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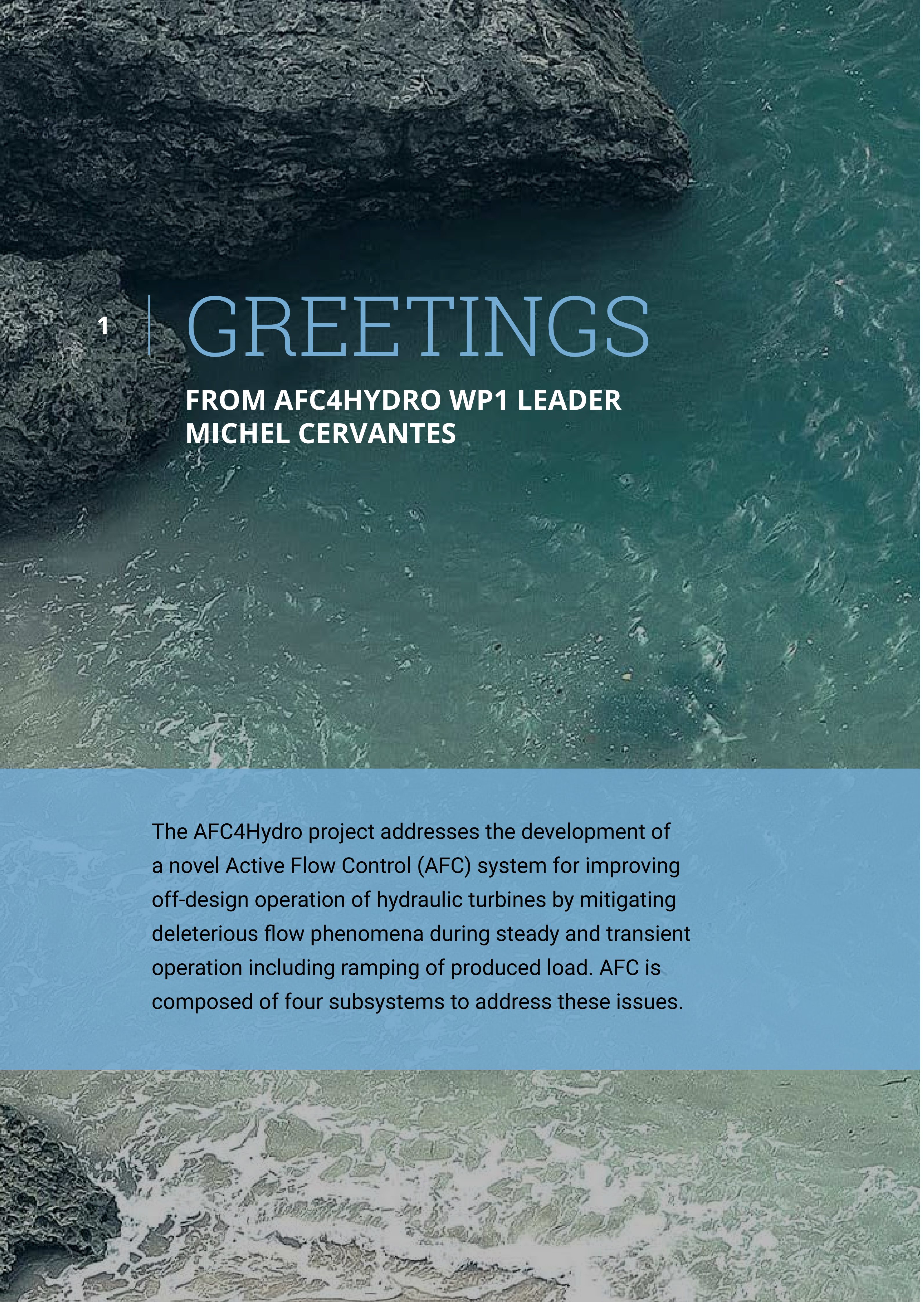
NEWSLETTER APRIL 2021

E-mail:	Web:	Number:	Date:
ole.g.dahlhaug@ntnu.no	h2020hydroflex.eu	Newsletter 06	30/04/2021
wp5@afc4hydro.eu	afc4hydro.eu	Newsletter 02	



1

GREETINGS

FROM AFC4HYDRO WP1 LEADER MICHEL CERVANTES

The AFC4Hydro project addresses the development of a novel Active Flow Control (AFC) system for improving off-design operation of hydraulic turbines by mitigating deleterious flow phenomena during steady and transient operation including ramping of produced load. AFC is composed of four subsystems to address these issues.

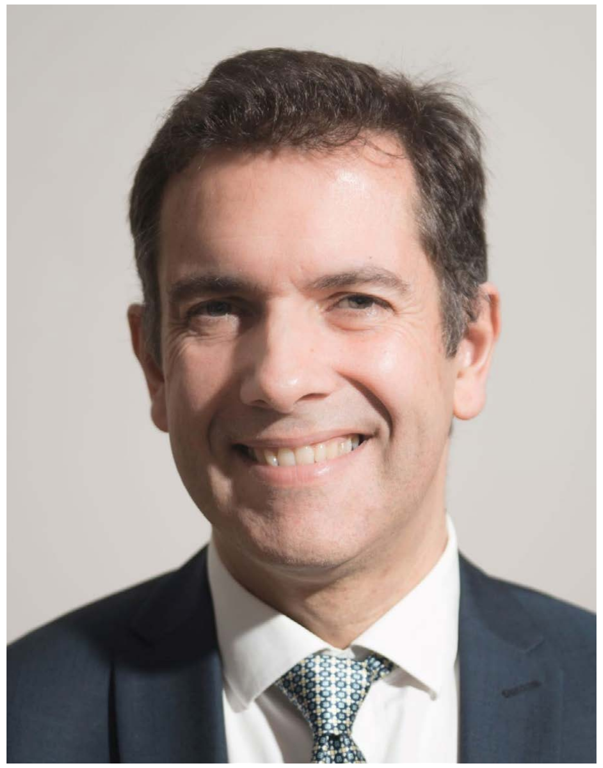
WP1 focuses on the development of a technique to mitigate the part-load rotating vortex rope named Injection of Pulsating Momentum (IPM). By injecting pulsating momentum into the turbine draft tube, the IPM aims to disturb the hydrodynamic flow instabilities leading to the formation of harmful vortical flows. The idea of injecting pulsating momentum into the draft tube stems from a scientific article that I read a few years ago in which it was shown that the so-called spiral vortex breakdown could be transformed into the less harmful bubble breakdown by injection of sinusoidal perturbations into the flow.

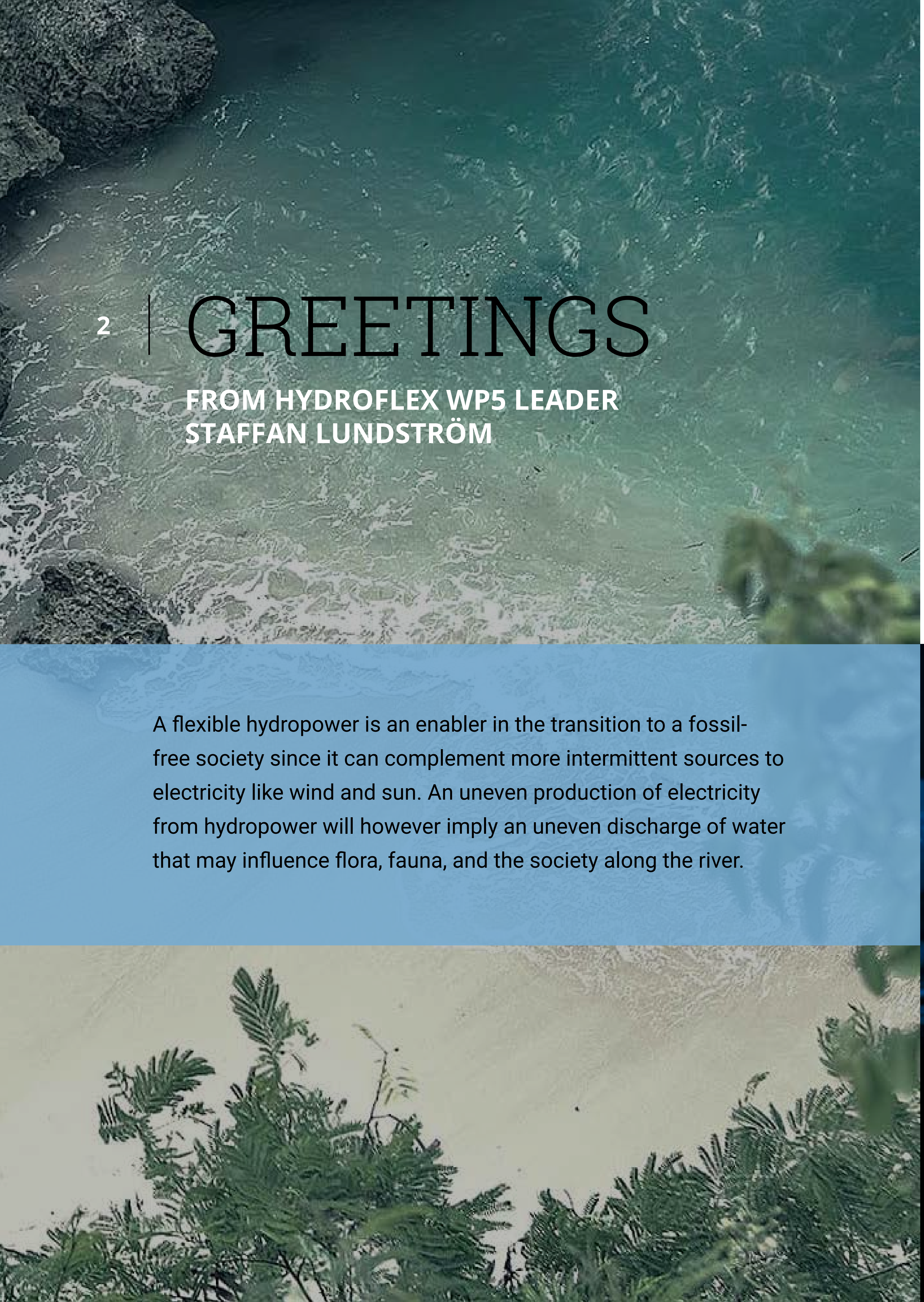
In WP1, we aim at combining the three cornerstones of fluid mechanical analyses; namely, theoretical, experimental, and numerical investigations when we develop our mitigation strategy.

Our idea is to use linear global stability analyses, both for increasing our understanding of the formation of the RVR, and to find the regions in the draft tube where it is most effective to inject the pulsating momentum. The stability analyses can then be used as input to our experimental and numerical investigations.
We work at different scales, from the laboratory up to full-scale machines.

The preliminary results are encouraging. Much work is left to do, it is an extremely exiting period of the project.

WP1 leader
Prof. Michel Cervantes,
Division of Fluid and
Experimental Mechanics
at the Department of
Engineering Sciences
and Mathematics.
Luleå University of
Technology





GREETINGS

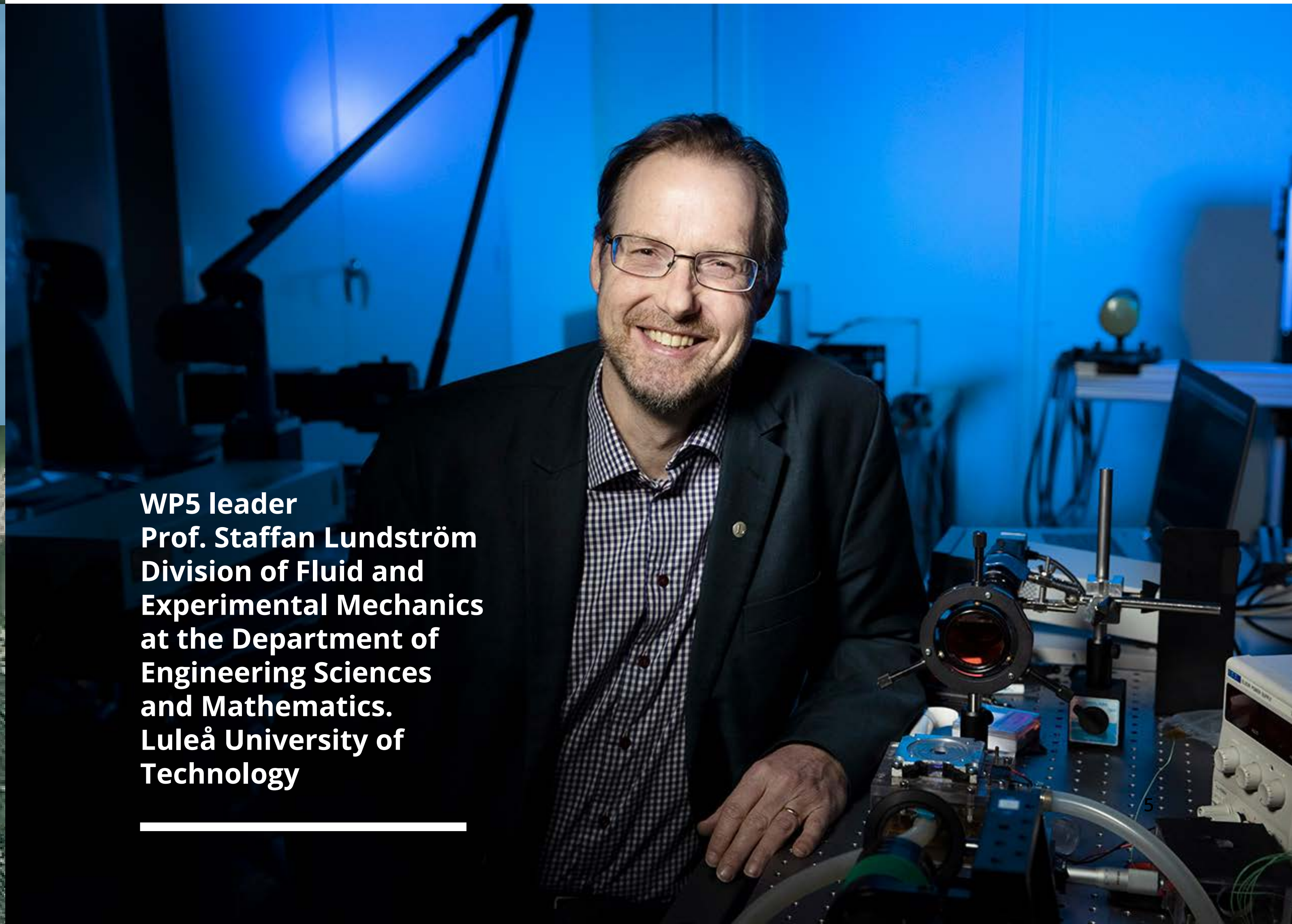
FROM HYDROFLEX WP5 LEADER STAFFAN LUNDSTRÖM

A flexible hydropower is an enabler in the transition to a fossil-free society since it can complement more intermittent sources to electricity like wind and sun. An uneven production of electricity from hydropower will however imply an uneven discharge of water that may influence flora, fauna, and the society along the river.

In HydroFlex we therefore develop technologies to mitigate an uneven discharge from the turbines. We also develop methods to study how mitigation technologies and natural mitigations affects the flow rate and water levels in the downstream river.

This knowledge is matched to models and knowledge about fish behavior in order to optimize mitigations and give suggestions on turbine running schemes and ramping rates at stops and starts.

We also interview stakeholders to get their views about a more flexible hydropower which is also an input to the turbine running schemes. Hence, although a flexible hydropower is driven by demands from the electrical grid, the ecology and the society along the river must be considered if Hydropower should be a sustainable source to electricity in the next 100 years or more.



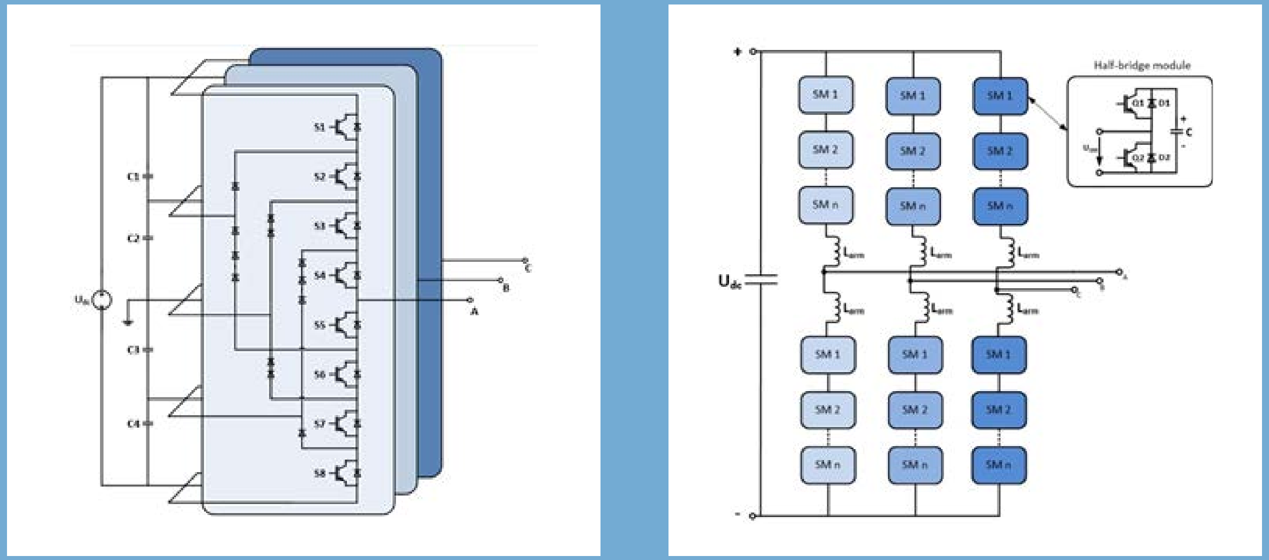
WP5 leader
Prof. Staffan Lundström
Division of Fluid and Experimental Mechanics at the Department of Engineering Sciences and Mathematics.
Luleå University of Technology

3 | PHD CANDIDATE

CHENGJUN TANG, CHALMERS UNIVERSITY OF TECHNOLOGY

Variable speed operation has become a trend in hydropower generation due to its contribution to the flexibility of the grid. To achieve the variable speed operation, a power converter is an essential part since it is the interface between the electric machine and the grid. However, the frequent start-stops of pumped-storage hydro power unit brings challenges to the lifetime of the power converter. In order to design a power converter which can be run with a long lifetime, the efficiency of the converter should be high to minimize the losses. Therefore, it is important to study the power converter from the efficiency point of view.

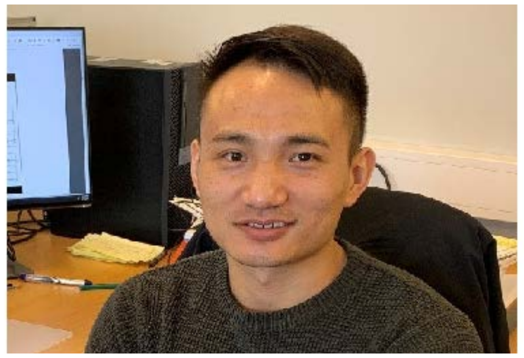
Figure 1. Typical multilevel converter topologies



(a) Five-level NPC converter

(b) Modular multilevel converter

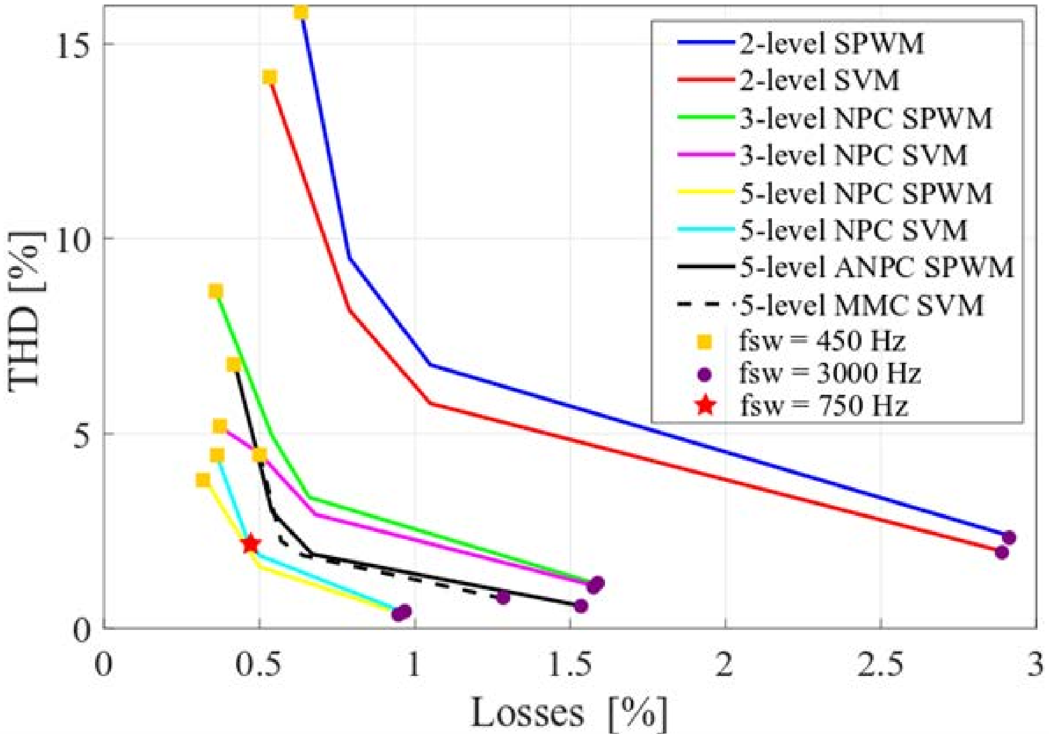
My work under task 4.3 of WP4 of the HydroFlex project is to compare the efficiency of the converter with various topologies and modulation techniques. Due to the high voltage level requirement of the converter, it is preferable to use the multilevel topology, such as the neutral-point-clamped (NPC) converter and the modular multilevel converter (MMC). These converters have been studied and simulated in MATLAB Simulink and PLECS, and the schematic diagrams of them are shown in Figure 1.



The results of the efficiency and current THD comparison of different converter topologies and switching frequency are shown in Figure 3. It can be seen that the five-level NPC converter using SVM with 750 Hz switching frequency has the best overall performance regarding the efficiency and current THD. However, the uneven distribution of losses among switches can bring an early failure of the converter, which will decrease the lifetime of the converter in return. Therefore, a tailored cooling method needs to be developed for the five-level NPC converter to mitigate the uneven loss distribution.

Figure 2. PhD candidate C. Tang, Chalmers University of Technology

Figure 3. Losses and current THD for different converters with a various switching frequency



4 | PHD CANDIDATE

HENRIK HOLMSTRÖM, LTU

Injection of pulsating momentum started with an idea to inject momentum from the draft tube walls into the draft tube to reduce the pressure pulsations caused by the rotating vortex rope (RVR) at part load operating condition. The momentum was injected through four circumferentially distributed holes in a horizontal plane close to the draft tube inlet. The pattern of the injection can be described as a sinusoidal wave where each injection has a phase shift relative each other.

More specific case was the attempt to reduce the pressure pulsations downstream of the injection inlets in the draft tube using pulsating momentum injection.
Numerical investigations on a down-scaled turbine with 100 mm runner diameter show that by using approximately 5 % of the operational flow, it is possible to significantly reduce the pressure pulsations downstream of the jet injection, see figure 1.

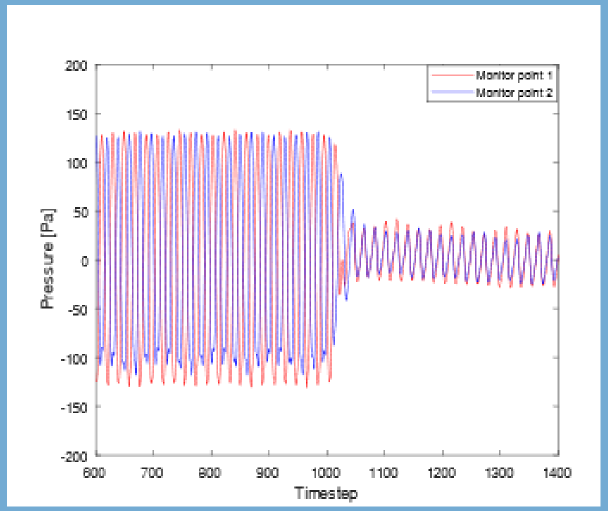


Figure 1. (a) Two monitor points located in the draft tube downstream of the injection inlets. The IPM is activated after 1000 timesteps and the pressure pulsations captured by the monitor points are thus reduced.

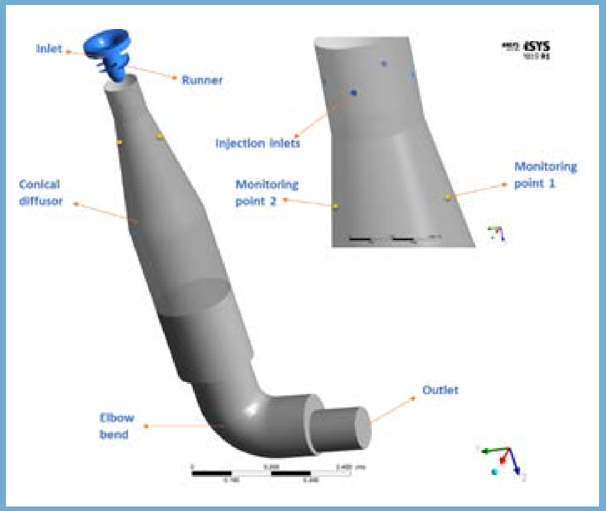


Figure 1. (b) The numerical setup of the down-scaled model of a propeller turbine located at Lulea University of Technology.

Another mitigation technique is currently being investigated using the Porjus U9 model as numerical setup. This technique uses stationary rods that are protruded into the draft tube with the aim to perturb the RVR.
Investigations of the rod diameter as well as the horizontal and vertical position in the draft tube are currently being investigated. The investigation is conducted using numerical software ANSYS CFX and is performed on the U9 model, which has a runner diameter of 400 mm.
Preliminary results indicate a reduction of the pressure pulsations caused by the RVR in the draft tube and pressure contours showing the RVR pulsations in a plane intersecting the draft tube before and after rods are protruded are presented in figure 2.

Presently I am eager to validate my numerical results against experimental data from the U9 model in Älvkarleby. These experiments are planned for mid-august 2021.

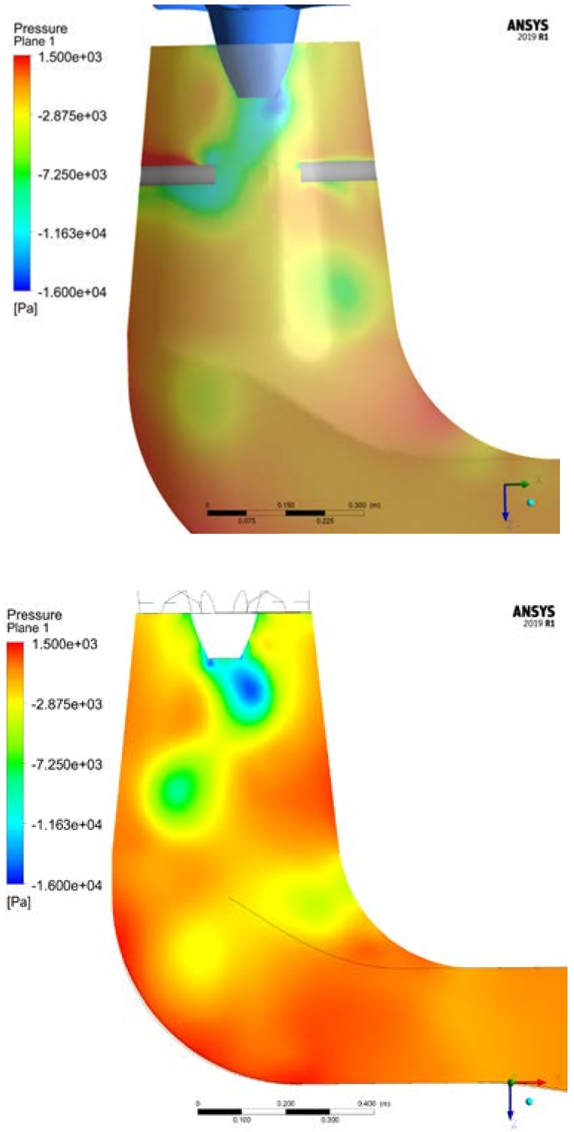


Figure 2. Pressure contour showing the RVR pressure pulsation in the draft tube and the stationary rods that are protruded into the draft tube.

Figure 3. PhD candidate Henrik Holmström, Luleå University of Technology

5 | PHD CANDIDATE

JOHANNES KVERNO

Design of a Francis turbine for many start-stop cycles per day and high ramping

The goal of my PhD (under Task 3.3 of WP3 of HydroFlex) is to perform on board measurements on a model Francis turbine in the test rig at the Waterpower laboratory at NTNU, focusing on the pressure in the inlet of the runner and strain at the trailing edge of the runner blades at several off-design conditions. The resulting data will be used to validate numerical simulations performed by our partners at EDR Medeso, and will give us a better understanding of the cost of flexible turbine operation.

So far, we have gotten the new HydroFlex Francis runner in house, tailor made for the measurements to be done. An initial performance test of the new runner has been done as well to check its behaviour.

The locations of the pressure sensors at the inlet as well as the strain gauges at the blade trailing edge have been carefully chosen with the help of numerical results from EDR Medeso, and the required equipment for the upcoming measurement campaign is selected. Locations can be seen in Figure 1 and Figure 2.

To ensure time synchronisation of all the measured inputs, the signal from the on board sensors will be transmitted through a slip-ring on the turbine shaft and fed to the data acquisition (DAQ) setup which records and stores all the data. In order to minimise the noise to signal ratio as the analogue data is passed through the slip-ring, the signal is to be amplified first, so a set of miniature amplifiers is to be installed in the centre of the runner as well, as seen in Figure 3.

The next step now is to get the equipment and install it on the runner blades and centre, and do a calibration of both the strain and pressure measurements. Calibration is done to get an idea of the magnitude of the measured values. Absolute calibration of strain gauges installed on complex geometries is challenging. Therefore, the strain gauges mounted on the blade surface will be calibrated using results from a Finite Element Analysis (FEA) in ANSYS.

A custom-made blade-fixing device will be used to apply calibrated weights, which will apply a vertical force on a known location on the instrumented blade. This exact setup will be reproduced in ANSYS and the measured signal will be calibrated against the calculated strains in the given locations, as seen in Figure 4. For the pressure calibration the whole runner, with pressure sensors and all, will be submerged in a pressure vessel, filled to the brim with water and then pressurised.

That way, we can apply a known pressure to the vessel and correlate it with the measured output from the sensors.

Once calibration is done, the next step is to install the runner in the Francis test rig and begin the measurement campaign.

Figure 1.
Strain gauge locations

Figure 2.
Pressure sensor locations

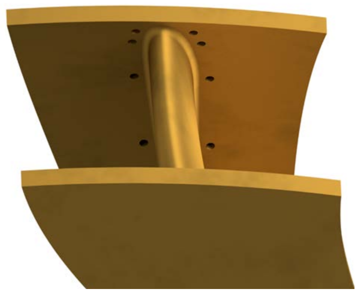


Figure 3.
Amplifier location in the runner centre

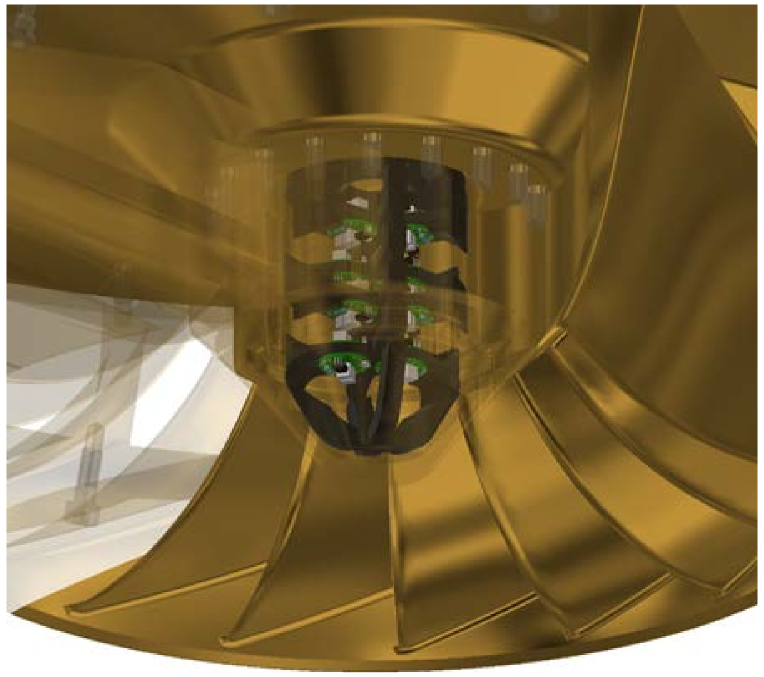
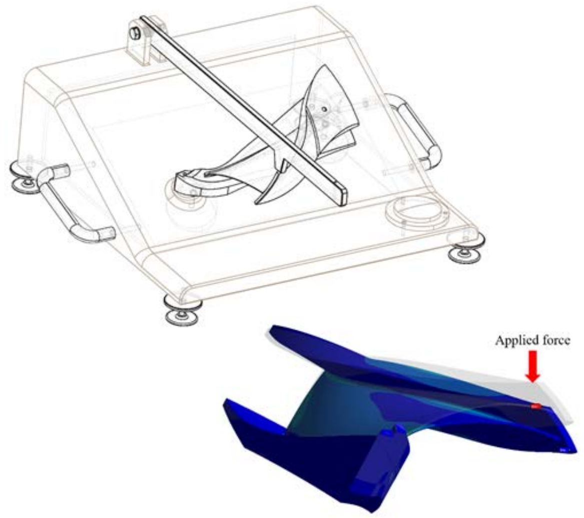


Figure 4. Strain gauge calibration
Figure 5. PhD candidate
Johannes Kverno, NTNU



HYDROFLEX ACTIVITIES

LAB TESTING

JESLINE JOY

Mitigation of the Rotating Vortex Rope in the Francis-99 Draft Tube with Guide Vane

During the initial phase of my research study, a guide vane system to mitigate the rotating vortex rope (RVR) effectively at part load (PL) operating condition was developed at LTU.
The guide vane system consists of a set of three vanesmade of an upper and lower hydrofoil, see figure 1. The upper hydrofoil is movable. The lower hydrofoil is fixed.The guide vane system is compact and robust, placed in the draft tube of the Francis-99 model turbine at certain distance from runner exit.

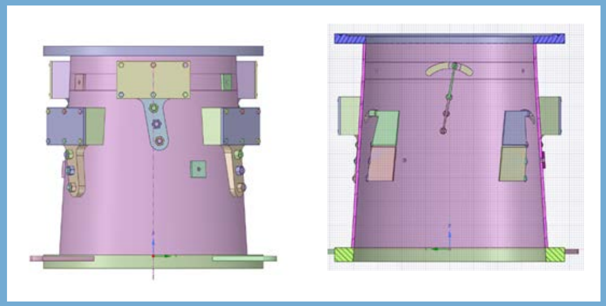
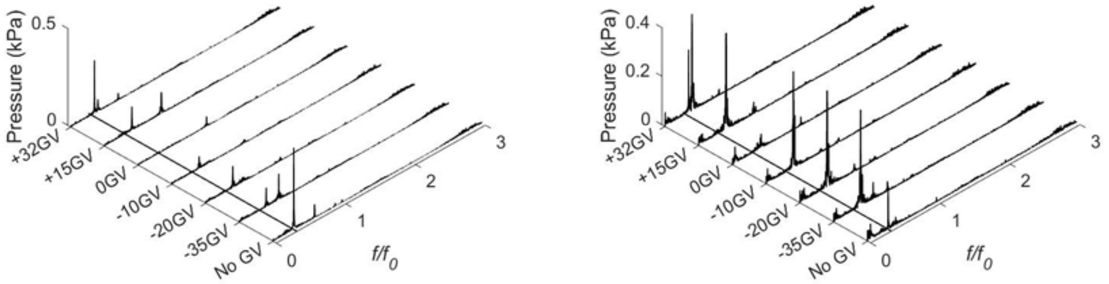


Figure1. Draft tube cone, guide vane system.

To perform the experiments, a new draft tube cone and the guide vane system was manufactured, see figure 1.
The draft tube cone was slighly modified to accommodate the moving upper hydrofoil of the guide vanes system. The experiments were performed at NTNU Waterpower laboratory during January-February 2021. The whole process was challenging but I was able to achieve the experiments.

Figure2. Jesline Joy,PhD candidate at Luleå University of Technology, performing experiments in the lab.



(a)

(b)

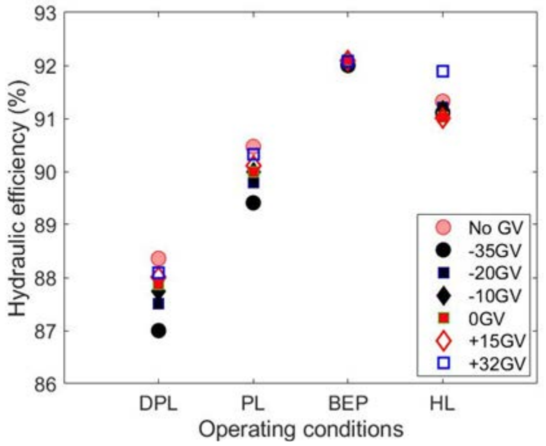


Figure 3. FFT analysis of the pressure signal at one of the pressure sensors in the draft tube and vaneless space respectively for the different draft tube GV (a) angles at DPL (b).

Figure 4. Hydraulic efficiency at different operating conditions for turbine without and with the guide vane systems at different upper hydrofoil angles.

The guide vanes system is found to mitigate the RVR expeimentally. Since the upper hydrofoil of the guide vane system is movable, the RVR mitigation analysis was performed for different upper hydrofoil angles.
The best results was achieved an upper hydrofoil angle of 0° For part load operating condition, there is a 50% to 90% decrement in the rotating mode, as a function of the upper hydrofoil angle. The plunging mode at PL was found to be insignificant.

The guide vanes system affects the hydraulic efficiency negatively at DPL, PL and positively at best efficiency point (BEP), high load (HL) operating condition. At BEP and HL, the maximum increment in hydraulic efficiency is +0.12% and +0.64% respectively. At DPL and PL, the minimum hydraulic efficiency decrement is -0.29% and -0.17%, respectively and maximum hydraulic efficiency decrement is -1.54% and -1.2% respectively. The hydraulic efficiency penalty for the 'maximum RVR mitigation' is -0.55% and -0.52% at DPL and Pl, respectively. More details can be found in figure 4.

This experiment was carried out under Task 3.1 of WP3 of HydroFlex.

AFC4HYDRO ACTIVITIES

7

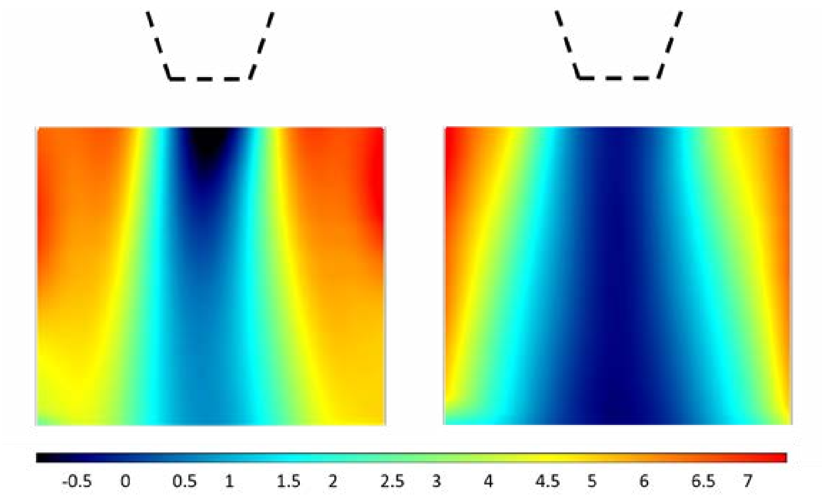
IPM ANALYSES

AT LTU

My work in WP1 includes theoretical, numerical and experimental analyses with which I'm aiming at improving the IPM system. So far, I have mostly been involved in designing, building and characterizing the down-scaled test rig at Luleå University of Technology (LTU).

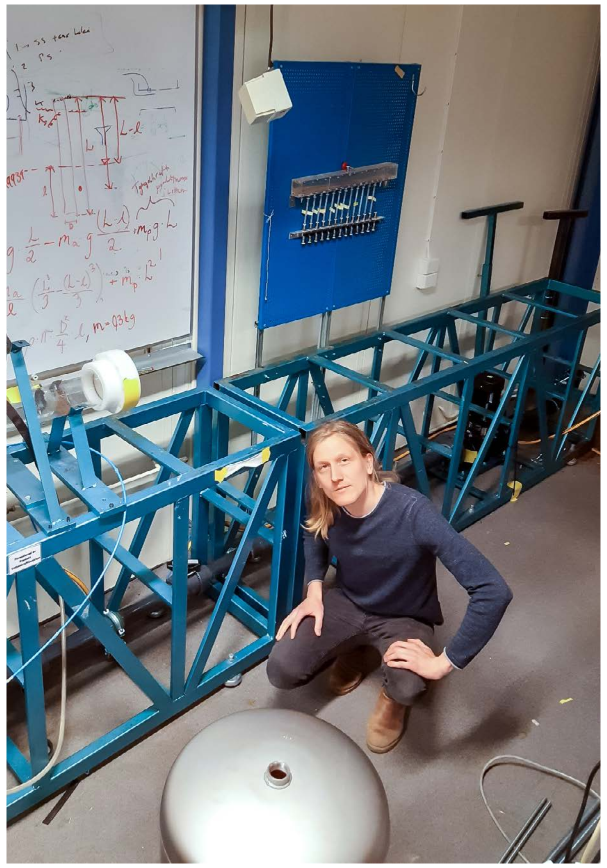
This first phase of the project has been quite diverse, spanning tasks such as CAD modeling, gluing PVC pipes as well as wiring sensors and control systems. Although these tasks have been very interesting and challenging, I am really looking forward now to head on to our attempts to mitigate the rotating vortex rope (RVR), both at LTU and later on this year at Vattenfall's laboratory in Älvkarleby.

Figure 1.
PIV measurements from the LTU test rig draft tube at the best efficiency point (left) and part load (right).



Characterization of the rig was initially performed using pressure measurements in the draft tube so that we could find the operating points at which the RVR was present. When we had found the operating point with the most prominent RVR pressure fluctuations, more detailed studies were conducted in which we measured the velocity field in the draft tube using particle image velocimetry (PIV). These measurements are also valuable not only for characterizing the test rig, but also as input to validate the numerical codes that my colleagues are working with.

Figure 2.
Assembling of the LTU test-rig.



So far, I have spent a lot of time in the lab; however, my main task in this project is to work with so called global stability analysis. Global stability analysis is a theoretical and numerical tool that is used to predict conditions at which a fluid flow becomes prone to hydrodynamic instabilities, with the most common example being the transition from laminar to turbulent flow. In the frame of AFC4Hydro, we hope that global stability analysis will help us to increase our understanding of the RVR by treating it as a hydrodynamic instability. In addition to providing fundamental insight into the RVR formation, by using something called adjoint global stability analysis, we hope to be able to obtain a theoretical answer about where in the draft tube flow that it is most effective to perform mitigation in order to decrease the RVR pressure pulsations.
Having such an answer can significantly increase the effectiveness of the flow control systems, and avoid ad-hoc solutions that only works in a specific turbine.

Dr Joel Sundström,
Division of Fluid and
Experimental Mechanics
at the Department of
Engineering Sciences
and Mathematics.
Luleå University of
Technology

8

CAPITALISING ON COLLABORATION TO ADVANCE HYDROPOWER RESEARCH

In the past months, the EERA Joint Programme on Hydropower has conducted a series of new activities to increase not only its level of engagement but also the impact of its members in the energy research community.

Over the course of the first months of 2021, a series of meetings was held to address the soon-to-be-published calls of Horizon Europe, the next research framework programme of the European Union.
During these meetings, more than 20 members have taken part to consortium-building activities on selected topics with potential relevance for the hydropower sector. The meetings have produced a positive result, fostering the creation of multiple potential proposals that span the entire hydropower research field. Discussions are now being held between members to connect capacities and researchers in order to apply to the Horizon Europe calls, once published officially by the European Commission.

The Joint Programme has also produced two documents that will be key to understand the next steps in its development. The first was an update of the Joint Programme's Strategic Research Agenda (SRA), summarising the state of play in the hydropower research sector and the main challenges faced by the different groups of the Joint Programme.
The SRA represents the blueprint for the activities conducted and will be updated over the course of the next years according to the most relevant and updated changes in the hydropower sector.

The second document is the Joint Programme Annual Report for 2020, a document showcasing the main activities performed in the past year. Although hampered by the Covid-19 pandemic, the group has demonstrated its willingness to collaborate on common issues. Not only two proposals were submitted, one project in the context of Horizon 2020 and one proposed COST Action, but also new fora were launched.
This is the case for the JP Hydropower Advisory Board, a group of industry representatives that has the objective to strengthen the relationship between industry and research.
However, among the main activities performed, particularly relevant has been the contribution to the Clean Energy Transition Partnership's (CETP) Strategic Research and Innovation Agenda (SRIA).

The Joint Programme, thanks to the role of advisor played by EERA to the CETP, was invited to provide input regarding the Hydropower sector. Thirteen editors from the JP have collaborated on the document, which was included in the Input Paper on "Renewable Technologies".

Project coordinator of HydroFlex, Ole Gunnar Dahlhaug is also the coordinator of EERA JP Hydropower.

MORE INFORMATION ON THESE ACTIVITIES AND ADDITIONAL RELEVANT NEWS ON THE JOINT PROGRAMME ARE AVAILABLE AT WWW.EERA-HYDROPOWER.EU

Raffaele Guerini,
Policy & Communications Officer / JP Hydropower Manager,
European Energy Research Alliance

SUMMARY OF

PUBLIC WORKSHOP

“FLEXIBILITY NEEDS IN THE NORDIC POWER SYSTEM TOWARDS 2030”

The third HydroFlex workshop took place on April 21, 2021. Due to covid-19 and travel restriction, the event, which was planned to be arranged at Luleå Technical University (LTU), Sweden had to be converted to a digital workshop. More than 80 speakers and participants joined the 3.5 hours long workshop.

The theme of the workshop was “Flexibility needs in the Nordic power system towards 2030”. In three sessions:

- Changing operating conditions
- Changing market operators
- Flexibility needs in 2030

The presenters and audience pondered the following questions:

- *How will Nordic hydropower as part of the European power supply system be operated?*

- *What are the main drivers for change in flexibility provision by hydropower plants in the Nordics?*

- *What benefits does an increased flexibilization of hydropower have in the Nordic power market?*

- *To what extent is flexibility provision from the Nordics possible for North- and Central Europe? What are the necessary conditions for this to happen?*

In general, most of the participants agreed that at least for the next two decades the development of more intermittent renewable energy in the Nordic region will be the most important driver for the flexibility needs in the Nordic power system. Based on the current foresight this implies a moderate increase in flexibility of operation and number of start-stops.
In closing, it was argued that demand response and battery will be the most important solution on short time scale and also on smaller geographic scale (smaller scale than the price areas).

A more full account is available at the HydroFlex website h2020hydroflex.eu.

THANK YOU

EUROPEAN COUNCIL

NTNU

UPC

UPPSALA UNIVERSITET

CHALMERS UNIVERSITY OF TECHNOLOGY

SPV

LULEÅ UNIVERSITY OF TECHNOLOGY

FDB Flow Design Bureau

SINTEF

RAINPOWER

University of Strathclyde Glasgow

Lyse

NINA Norwegian Institute for Nature Research

Statkraft

Multiconsult

VATTENFALL

ABB

EDR MEDESO

IAEW Institute of Power Systems and Power Economics

RWTH AACHEN UNIVERSITY

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EERA
European Energy Research Alliance

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