to add a hydropower commitment model. Some of the key aspect required for a successful extension of the RWTH-model was

- Ensure an interpolation scheme of the hourly wind data down to 15-minute time steps while maintaining the correct amount of volatility
- Parameterization of the hydro power fleet
- Rule based/heuristic scheduling algorithm

Early in the HydroFlex project, three different scenarios for future development of the European power system was defined. These three scenarios are denoted Reference, Green Hydro and Prosumer. The variation in the different scenarios were mainly in the amount of intermittent renewable energy sources in the production mix in the reference years 2030 and 2040. In addition, the magnitude of consumer flexibility is also varied.

Simulations for these three reference scenarios were done, to determine their influence on the flexibility needs. In the simulation, the bidding areas Norway (north), Norway South and Sweden. This is a simplification in comparison with the reality today where Norway and Sweden have 9 price areas. The main results from the modelling are the following:

- The difference in the number of starts and stops for the hydropower units investigated are quite moderate between the different scenarios.
- The main driver for increased flexibility needs in the Nordic region is driven by the development of wind power.

The second point was confirmed by adding an additional “Max start/stop cycle” scenario, where the wind installation in Norway is increased to 28 GW (270% of Green Hydro).

The above conclusion may seem contradictory to earlier discussion regarding the Nordic region as a “green battery” for Europe. However, the market model predicts that the spread between day time and night time prices in Europe is sufficiently large that all capacity will be used for import at daytime and export at night time and thus there will be no capacity for intraday flexibility trading.

In the second keynote, Maik Schönefeld (RWTH), presented to ongoing work related to stability investigations. A model for a hydraulic turbine with inelastic water column is implemented in an existing grid model. In addition to a traditional synchronous machine, a frequency converter interface is introduced between the generator and the grid. This permits implementation of virtual inertia that can help to stabilize the grid and provide more rapid frequency restoration following faults. Both the simulations on the “New England” IEEE 39-Bus system as well as current NORDEL grid model confirms that virtual inertial greatly reduced the frequency deviation following a fault.

Following the two keynote speakers, a panel discussion addressed the question on how industry representatives view the role of Nordic/Swedish hydropower in the future European energy system. Both Johan Bladh from SwedEnergy and Fredrik Engström, Vattenfall concluded in their introductory remark that the impact of wind power and in particular the variability of the wind power is clearly visible in the power market today. Johan also highlighted that there currently is not clear what will the production mix in the future. Nuclear power is still providing on average 60 TWh, but this is expected to decrease as aging units are decommissioned. Fredrik highlighted that wind and other renewable sources probably will ensure that there is a net gross energy balance, but that there may be a shortage of peak power in particular periods. Further market development related to flexibility services will be important and is discussed, also politically.

WP3 webinar: Flexible turbines

<table>
<tr><th>Time</th><th>Description</th><th>Name</th></tr>
<tr><td>10:00</td><td>Introduction to HydroFlex WP3</td><td>Igor Iliev (NTNU)</td></tr>
<tr><td>10:10</td><td>Adjustable guide vanes in hydraulic turbine draft tube: A concept to control pressure pulsations</td><td>Jesline Joy (LTU)</td></tr>
<tr><td>10:55</td><td>A tool for hydraulic and mechanical design of guide vane system</td><td>Marija Lazarevikj (UKIM)</td></tr>
<tr><td>11:40</td><td colspan="2">Panel discussion: Flexible turbines – an industrial perspective
panellist:
• Anders Bard, SWECO
• Jan Tore Billdal, Rainpower
moderator:
• Igor Iliev, NTNU</td></tr>
</table>

Table 3 - Program for WP3 webinar held on September 30, 2020

The research goal within WP3 is to develop Francis turbines adapted to variable speed operation. Tasks included in the work package includes development of design tools as well as improvements in the computational tool chain, including the computational fluid dynamics (CFD) and computation structural dynamics (CSD). In his introductory presentation to WP3, Igor Iliev, NTNU, presented the tasks and deliverables of WP3.

In the first keynote, Jesline Joy (LTU), presented here work on developing adjustable guide vanes in the draft tube of Francis turbines. One feature of Francis turbines is the rotation vortex rope (RVR) at part load. The RVR may cause both pressure- and power oscillations. In some cases, these oscillations may require restrictions on the operating range and thus limit the flexibility of the units. A reliable, practical and cost-effective means of reducing or ideally eliminating the RVR without significantly reducing the efficiency would be valuable for many existing and new power plants. I here work, Jesline first considered an ideal design with a dense cascade. Next, a more realistic design with either 3 blades or 2 blades were optimized, both in terms of position and shape. A solution, with one fixed part and one movable part was selected in order achieve good performance at part load, best efficiency point and full load. The experimental verification is planned for first quarter of 2021.

In the second keynote, Marija Lazarevikj (UKIM), presented her work on developing a tool for hydraulic and mechanical design of guide vane system. Both the stay vanes and guide vane are parametrized using Bezier curves for the profile thickness and camber line. Using commercial tools (Matlab and Ansys) a tool chain for doing parametric investigation and optimization has been developed. The computational optimization is ongoing and expected to be completed in the near future. The experimental validation of the design will be done in the laboratory at NTNU when the optimized design has been completed.

Following the two keynote presentations, two representatives from the hydropower industry, Anders Bard, SWECO and Jan Tor Billdal, Rainpower participated in a panel discussion. Both industry representatives confirmed that there is an increased focus on flexible operation from power companies purchasing turbines. This is most commonly reflected in an increased number of start/stops per year in the turbine specification. For the designers there is still a challenge to predict the performance accurately and reliably at off-design condition with the typical tools used in the design stage. Even though flexibility of operation is a desirable goal, it is difficult to quantify the cost of such operation. This is both related to the equipment cost as well as the operation cost, due to potentially more rapid wear and degradation due to more severe loads on equipment.

WP 4 webinar: Flexibility of generator and converter

Time	Description	Name
13:00	Introduction to HydroFlex WP4	Urban Lundin, Uppsala University

13:15	Provision of ancillary services using converter-connected hydropower	Max Parker, University of Strathclyde
14:05	Modulation techniques for multilevel converter	Chengjun Tang, Chalmers
15:05	Panel discussion: Market and development opportunities for advanced generator technologies and converters - an industrial perspective panellists: • Øivind Linnebo, ABB • Bo Hernnäs, Voith moderator: • Bjarne Børresen, Multiconsult	

Table 4 - Program for WP4 webinar held on October 13, 2020

The research goal of WP4 is to develop new technology related to generators and converters. Initially, the work package leader Urban outlined the main tasks. One of the principal avenues of the project is to investigate of a full size frequency converter can be used in connection with a traditional, salient pole synchronous generator. Using modern power electronics combined with modern governing algorithms it may be possible to provide much more flexible operation and deliver new types of ancillary services.

This topic was further detailed in keynote 1, presented by Max Parker, University of Strathclyde. In his work, a dynamic model including a high head hydropower plant is combined with a full-sized frequency converter. The model confirmed that the proposed variable speed unit could provide good frequency response, fast start and synthetic inertial.

In keynote 2, Chengjun Tang (CUT) presented investigation of the power electronics and in particular the frequency converter. A challenge with a basic two level converter is the high frequency ripples related with the square wave. These high frequency components may potentially cause increased wear and damage to the isolation both in the generator and the transformer. Using a multilevel converter, a closer resemblance to a sine wave can be produced. Different multilevel topologies as well as modulation techniques were presented. In the future development of this work, the converter models will be coupled with analysis of losses as well as prediction of lifetime of the components.

In the following panel discussion, Øivind Linnebo, ABB and Bo Hernnäs, Voith presented some viewpoints from the industry on the research topics. It was confirmed that industry finds the topic interesting and is following the development closely. On the other hand it was commented that a full size converter is expensive and that the price premium for regulating services does not warrant such an investment today. From a technical point of view, it is supposed that full size converter up to 100 MW may be feasible. In the following discussion it was speculated that maybe smaller hydropower installation could be a useful pilot installation.

WP5 webinar: Environmental impacts and their mitigation

<table>
<tr><th>Time</th><th>Description</th><th>Name</th></tr>
<tr><td>10:00</td><td>Introduction to HydroFlex WP5</td><td>Staffan Lundström, LTU</td></tr>
<tr><td>10:15</td><td>Numerical modelling of discharge fluctuation mitigation measure for optimizing hydropower plant operations</td><td>Omid Saberi, NTNU</td></tr>
<tr><td>10:55</td><td>Modelling the effect of hydropower regulation on the salmon production in the River Nidelva</td><td>Richard Hedger, NINA</td></tr>
<tr><td>11:30</td><td colspan="2">Panel discussion: Flexible hydropower plants and environmental challenges
panellists:
• Patrik Andreasson, Vattenfall R&D
• Birgitta Malm-Renöfält, Umeå universitet
• Åsa Widén, Umeå universitet
Moderator: Staffan Lundström</td></tr>
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Table 5 - Program for WP5 webinar held on October 21, 2020

More flexible operation of hydropower plants, including more start stops and faster ramping rates will lead to increased variation of discharge from the turbines. For turbines connected to small reservoirs, this will cause more rapid and severe variations of water elevation. For turbines drawing water from a river and discharging to a river the this will impact the flow condition in the river. In both cases this will potentially have environmental impact. For people using either a lake or a river for commercial or recreational purpose, the changes due to flexible operation can be viewed as highly negative. These topics is addressed in WP5. In his introduction to WP5, the leader, Staffan Lundström, LTU, outlined the task of the work package. On the mitigation side, a novel concept to smooth out discharge oscillations is developed. In order to quantify the magnitude of the environmental impact, modelling is done to understand the impact, in particular on fish. There is also plans to investigate the social acceptance accept of flexible hydro power operation. Due to concerns regarding possible infection, the initial public survey has been postponed and will be replaced by a literature survey.

In keynote 1, Omid Saberi, NTNU presented the initial work performed to simulate and optimize the ACUR system. A large underground cavern is used to store water that can be released when the discharge is reducing. When the discharge is increasing again, the underground cavern is filled up again. Looking at a theoretical dispatching pattern and considering different outflow curves, the size of the underground cavern has been optimized.

In keynote 2, Richard Hedger, NINA presented the ongoing work to develop a individual based, simulation model to predict the impact of hydropower regulation on salmon production in the river Nidelva. The model includes a complete description of the evolutionary cycle of salmon, from eggs to adults and reproduction. In the spatial model the river stretch considered is divided up in 25 long segments. Using a hydrological model, the discharge variation due to different hydropower operation can be simulated. This include the local velocity distribution as well as the dewatering of certain portions of the riverbed when the flow is reduced. The model is still under development and calibration. Future activities will include simulation under new hydro peaking regimes and modelling effect of successive stranding events.

In the ensuing panel discussion, the panellists, Patrik Andreasson, Vattenfall R&D, Birgitta Malm-Renöfält, Umeå universitet and Åsa Widén, Umeå universitet discussed the results presented. In relation to the ACUR system, there was some question raised in relation to what the cost of the system would be and if the premium price of the peaking power will be sufficient to justify the cost of this system. It was also some discussion related to the applicability of system for low head hydropower plants where the discharge is much larger. The panellist were positively interested in the individual based modelling for Nidelva and was encouraging to proceed with the planned coupling of the ACUR simulation and optimization and the hydropeaking impact on fish populations. In the closing it was highlighted that impact of future climate change may be very significant and should be included in the modelling.