ANNUAL REPORT

2020

HydroCen
NORWEGIAN RESEARCH CENTRE
FOR HYDROPOWER TECHNOLOGY

FME
CENTRE FOR
ENVIRONMENT-
FRIENDLY ENERGY
RESEARCH

HydroCen is a research centre for environmentally friendly energy. Our main objective is to enable hydropower to meet complex challenges and exploit new opportunities through innovative technological solutions.

The main research partners in HydroCen are The Norwegian University of Science and Technology (NTNU), SINTEF Energy Research and Norwegian institute for nature research (NINA). The centre has a total budget of 400 million NOK over eight years and is financed by the Norwegian Research Council (50%), the research institutions (25%) and partners from the hydropower industry (25%).

WP 1
Hydropower structures

WP 2
Turbine and generator

WP 3
Market and services

WP 4
Environmental design

2020 – THE YEAR FOR ADAPTABILITY, STAMINA, AND HARD WORK


Liv Randi Hultgreen

HydroCen has proved that we deliver world-leading research results even when it seems like the world has come to a halt. Our scientists have taken the challenge, found ways to cooperate and move forward, from home offices to labs, hydro power stations and watercourses. Please take the time to update yourself on our achievements, and join me in applauding our great staff of scientists!

In 2020 HydroCen has funded 21 projects and been part of additional 23 associated projects. 19 PhDs are part of these projects, and 32 Master Students have completed their thesis' with HydroCen. We have continued the very high level of research activity from previous years, resulting in a high rate of scientific publications and several conference presentations. Even though many conferences and meetings have gone digital this year, our scientists have taken an active part in a wide range of activities.

In 2019 we launched AlternaFuture, and this multi-disciplinary project was completed in 2020, proving that there are great opportunities to develop hydropower in Norway. In 2020 we have also done research on fault detection in generators, investigating the possibilities for automatic fault detection using AI and machine learning.

Another considerable achievement is the development of new solutions for fish fences in rivers, where our scientists have run a multi-disciplinary project to couple the knowledge of turbine engineers and biologists. I recommend you read up on the above-mentioned developments in this report, and encourage you to reach out to our scientists if you would like more information.

International cooperation has been - and still is- a focus area for HydroCen. I am proud of the high level and high quality of international research we are involved in. In February 2020 HydroCen arranged the international conference Hydropower Summit 2020, where the top-level agreement between the Norwegian Ministry of Petroleum and Energy and the US Department of Energy on hydropower research was signed. In the months thereafter many new research activities have materialized involving Norway and USA.

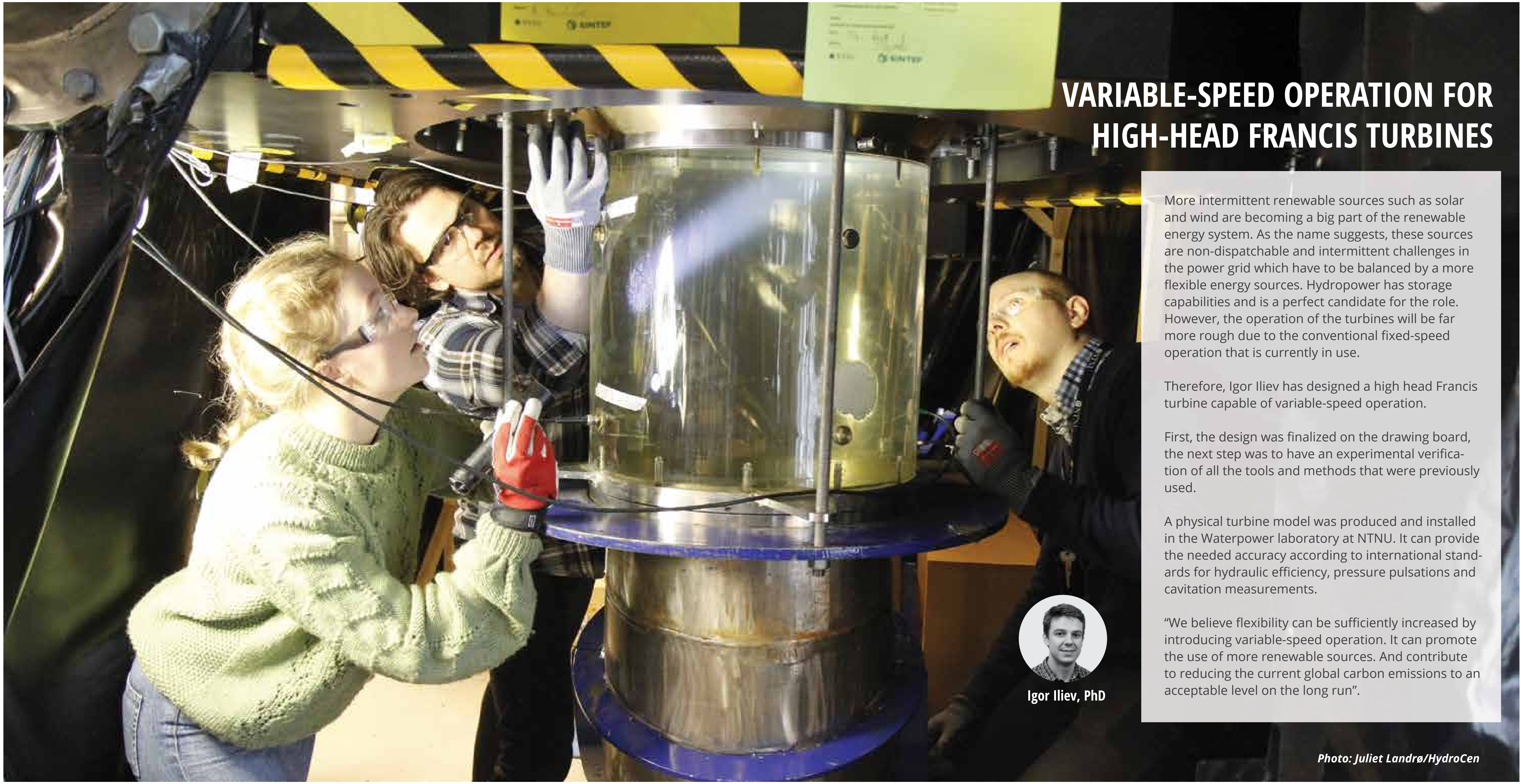
Every year our partners and scientists are encouraged to apply for new research activities that are aligned with HydroCen's strategies and the industry's needs. In 2020 one such new activity was the project ValueFlex, where we investigate the potential value more flexible operational modes may imply for hydropower producers. We look forward to learn about the findings when the project is completed in 2021.

In 2021 we will initiate 14 new projects, which will focus on the implications from more dynamic operational modes for equipment, tunnels, rivers, reservoirs, fish, value creation and modeling needs. One of these projects is PotOUt, a multi-disciplinary project that will focus on the potential for upgrading and expanding hydropower combining new technology and environmental design.

FME HydroCen's success lies in the hands of our world-leading scientists, our engaged and interested user partners, our ever-supportive board and leadership team. On behalf of the administration, I would like to thank you all!

Lastly, I personally would like to thank all of you, and Ole Gunnar Dahlhaug in particular, for the very warm welcome you have given me in 2020!

Liv Randi Hultgreen,
Executive Director, HydroCen



VARIABLE-SPEED OPERATION FOR HIGH-HEAD FRANCIS TURBINES

More intermittent renewable sources such as solar and wind are becoming a big part of the renewable energy system. As the name suggests, these sources are non-dispatchable and intermittent challenges in the power grid which have to be balanced by a more flexible energy sources. Hydropower has storage capabilities and is a perfect candidate for the role. However, the operation of the turbines will be far more rough due to the conventional fixed-speed operation that is currently in use.

Therefore, Igor Iliev has designed a high head Francis turbine capable of variable-speed operation.

First, the design was finalized on the drawing board, the next step was to have an experimental verification of all the tools and methods that were previously used.

A physical turbine model was produced and installed in the Waterpower laboratory at NTNU. It can provide the needed accuracy according to international standards for hydraulic efficiency, pressure pulsations and cavitation measurements.

“We believe flexibility can be sufficiently increased by introducing variable-speed operation. It can promote the use of more renewable sources. And contribute to reducing the current global carbon emissions to an acceptable level on the long run”.

Igor Iliev, PhD

Photo: Juliet Landrø/HydroCen

HOW HEALTHY ARE THE MAIN ARTERIES OF THE HYDROPOWER PLANT?

In Norwegian hydropower we mostly operate with unlined pressure tunnels, meaning that the water is in direct contact with the rock and that the water pressure is transferred to the rock.

Previously, it was believed that as long as the weight of the rock above the tunnel, the overburden, was greater than the water pressure inside the tunnel, the design was safe and the tunnel would not crack as a result of the pressure.

Unfortunately, it's not that simple. Large variations in rock stress, not corresponding to the weight of overburden, has been observed at several power plants. In a few cases such stress variability was left undetected due to lack of stress measurements. This causes dramatic and very costly hydraulic failure. Even though it now is more or less standard to perform stress measurements, those are few and far apart, often leaving kilometres of tunnel essentially untested. In his research Henki Ødegaard is therefore trying to develop a cost-effective and simplified version of the hydraulic jacking rock stress measurements.
Read more: Design of unlined pressure tunnels in Norway - limitations of empirical overburden criteria and significance of in-situ rock stress measurements

Doing tests in the tunnel.
Photo Erlend Andressen

Henki Ødegaard and the test-device called Blåstål
Photo: Tone Nakstad

APPLYING SIMULATOR TO A REAL INVESTMENT PROBLEM

We have testet a first first version of a new simulator on a real investment project. The purpose was to simulate operation and calculate production revenue for alternative upgrades of the Duge pumped storage plant, owned and operated by the Sira-Kvina power company. This experience gave very good insight into the problems that the simulator is designed to analyze and is an important input to ongoing work in WP 3.3. The simulator includes more physical details than what existing tools can do and will give better decision support for investments. An example is given in the figure comparing information about pumping operation from current tool (ProdRisk) with the new simulator (ProdRisk-SHOP).

Birger Mo
Hans Olaf Hågenvik

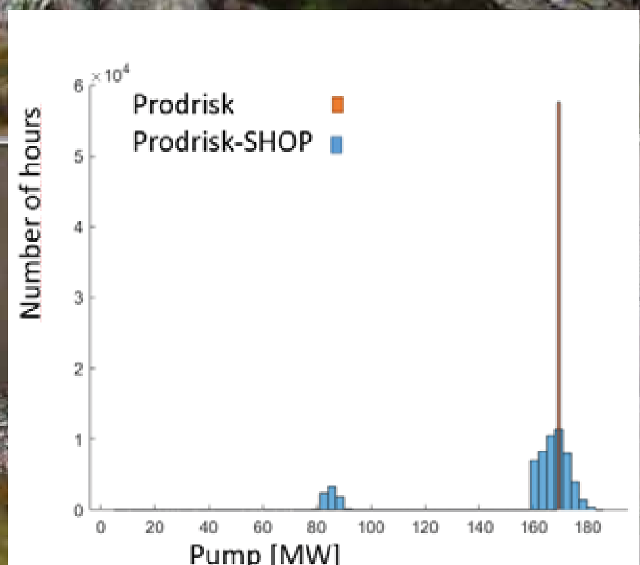


Photo: Sira-Kvina Kraftselskap

A WIDER APPROACH TO ENVIRONMENTAL DESIGN IN RIVER NEA

Environmental design aims to evaluate, develop and implement measures to improve environmental conditions in regulated rivers, taking into consideration other societal interests as well hydropower production in itself.

This concept was originally developed for Atlantic salmon in regulated rivers and with River Nea as our study river we have expanded the concept to include larger parts of the ecosystem (fish and benthic animals) as well as human interests such as leisure activities.

Since 2018, hydrologists, biologists and social scientists from HydroCen have joined forces to investigate how environmental conditions can be improved in the river by using state-of-the-art technologies with a cross disciplinary approach.

Scientists have studied how the numerous weirs in the river impact the local brown trout population and benthic invertebrates, and have identified bottlenecks for the populations.

This has been done using both traditional methods and modern tools such as remote sensing drones, airplanes and laser, as well as genetic methods such as environmental DNA and barcoding.

The leisure use of River Nea and nearby areas by local inhabitants and tourists has been studied, as well as how potential mitigation measures are perceived. This extensive work will be presented further in a report during the spring of 2021.

Photos: Line Sundt-Hansen

Jonas Bergmann Paulsen, Innovation Manager

INNOVATION IN HYDROCEN

Cross-disciplinary projects, dialogue with the hydropower industry and increased focus on impact and implementation are some of the success criteria when it comes to innovation in HydroCen.

Securing relevance through the technical committees
HydroCen continues the close relationship between the work packages and the technical committees. The close dialogue ensures that HydroCen's research has a direction and focus which is relevant for the whole range of participants in the hydro power sector. This includes equipment manufacturers, power plant owners, grid owners and governmental regulatory authorities.

Utilizing the range of the technical committees increases the relevance, potential impact and the likelihood of results being implemented and thereby improving the innovation process.

Increased focus on impact
HydroCen has had an increasing focus on potential impact from the research. Impact in HydroCen is defined as value creation in and from the hydropower sector and/or societal benefits including environmental impact.

The UN Sustainable Development Goals (SDG) are used as a guideline to ensure societal benefits such as access to sustainable and reliable energy, protection and restoration of freshwater habitats, resilience towards climate change and climate related disasters and sustainable use of water resources.

Increased focus on implementation
HydroCen has had an increased focus on implementation to increase the likelihood of results being utilized. Project managers are encouraged to include potential implementing entities in their research. There are two reasons for this: One is to increase the relevance of the research and the other is to define the interface between the researchers and implementors.

Funding may be one of the cornerstones in bridging the gap, and therefore a larger part of the financial mechanisms are considered when projects are maturing. In 2020 NTNU, NINA, Agder Energi, Sweco and STEIS Mekaniske Verksted cooperated on implementing a "fish fence" pilot in the Mandal river. This is a solution which potentially can greatly reduce the fatality rate of salomon smolt without impacting the power production of the hydro power plant. With assistance from the other entities STEIS Mekaniske verksted applied Innovation Norway for funding through the Environmental technology scheme which was approved. The remaining cost was covered by Agder Energi, whom received funding through the alliance "Nature Made Star".

Industry-academia interface
Through lessons learned HydroCen has seen the need of clarifying the interface between researchers and implementors. In several projects a mismatch between the expectations from the different stakeholders has been identified. The mismatch might be regarding the maturity level of technology being developed where the researchers have reached the project objectives, but the maturity level is too low for industry partners without substantial further R&D.

Aligning the researchers expected output and required industry input at an early stage is therefore one of the challenges HydroCen has identified as a prerequisite for efficient innovation processes.

Open calls as a driver for innovation
In HydroCen's experience, ideas with high innovative potential are more likely to occur in cross-disciplinary projects.

Based on this experience the cross-disciplinary project AlternaFuture was established in 2019. The project used an unconventional approach where a theoretical exercise in extreme remodelling of a hydropower system was conducted.

During the exercise potential solutions to complex problems surfaced in the cross section between the different disciplines involved. These solutions will be further investigated in other projects. New open call projects that has a focus on innovation drivers such as cross-disciplinary, impact orientation and approach secure resources necessary to drive the results up on the TRL-scale will be prioritized.

Photo: Torbjørn Forseth/NINA/HydroCen

Photo: Torbjørn Forseth/NINA/HydroCen

COLLABORATION LED TO INNOVATION

Fish need to migrate to secure food and reproduction. In HydroCen a unique coalition between biologists and engineers has secured a new innovation to guide fish past the turbines.

In 2020 we installed the prototypes for a Fish fence in the Mandal river. The construction consists of floating docks, with metal racks under the surface. These racks are designed to create special eddies that lead the smolt along the fences and past the water intake at Laudal power station (Agder Energi).

The prototype test was a success and in the spring of 2021 a 70 meter construction will be installed, and researchers will monitor smolt to study how the fish fence affects the behavior of the fish. If this HydroCen innovation works on a large scale, it can become an important solution for fish migration at several power plants both in Norway and other parts of the world.

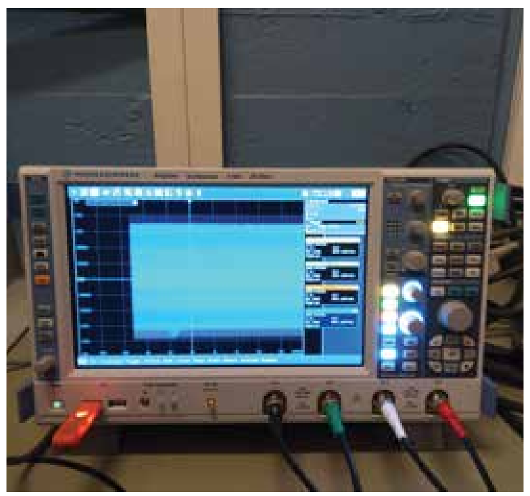
Further reading: Miljødesign Mandalselva. Samlet tiltaksplan og oppsummering

Hossein Ehya
PhD Fellow

TESTING AT KALVEDALEN

Finding early stage faults inside a hydropower generator is extremely difficult, but this year HydroCen PhD Hossein Ehya has been able to do just that. When reports came from Kalvedalen power plant (Hafslund-Eco) that the vibration level of the generator had significantly increased, Hossein went and measured the stray magnetic field and vibration in the generator. The sensors were attached on the stator back side and the generator operated in both no-load and full load.

The obtained signal was analyzed using an advanced signal processing tool. The results show that the generator has a short circuit fault in the rotor field winding and a dynamic eccentricity fault. These faults are almost impossible to detect, but now Hossein may be one of the first in the world to develop a monitoring system that will determine these types of faults in hydropower plants.



Photos: Hossein Ehya/NTNU/HydroCen

ALTERNAFUTURE: MORE POWER AND BETTER ENVIRONMENT

Major upgrades of existing hydropower systems can provide both significantly more power and a positive environmental effect through the use of environmental design.

In the AlternaFuture project, the researchers forced themselves to study the hydropower system from a new perspective. Allowing themselves to look outside the usual constraints and accepted truths.

Among other things, they have looked at how we could triple the installed capacity by including large pumped storage power plants.
- An upgrade of existing hydropower systems done correctly, using environmental design, can overall have positive consequences for the environment, says NTNU researcher Kaspar Vereide, who is project manager in the HydroCen project AlternaFuture.

Researchers also saw that such an upgrade of existing power systems can have a major positive effect on flood mitigation.

Larger ponds and larger reservoirs are some of the upgrades the researchers have used in some of their different scenarios, in addition to pumped storage power plants and a so-called flood power plant.

Engineers and biologists create innovative solutions together
- In such a theoretical project as AlternaFuture is, we did what we wished we could do in all development projects: Involve the environmental side from the start and contribute to setting the premises for the process, says Torbjørn Forseth, researcher at the Norwegian Institute for Natural Research (NINA).

This collaboration has helped to uncover where current technology has potential for improvement in future upgrades and expansions of existing hydropower plants, and which technological solutions should be developed to be able to make such extreme upgrades in a better way.

When the biologists, for example, pointed out that taking large amounts of water into a tunnel and sending it out into the sea would kill large amounts of fish, the engineers came up with proposals for new technical solutions for sifting the water.

- AlternaFuture first and foremost shows that when biologists and social scientists sit together with engineers, we get much better results than when we sit separately, says Forseth.

Read the report: HydroCen Report nr. 18: AlternaFuture Final Report

PHD'S IN HYDROCEN

Igor Iliev

PhD-Thesis
Francis turbines for variable speed operation.

Ascribing to the recent trends of market-driven electricity production and increased deployment of non-dispatchable renewables globally, several researchers have suggested the use of variable speed technology to improve the operational flexibility and efficiency of conventional Francis turbines.

In this thesis, the main objective is twofold. The first part was to provide a more detailed analysis of the efficiency gains and pressure fluctuations aspects that the technology could provide for low specific speed machines. In the second part, methods for numerical optimization are used to conduct a detailed parametric study on the possibility to improve the variable speed performance of a reference turbine.

The main accent is placed on the point that a turbine, which is meant to be operated at variable speeds exclusively, should be designed and optimized for that purpose from day one, and this may not necessarily be equal to the design philosophy of a synchronous speed representative.

This study provided an essential basis for the further work, suggesting that the level of efficiency gain from the variable speed operation is greatly dependent on the hydraulic design of the runner. Additionally, it is shown that when operating at rotational speeds specifically optimized for maximum efficiency, the amplitudes of the pressure pulsations in both runners were either reduced or stayed at the same level as for the synchronous speed operation.

Iliev designed 421 hydropower turbines during his PhD-research and chose the best for variable speed operation.

Ganesh Hiriyanna Rao Ravindra

PhD-Thesis
Hydraulic and structural evaluation of ockfill dam behavior when exposed to throughflow and overtopping scenarios.

Dams are vulnerable to extreme flood events in turn leading to accidental overtopping. This in particular applies to rockfill dams comprised of pervious and erodible material. Obtaining better understanding of behavior of rockfill dam components under extreme loading conditions is of significance from stability and economic standpoints.

The aim of the research work forming the basis for the thesis has been to present descriptions of hydraulic and structural behaviors of rockfill dams under throughflow and or overtopping scenarios.

The overarching focus of the research has been to obtain a holistic evaluation of rockfill dam behavior when subjected to extreme loading conditions. This in turn is intended at improving the state of the art in design and construction of these structures.

Ravindra has published several scientific articles during his PhD-research. He has investigated flow and overtopping of rock fill dams and, among other things, found that the dam toe can be crucial in extreme load situations such as overtopping. The data from the doctoral thesis will now be used to develop improve the design of the dam toe of rock fill dams.

Lena Selen

PhD-Thesis
Assessment on the swelling and disintegration potential of weak and weathered rocks in water tunnels of hydropower projects - a contribution based on use of laboratory testing methods

Swelling of rocks is a time-dependent phenomenon and a result of multiple and interactive rock characteristics interplaying in a complex picture. Further, the swelling responses of the rock mass are conditioned on the project-specific phases of operation and the consequential changes in rock material characteristics over time.

The extensive laboratory work in combination with the wide-ranged cooperation has resulted in suggestions on project-specific modifications on standardized laboratory tests which enable an interpretation of weak rock behavior closer to the in-situ situation of water tunnels. Improvements are made explicit on the oedometer swelling test procedure in operation at the NTNU laboratory, including preparation techniques and apparatus configuration, and investments on new equipment is in progress. Additionally, the research includes an experimental application of the in-situ flatjack test normally used to measure in-situ stresses around tunnels which now is installed in a hydropower tunnel to measure changes in stress during the initial phase of operation. The flatjacks will hopefully produce valuable data for comparison with and evaluation of the obtained laboratory results.

The overall findings are highly relevant for the hydropower industry but may also be relevant for other geotechnical projects where weathered and swelling rock materials cause challenges related to construction and/or operation of geotechnical structures.

BRIEF FROM THE BOARD

Representing a broad part of Norwegian hydropower production and management, HydroCen's Board strongly supports and applauds the excellent scientific activities driven forward by HydroCen. As industry partners, we are heavily committed to the ongoing projects, and actively participate with test cases, technical support and data contribution.

HydroCen is well managed, with a very high level of industry involvement, research activity and international affiliations. The center has successfully introduced international projects working with European, US and Asian research environments, and the portfolio of associated project continues to grow.

As HydroCen has approached the halfway mark in 2020, several important research results have materialized, which the industry is now implementing. The board is very pleased with the direction of the center's research activities and the high level of scientific quality in both research and publications. HydroCen plays a vital role in defining hydropower's opportunities in Norway's and Europe's power system going forward, as well as adressing the coming challenges with a more flexible power system in near future.

Ivar Arne Børset,
Chairman of the Board

Alf Inge Berget
E-CO

Eivind Heløe
Energi Norge

Knut Samdal
SINTEF

Olav Bolland
NTNU

Erik Skorve
BKK

Ingeborg Palm Helland
NINA

Harald Rikheim
NRC

Liv Randi Hultgreen
NTNU/Board Secretary

Rune Flatby
NVE

Photo: Juliet Landrø/HydroCen

INTERNATIONAL INTEREST IN HYDROCEN

In 2020 HydroCen has reached out even further internationally. We have organised the international collaboration along five main axes, ensuring knowledge transfer to/from relevant regions, excellent research groups and participation in technological fora.

The two strongest axes are geographically focused towards the Nordic and European regions, the third axis is towards Asia where large-scale development of hydropower is on-going. The forth axis to America and the fifth axis is towards the participation in technological fora. More than 60 international institutions are in contact with HydroCen through these axis.

CANADA:
Meetings with the HYCANOR-associates in the INTPART-research exchange programme.

USA:
Strategic cooperation with USDoE and several National Research Laboratories. MoU signed between USDoE and Norwegian Department of Energy in 2020. There were about 100 participants at the Hydro Power Summit, and this resulted in more than 10 collaborative projects between the USA and Norway.

BRAZIL:
Meetings with CEPEL (Electrical Energy Research Center) for possible cooperation on developing models for hydropower planning.

SWITZERLAND:
Researcher cooperation, and Scientific Committiee-member Prof Dr.Thomas Staubli.

SWEEDEN, ÄLVKARLEBY:
Vattenfall is partner in HydroCen, contributing with world class laboratories to study fish migration, dam-safety, turbines, generator operation and digitalisation tools.

EU:
There are 8 ongoing hydropower technology projects funded by the European Commission in 2020. HydroCen partners are working in 5 of these, and coordinating the HydroFlex-project which started in 2018, (www.h2020hydroflex.eu). HydroCen personnel lead the JP-hydropower and are active within the establishment of new projects and consortiums. Operation of Joint Programme Hydropower in EERA.

ALBANIA, MOGLICË:
Lena Selen presented her PhD Thesis investigating effects of swelling rock mass on stability and support in hydropower tunnels.

NEPAL, KATHMANDU:
Further strengthening of the research cooperation between Nepal, India and Norway. The Energize Nepal-project is still going strong with yearly student exchange and attendance at the yearly conference CHRT at Kathmandu University.

INDIA, ROORKEE:
The Indian Institute of Technology Roorkee continue to work together with HydroCen researchers and Kathmandu university to develop sediment resistant Francis turbines and new methods for data collection and modelling.

AUSTRALIA:
Meetings and cooperation with Hydro Tasmania, and MOU with the state government of Tasmania.

NORWAY AND USA SIGNED DEAL TO COOPERATE ON HYDROPOWER RESEARCH

Hydropower can be the key to realizing a stable renewable energy system. Both the US and Norway have a lot of hydropower resources and need to figure out how they can become more flexible, smarter and more environmentally friendly.

In 2020 HydroCen facilitated the Hydropower Summit where the Norwegian Ministry of Petroleum and Energy and the United States Department of Energy signed an MoU (Memorandum of Understanding) to strengthen and formalize and strengthen the research collaboration on hydropower.

— We are delighted to participate in this broadening of the energy collaboration, said Conner Prochaska, Chief Commercialization Officer, U.S. Department of Energy.

— It is exciting to see the amazing research that is happening here in Norway when it comes to hydropower and how committed the government and researchers are to going to the next step of hydropower research to get to a cleaner world, he said.

Increased security in the renewable energy system
The world needs more clean energy, and we have to pull together to solve the challenges we have today. Hydropower as a research topic has now been revitalized, due to its capacity to store energy.

With the increasing availability of solar- and wind power, the energy system needs a flexible stabilizer that can deliver energy when the wind isn't blowing or the sun doesn't shine. Today, that function is handled by thermal energy sources many places, but hydropower has the potential to be a sustainable and secure alternative.

—Through shared research, our partnership will produce new knowledge that will support the development and deployment of new, advanced hydropower resources, said Prochaska.

State secretary Odd Emil Ingebrigtsen signed the MoU on behalf of the Norwegian Government and addressed the need for new technology and better environmental solutions.

—Hydropower is the backbone of the Norwegian energy system, but it can still be improved. Efficiency is one thing, environment is another, and I am glad to see that those are both on the agenda today.

Researchers have met in several workshops to discuss specific research topics for collaboration.

Read more on hydrocen.blog

HAS DESIGNED A TURBINE THAT CAN HANDLE SEDIMENTS

The global development of hydropower is an important step towards low-carbon energy system and society. Todays hydropower technology is mainly developed for areas with no sediment in the water – such as Norway.

Himalaya is one of the areas in the world where there is a huge potential for hydropower, but its rivers also transport extremely high sediment loads.

FranSed is a collaborative project between NTNU/HydroCen, Indian Institute of Technology Roorkee (IITR) and Kathmandu University (KU), and the main aim is to develop of Francis turbines that are able to handle large amounts of sediments.

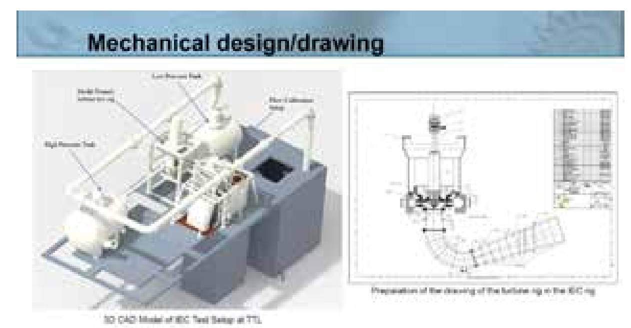
In 2020 a series of experiments is being carried out in the Turbine Testing Lab at Kathmandu University for investigating the correlation between several parameters affecting sediment erosion.

Recently, one of the major objectives of the project, designing a Francis turbine runner for variable speed operation was completed!

The research team of FranSed-project is currently involved in validating the new design using Rotating Disc Apparatus, and have signed an agreement with Butwal Power Company for prototype turbine testing.

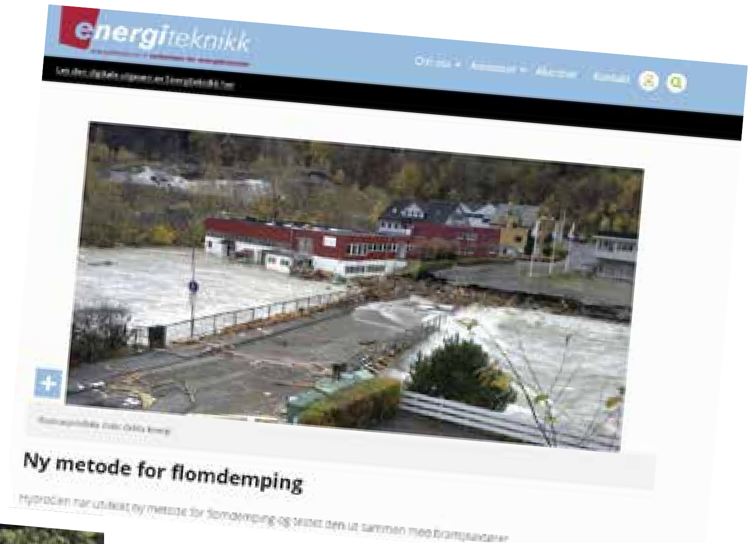
Read more about FranSed -or Energize Nepal (http://energizenepal.ku.edu.np/)

Saroj Gautam working with experiment in Rotating Disc Apparatus. Photo: Sailesh Chitrakar



HYDROCEN IN THE MEDIA

In 2020 HydroCen has been featured in a large range of media outlets such as national tv, radio and newspapers, as well as local media and technical magazines. In total HydroCen and our researchers have been mentiones in more than 180 articles and broadcasts. Researchers also participated in more than 25 popular science webinars. In 2020 we have also established a better SharePoint-site to facilitate more collaboration between partners and researches both in Norway and internationally.



OUR OULETS

Blog:
18 blog posts with information, news and research results from HydroCen in 2020, more than 14000 visitors.

Vannposten:
Weekly newsletter for researchers and partners. 24 publications and about 200 recipients

Website:
Information and contact details for all projects and researchers in HydroCen. Publications and innovations are also listed on www.hydrocen.no.

Webinar:
More than 25 webinars posted on Hydro-Cens YouTube-channel and others.

SOCIAL MEDIA

509

Twitter:
Sharing news and articles, and follow-ing the public debate. 509 followers.

468

Facebook:
Sharing articles and news with our 468 followers

404

LinkedIn:
404 followers and aiming to increase activity

ORGANISATION

Board

Name	Institution	Function
Ivar Arne Børset	Statkraft	Chairman of the Board
Ingeborg Palm Helland	NINA	Board member
Knut Samdal	SINTEF	Board member
Eivind Heløe	Energi Norge	Board member
Rune Flatby	NVE	Board member
Erik Skorve	BKK	Board member
Alf-Inge Berget	E-CO	Board member
Olav Bolland	NTNU	Board member
Liv Randi Hultgreen	NTNU	Executive Director/Board Secretary
Harald Rikheim	NRC	Observer
Juliet Landrø	NINA	Observer
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Petter Støa	Sintef Energi	Deputy board member
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Jane Berit Solvi	Skagerak	1. deputy board member
Tormod Eggan	TrønderEnergi	2. deputy board member
Bjørn Honningsvåg	Lyse	3. deputy board member

Executive Management Team and Admnistration

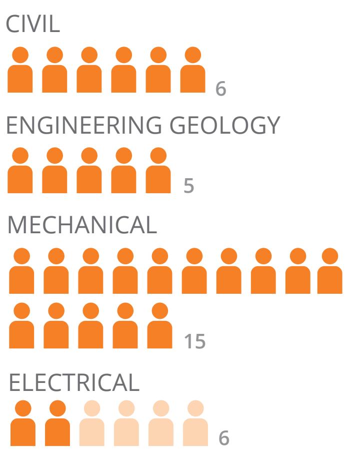
Name	Institution	Function
Liv Randi Hultgreen	NTNU	Executive Director/Board Secretary
Ole Gunnar Dahlhaug	NTNU	Member
Line Sundt-Hansen	NINA	Member
Michael Belsnes	SINTEF	Member
Gaute Egeland Sanda	Hydro	Member
Sigve Næss	BKK	Member
Ida Kristin Antonsen	NTNU	Coordinator
Juliet Landrø	NTNU	Communications officer
Birk Fiveltun	NTNU	Finance officer
Jonas Bergmann-Paulsen	NTNU	Innovation Manager

Researchers

Name	Institution	Main research area
Anders Foldvik	NINA	Hydropower structures
Bendik Torp Hansen	SINTEF	Hydropower structures
Elena Pummer	NTNU	Hydropower structures
Fjóla G. Sigtryggsdóttir	NTNU	Hydropower structures
Julie Charmasson	SINTEF	Hydropower structures
Kaspar Vereide	NTNU	Hydropower structures
Krishna Panthi	NTNU	Hydropower structures
Leif Lia	NTNU	Hydropower structures
Nils Reidar Bøe Olsen	NTNU	Hydropower structures
Nils Ruther	NTNU	Hydropower structures
Siri Stokseth	NTNU	Hydropower structures
Arne Nysveen	NTNU	Turbine and generators
Atsede G. Endegnanew	SINTEF	Turbine and generators
Bernt Lie	USN	Turbine and generators
Bjørnar Svingen	NTNU	Turbine and generators
Chirag Trivedi	NTNU	Turbine and generators
Eivind Solvang	SINTEF	Turbine and generators
Espen Eberg	SINTEF	Turbine and generators
Gunne Hegglid	USN	Turbine and generators
Henrik Enoksen	SINTEF	Turbine and generators
Jonas Kristiansen Nøland	NTNU	Turbine and generators
Jørn Foros	SINTEF	Turbine and generators
Karl Merz	SINTEF	Turbine and generators
Kjell Ljøkelsøy	SINTEF	Turbine and generators
Kjetil Uhlen	NTNU	Turbine and generators
Maren Istad	SINTEF	Turbine and generators
Ole Gunnar Dahlhaug	NTNU	Turbine and generators
Olve Mo	SINTEF	Turbine and generators
Pål-Tore Storli	NTNU	Turbine and generators
Roger Olsson	NGI	Turbine and generators
Roy Nilsen	NTNU	Turbine and generators
Sailesh Chitrakar	KU	Turbine and generators
Sverre Hvidsten	SINTEF	Turbine and generators
Torbjørn Nielsen	NTNU	Turbine and generators
Tuan T. Nguyen	SINTEF	Turbine and generators
Arild Helseth	SINTEF	Market and services
Arnt Ove Eggen	SINTEF	Market and services
Birger Mo	SINTEF	Market and services
Christian Øyn Naversen	SINTEF	Market and services
David Barton	NINA	Market and services
Hans Ivar Skjelbred	SINTEF	Market and services
Hans Olaf Hågenvik	SINTEF	Market and services
Ingeborg Graabak	SINTEF	Market and services
Lennart Schönfelder	SINTEF	Market and services
Linn Emelie Schäffer	SINTEF	Market and services
Magnus Korpås	NTNU	Market and services
Mari Haugen	SINTEF	Market and services
Michael Belsnes	SINTEF	Market and services
Stein-Erik Fleten	NTNU	Market and services
Tor Haakon Bakken	NTNU	Market and services
Ana Adeva Bustos	SINTEF	Environmental design
Ana Teixeira da Silva	NINA	Environmental design
Atle Harby	SINTEF	Environmental design
Audun Ruud	NINA	Environmental design
Berit Köhler	NINA	Environmental design
Frode Fossøy	NINA	Environmental design
Ingeborg Palm Helland	NINA	Environmental design
Ingebrigt Uglem	NINA	Environmental design
Karl Øystein Gjelland	NINA	Environmental design
Knut Alfredsen	NTNU	Environmental design
Line Sundt-Hansen	NINA	Environmental design
Marcell Szabo-Meszaros	SINTEF	Environmental design
Margrete Skår	NINA	Environmental design
Peggy Zinke	NTNU	Environmental design
Richard Hedger	NINA	Environmental design
Terje Bongard	NINA	Environmental design
Tonje Aronsen	NINA	Environmental design
Torbjørn Forseth	NINA	Environmental design
Ulrich Pulg	NORCE	Environmental design
Øystein Aas	NINA	Environmental design
Jochen Aberle	TU Braunschweig	Associated project
Thomas Staubli	Hochshule Luzern	Scientific committee
Niels Jepsen	Technical University of Denmark	Scientific committee
Juan Ignacio Pérez-Díaz	Technical University of Madrid	Scientific committee
Markus Aufleger	University of Innsbruck	Scientific committee

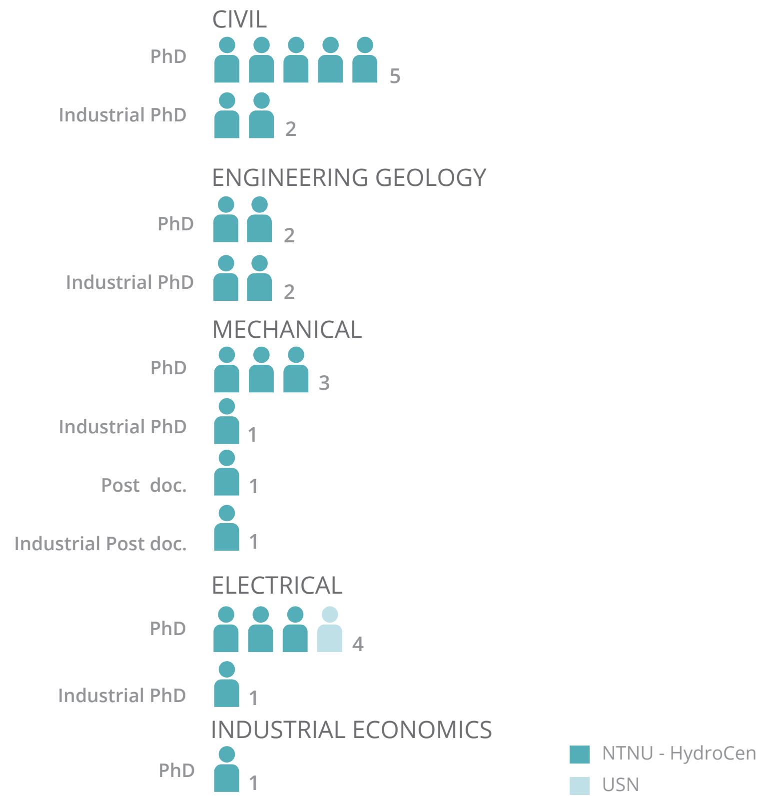
MASTER STUDENTS

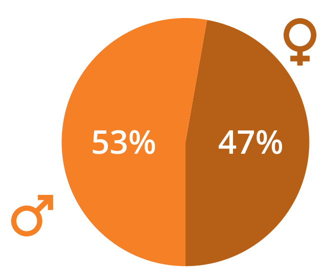
In 2020 we had a total of 32 master students at NTNU and The University of South-Eastern Norway (USN) within the field of hydropower. The distribution between the disciplines Civil, Engineering geology, Mechanical and Electrical is shown in the figure below.



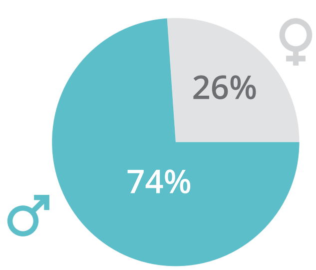
PHD AND POST DOCS.

In 2020 a total of 23 PhD and Post docs were in HydroCen. They worked within Civil, Engineering geology, Mechanical, Electrial and Industrial economics.

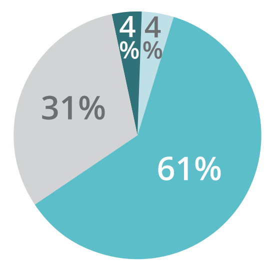




Gender distribution



Gender distribution



Distribution between PhD, Post doc. and industrial-PhD and post doc

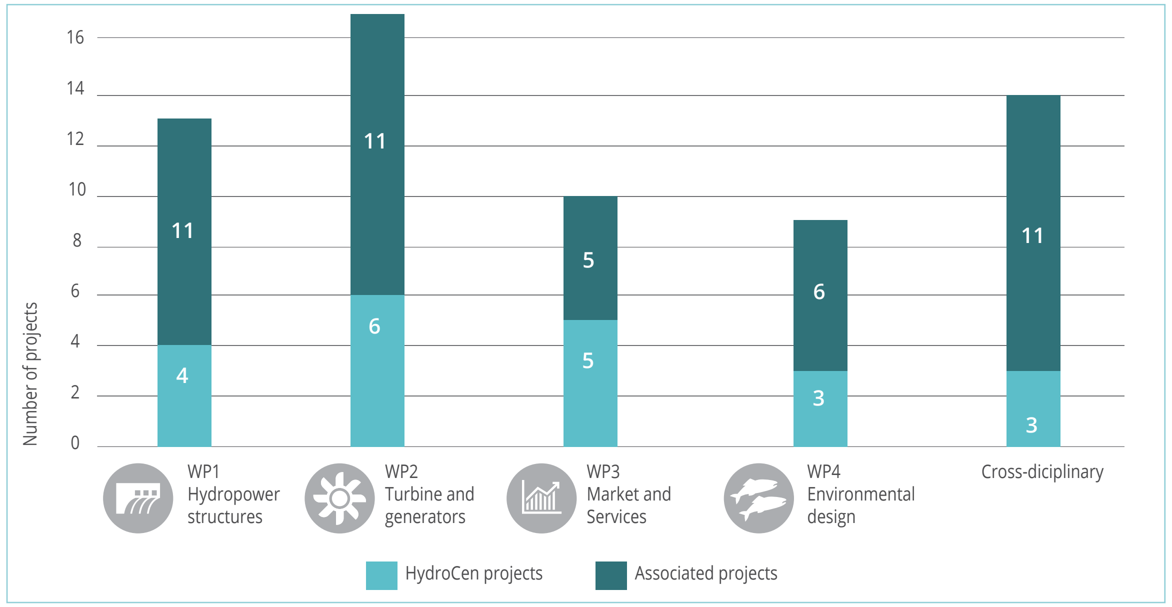
PhD and Post doc. in HydroCen, active in 2020					
Name	PhD Post doc.	Gender	Nationality	Topic	Period
Andreas Kleiven	PhD	M	Norwegian	Investment Decisions in Upgrading and Refurbishment of Hydropower Plants	2017-2020
Celine Faudot	Post doc.	F	French	Fatigue Loads on Turbines attached to a Conduit System	2017-2020
Ganesh Ravindra	PhD	M	Indian	Embankment dam safety under extreme loading conditions	2017-2020
Helene Dagsvik	PhD	F	Norwegian	Reversible Pump-Turbines in Existing Power Plants	2017-2020
Kristian Sagmo	PhD	M	Norwegian	Flow manipulation for improved operation of hydraulic turbines	2017-2020
Livia Pitorac	PhD	F	Romanian	Upgrading of hydropower plants to pumped storage plants: reconstruction and improvements of the tunnel system	2017-2020
Bibek Neupane	PhD	M	Nepalese	Long-term impact on unlined tunnels of hydropower projects due to frequent start stop sequences	2017-2021
Henki Ødegaard	PhD	M	Norwegian	Optimization of test methods and design of transition zones in unlined pressure tunnels	2017-2021
Håkon Sundt	PhD	M	Norwegian	Environmental design for multiple interests under future flexible hydropower operation	2017-2021
Lena Selen	PhD	F	Norwegian	Effects of swelling rock and swelling clay in water tunnels	2017-2021
Ola Haugen Havrevoll	PhD	M	Norwegian	Rock traps in pumped storage and peaking power plants	2017-2021
Bjørn Solemslie	Post doc.	M	Norwegian	Resonance and pressure pulsations in High Head Francis Runner	2018-2020
Raghbendra Tiwari	PhD	M	Nepalese	Frequency converter solutions and control methods for variable speed operation of pump storage plant	2018-2020
Diwash Lal Maskey	PhD	M	Nepalese	Sediment handling at the intake of the hydropower plants: A toolbox for decision making	2018-2021
Hossein Ehya	PhD	M	Iranian	Electromagnetic Analysis and Online Fault detection of Hydropower Generators	2018-2021
Nirmal Acharya	PhD	M	Nepalese	Design of a Francis turbine that accomodates high sediment concentration	2018-2021
Shohreh Monshizadeh	PhD	F	Iranian	The Flexible Hydro Power Unit	2018-2021
Tor Inge Reigstad	PhD	M	Norwegian	Grid Integration of Variable Speed Hydro Power Plant	2018-2021
Halvor Kjærås	PhD	M	Norwegian	Modeling of fish guidance by floating devices	2018-2022
Geir Helge Kiplesund	PhD	M	Norwegian	Embankment dam safety under extreme loading conditions: Bre-aching of embankment dams	2019-2022
Igor Iliev	Post doc.	M	Macedonian	Focused research in hydraulic turbines	2020-2022
Linn Emelie Schäffer	PhD	F	Norwegian	Modelling of Environmental Constraints for Hydropower Optimiza-tion Problems	2020-2023
Subhojit Kadia	PhD	M	Indian	Numerical modelling of sediment bypass tunnels.	2020-2023

FINANCIAL STATEMENT HYDROCEN 2020

			All figures in 1000 NOK
Funding	**Funding**	**In-kind**	**Total**
The Research Council of Norway	28 898		28 989
Industry partners	10 023	3 519	13 542
Research partners		17 838	17 838
Total funding 2020	**38 921**	**21 357**	**60 278**
Revenue 2020	**Funding**	**In-kind**	**Total**
Sintef Energi	13 245	4 787	18 032
NINA	6 341	2 543	8 884
NGI		407	407
USN	1 125	44	1 169
KU	200	77	277
NTNU	18 010	9 980	27 990
Industry in-kind		3 519	3 519
Total Costs 2020	**38 921**	**21 357**	**60 278**

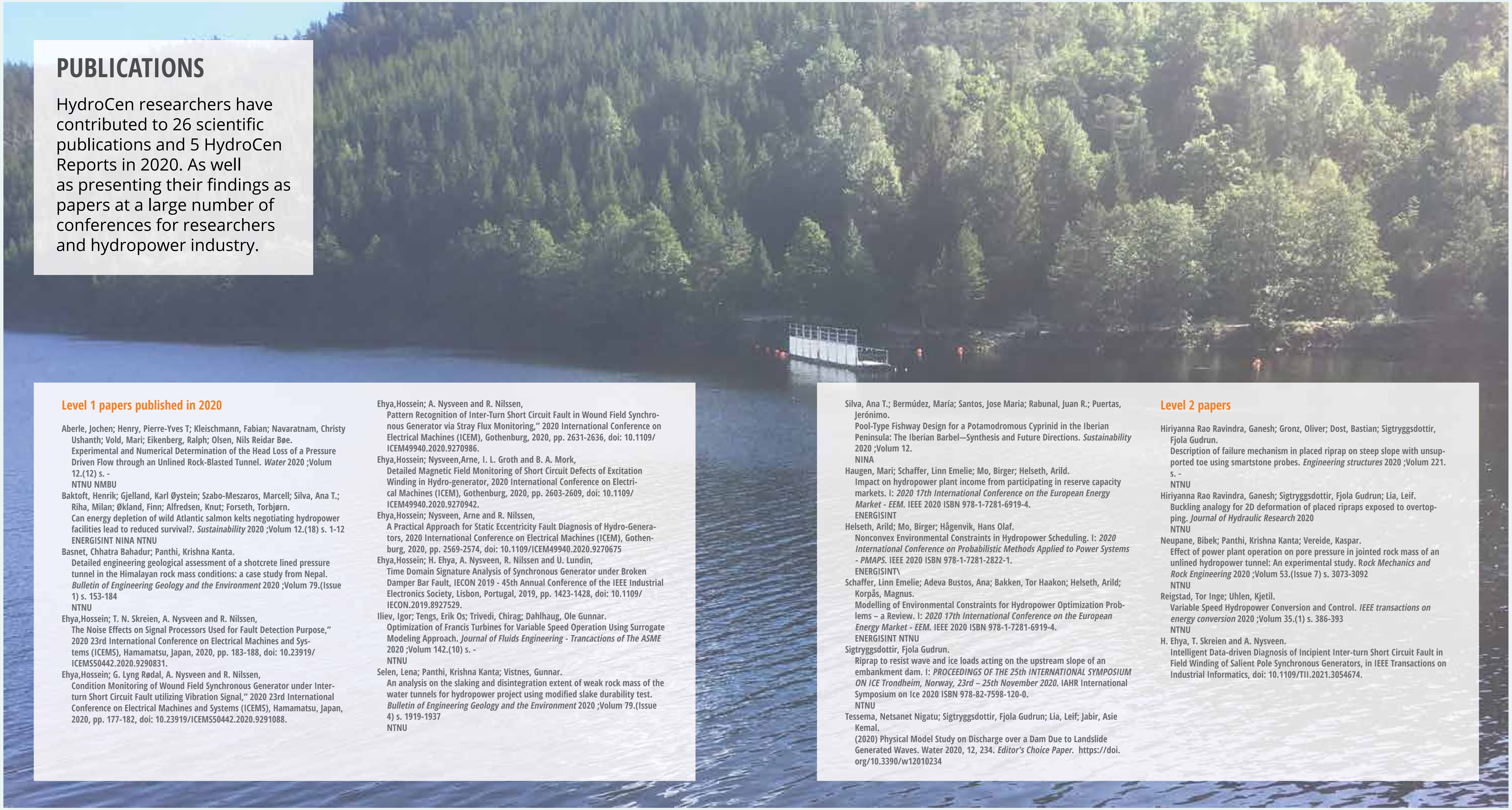
PROJECTS OVERVIEW 2020

A total of 65 projects related to hydropower were ongoing in 2020. 44 of these are associated projects within hydropower where HydroCen' s researchers are involved.



HydroCen Projects		
Project name	Project leader	Field of study
1.1 Tunnels, penstocks and surge chambers	Krishna Panthi	Hydropower structures
1.2 Dam construction and dam saftey	Fjola G. Sigtryggsdottir	Hydropower structures
1.3 Sediment handling	Nils Rüther	Hydropower structures
1.4 Fish friendly hydropower intakes	Leif Lia	Hydropower structures
2.1 Variable speed operation	Olve Mo	Turbine and generators
2.2 Fatigue loads on turbines	Torbjørn Nielsen	Turbine and generators
2.3 Pump turbines in existing power plants	Pål-Tore Storli	Turbine and generators
2.4 Turbine and Generator Lifetime	Maren Istad	Turbine and generators
2.5 Flexible Hydropower Unit	Kjetil Uhlen	Turbine and generators
2.6 New Design of Guide Vanes	Pål-Tore Storli	Turbine and generators
3.1 Future market structures and prices	Birger Mo	Market and services
3.2 Remaining useful life, failure probability	Arnt Ove Eggen	Market and services
3.3 Optimal hydro design in the future power system	Birger Mo	Market and services
3.4 Environmental constraints and uncertainties – impact on revenues	Arild Helseth	Market and services
3.5 Water resources assessment tool	Lennart Schönfelder	Market and services
4.1 Implementing and founding environmental design solutions (EDS)	Berit Köhler	Environmental design
4.2 Two-way Fish Migration	Ana da Silva	Environmental design
4.3 Environmental design	Atle Harby	Environmental design
5.1 AlternaFuture	Kaspar Vereide	Cross-disciplinary
5.2 Valueflex	Michael Belsnes	Cross-disciplinary
5.3 Digitalization	Hans Ivar Skjelbred	Cross-disciplinary

Associated Projects				
Project name	Project leader	Field of study	Type	Project owner
ALPHEUS	Pål-Tore Selbo Storli	Cross-disciplinary	EU H2020	TU Delft
CoBas	Christian Andresen	Market and services	IPN	SINTEF
DeGas	Ole Gunnar Dahlhaug	Cross-disciplinary	KPN	NTNU
DIRT-X	Nils Rüther	Market and services	EU H2020	NTNU
Elvemuslingens miljøkrav	Bjørn M. Larsen	Hydropower structures	Government	NINA
EnergizeNepal	Nawaraj Sanjel	Cross-disciplinary	Government	Kathmandu University
FishPath	Torbjørn Forseth	Environmental design	NFR	NINA
FIThydro	Peter Rutschmann	Turbine and generators	EU H2020	TU Münich
Fleksibel Sandfang (FlexS)	Kaspar Vereide	Turbine and generators	Industry	Sira Kvina Kraftselskap
FlomQ	Nils Rüther	Hydropower structures	IPN	Energi Norge
Francis-99	Chirag Trivedi	Environmental design	NTNU internal	NTNU
FranSed	Ole Gunnar Dahlhaug	Turbine and generators	Government	NTNU
HiFrancis	Ole Gunnar Dahlhaug	Turbine and generators	KPN	NTNU
HiFrancis FSI Toolkit	Martin Holst	Hydropower structures	IPN	EDRMedeso
HYCANOR	Ingeborg Palm Helland	Turbine and generators	INTPART	NINA
HydroBalance	Michael Belsnes	Market and services	KPN	SINTEF
HydroCen Labs	Ole Gunnar Dahlhaug	Cross-disciplinary	RCN Infrastructure	NTNU
HydroFLEX	Ole Gunnar Dahlhaug	Cross-disciplinary	EU H2020	NTNU
HydroStator	Arne Nysveen	Turbine and generators	KPN	NTNU
HyMo	Atle Harby	Environmental design	Government	SINTEF
HYPOS - Hydropower Suite	Nils Rüther	Turbine and generators	EU H2020	NTNU
IntHydro	Hossein Farahmand	Cross-disciplinary	IKT PLUSS	NTNU
JP hydropower/ EERA	Sara Heidenreich	Cross-disciplinary	RCN MVO	NTNU
Life expectancy calculations for Francis	Petter Østby	Turbine and generators	IPN	Rainpower
LitRo	Morten Kjeldsen	Hydropower structures	IPN	Flow Design Bureau
Miljødesign Mandalselva	Torbjørn Forseth	Environmental design	Industry	NINA
Miljødesignhåndbok for ørret i magasin	Ingeborg Palm Helland	Turbine and generators	Government	NINA
MonitorX	Maren Istad	Hydropower structures	IPN	Energi Norge
MultiSHARM	Marte Fodstad	Market and services	KPN	SINTEF
Capacity Building in Higher Education within Rock and Tunnel Engineering	Krishna K. Panthi	Cross-disciplinary	NORHED II	NTNU
Hydraulic Research and Education Laboratory and Dam Safety in Ethiopia	Leif Lia	Cross-disciplinary	NORHED II	NTNU
Nye miljørestriksjoner	Einar Kobro/ Ingeborg Graaba	Market and services	IPN	SINTEF
PlaF	Leif Lia	Hydropower structures	Industry	NTNU
PRIBAS	Arild Helseth	Hydropower structures	KPN	SINTEF
Reversible pumpeturbiner	Torbjørn Nielsen	Turbine and generators	Industry	NTNU
ROCARC	Charlie Chunlin Li	Hydropower structures	Samarbeidsprosjekt for samfunn & næring	NTNU
SafePASS	Torbjørn Forseth	Environmental design	KPN	NINA
SediPASS	Nils Rüther	Turbine and generators	KPN	NTNU, NVKS
Skred i magasin	Leif Lia	Hydropower structures	Government	NTNU
Stable Dams	Bård Arntsen	Hydropower structures	KPN	Norut
Strengthening the higher education at Kathmandu University	Ole Gunnar Dahlhaug	Cross-disciplinary	NORHED II	NTNU
STRIVAN	Siri Stokseth	Hydropower structures	IPN	NTNU
SusWater	Atle Harby	Environmental design	KPN	SINTEF
TunnelRoughness	Jochen Aberle	Cross-disciplinary	KPN	NTNU, NVKS



PUBLICATIONS

HydroCen researchers have contributed to 26 scientific publications and 5 HydroCen Reports in 2020. As well as presenting their findings as papers at a large number of conferences for researchers and hydropower industry.

Level 1 papers published in 2020

Aberle, Jochen; Henry, Pierre-Yves T; Kleischmann, Fabian; Navaratnam, Christy Ushanth; Vold, Mari; Eikenberg, Ralph; Olsen, Nils Reidar Bøe.
Experimental and Numerical Determination of the Head Loss of a Pressure Driven Flow through an Unlined Rock-Blasted Tunnel. *Water* 2020 ;Volum 12.(12) s. -
NTNU NMBU

Baktoft, Henrik; Gjelland, Karl Øystein; Szabo-Meszaros, Marcell; Silva, Ana T.; Riha, Milan; Økland, Finn; Alfredsen, Knut; Forseth, Torbjørn.
Can energy depletion of wild Atlantic salmon kelts negotiating hydropower facilities lead to reduced survival?. *Sustainability* 2020 ;Volum 12.(18) s. 1-12
ENERGISINT NINA NTNU

Basnet, Chhatra Bahadur; Panthi, Krishna Kanta.
Detailed engineering geological assessment of a shotcrete lined pressure tunnel in the Himalayan rock mass conditions: a case study from Nepal. *Bulletin of Engineering Geology and the Environment* 2020 ;Volum 79.(Issue 1) s. 153-184
NTNU

Ehya,Hossein; T. N. Skreien, A. Nysveen and R. Nilssen,
The Noise Effects on Signal Processors Used for Fault Detection Purpose," 2020 23rd International Conference on Electrical Machines and Systems (ICEMS), Hamamatsu, Japan, 2020, pp. 183-188, doi: 10.23919/ICEMS50442.2020.9290831.

Ehya,Hossein; G. Lyng Rødal, A. Nysveen and R. Nilssen,
Condition Monitoring of Wound Field Synchronous Generator under Inter-turn Short Circuit Fault utilizing Vibration Signal," 2020 23rd International Conference on Electrical Machines and Systems (ICEMS), Hamamatsu, Japan, 2020, pp. 177-182, doi: 10.23919/ICEMS50442.2020.9291088.

Ehya,Hossein; A. Nysveen and R. Nilssen,
Pattern Recognition of Inter-Turn Short Circuit Fault in Wound Field Synchronous Generator via Stray Flux Monitoring," 2020 International Conference on Electrical Machines (ICEM), Gothenburg, 2020, pp. 2631-2636, doi: 10.1109/ICEM49940.2020.9270986.

Ehya,Hossein; Nysveen,Arne, I. L. Groth and B. A. Mork,
Detailed Magnetic Field Monitoring of Short Circuit Defects of Excitation Winding in Hydro-generator, 2020 International Conference on Electrical Machines (ICEM), Gothenburg, 2020, pp. 2603-2609, doi: 10.1109/ICEM49940.2020.9270942.

Ehya,Hossein; Nysveen, Arne and R. Nilssen,
A Practical Approach for Static Eccentricity Fault Diagnosis of Hydro-Generators, 2020 International Conference on Electrical Machines (ICEM), Gothenburg, 2020, pp. 2569-2574, doi: 10.1109/ICEM49940.2020.9270675

Ehya,Hossein; H. Ehya, A. Nysveen, R. Nilssen and U. Lundin,
Time Domain Signature Analysis of Synchronous Generator under Broken Damper Bar Fault, IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society, Lisbon, Portugal, 2019, pp. 1423-1428, doi: 10.1109/IECON.2019.8927529.

Iliev, Igor; Tengs, Erik Os; Trivedi, Chirag; Dahlhaug, Ole Gunnar.
Optimization of Francis Turbines for Variable Speed Operation Using Surrogate Modeling Approach. *Journal of Fluids Engineering - Trancactions of The ASME* 2020 ;Volum 142.(10) s. -
NTNU

Selen, Lena; Panthi, Krishna Kanta; Vistnes, Gunnar.
An analysis on the slaking and disintegration extent of weak rock mass of the water tunnels for hydropower project using modified slake durability test. *Bulletin of Engineering Geology and the Environment* 2020 ;Volum 79.(Issue 4) s. 1919-1937
NTNU

Silva, Ana T.; Bermúdez, María; Santos, Jose Maria; Rabunal, Juan R.; Puertas, Jerónimo.
Pool-Type Fishway Design for a Potamodromous Cyprinid in the Iberian Peninsula: The Iberian Barbel—Synthesis and Future Directions. *Sustainability* 2020 ;Volum 12.
NINA

Haugen, Mari; Schaffer, Linn Emelie; Mo, Birger; Helseth, Arild.
Impact on hydropower plant income from participating in reserve capacity markets. I: *2020 17th International Conference on the European Energy Market - EEM*. IEEE 2020 ISBN 978-1-7281-6919-4.
ENERGISINT

Helseth, Arild; Mo, Birger; Hågenvik, Hans Olaf.
Nonconvex Environmental Constraints in Hydropower Scheduling. I: *2020 International Conference on Probabilistic Methods Applied to Power Systems - PMAPS*. IEEE 2020 ISBN 978-1-7281-2822-1.
ENERGISINT\

Schaffer, Linn Emelie; Adeva Bustos, Ana; Bakken, Tor Haakon; Helseth, Arild; Korpås, Magnus.
Modelling of Environmental Constraints for Hydropower Optimization Problems – a Review. I: *2020 17th International Conference on the European Energy Market - EEM*. IEEE 2020 ISBN 978-1-7281-6919-4.
ENERGISINT NTNU

Sigtryggsdottir, Fjola Gudrun.
Riprap to resist wave and ice loads acting on the upstream slope of an embankment dam. I: *PROCEEDINGS OF THE 25th INTERNATIONAL SYMPOSIUM ON ICE Trondheim, Norway, 23rd – 25th November 2020*. IAHR International Symposium on Ice 2020 ISBN 978-82-7598-120-0.
NTNU

Tessema, Netsanet Nigatu; Sigtryggsdottir, Fjola Gudrun; Lia, Leif; Jabir, Asie Kemal.
(2020) Physical Model Study on Discharge over a Dam Due to Landslide Generated Waves. Water 2020, 12, 234. *Editor's Choice Paper*. https://doi.org/10.3390/w12010234

Level 2 papers

Hiriyanna Rao Ravindra, Ganesh; Gronz, Oliver; Dost, Bastian; Sigtryggsdottir, Fjola Gudrun.
Description of failure mechanism in placed riprap on steep slope with unsupported toe using smartstone probes. *Engineering structures* 2020 ;Volum 221. s. -
NTNU

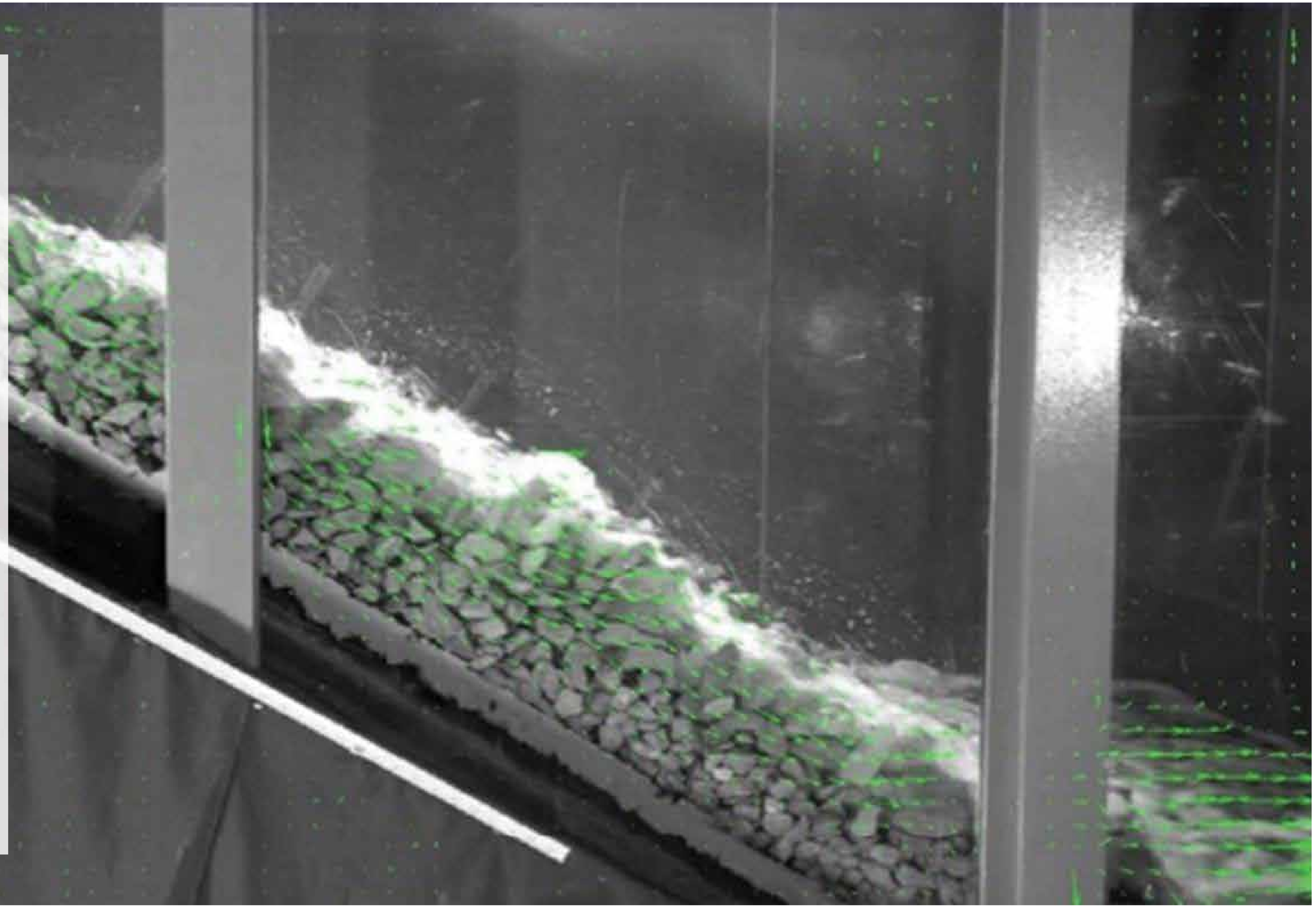
Hiriyanna Rao Ravindra, Ganesh; Sigtryggsdottir, Fjola Gudrun; Lia, Leif.
Buckling analogy for 2D deformation of placed ripraps exposed to overtopping. *Journal of Hydraulic Research* 2020
NTNU

Neupane, Bibek; Panthi, Krishna Kanta; Vereide, Kaspar.
Effect of power plant operation on pore pressure in jointed rock mass of an unlined hydropower tunnel: An experimental study. R*ock Mechanics and Rock Engineering* 2020 ;Volum 53.(Issue 7) s. 3073-3092
NTNU

Reigstad, Tor Inge; Uhlen, Kjetil.
Variable Speed Hydropower Conversion and Control. *IEEE transactions on energy conversion* 2020 ;Volum 35.(1) s. 386-393
NTNU

H. Ehya, T. Skreien and A. Nysveen.
Intelligent Data-driven Diagnosis of Incipient Inter-turn Short Circuit Fault in Field Winding of Salient Pole Synchronous Generators, in IEEE Transactions on Industrial Informatics, doi: 10.1109/TII.2021.3054674.

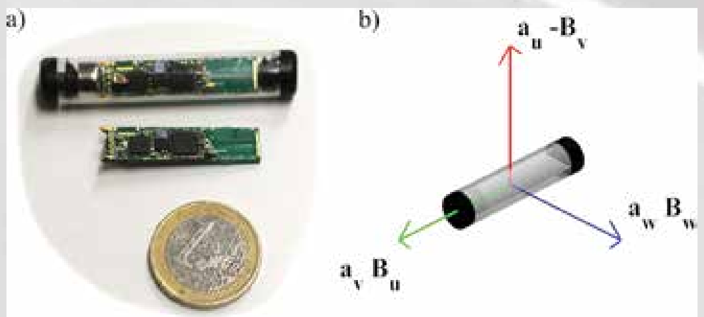
Photo: Torbjørn Forseth/NINA/HydroCen



Description of failure mechanism in placed riprap on steep slope with unsupported toe using smartstone probes

This article presents findings from experimental overtopping tests conducted on model placed ripraps unsupported at the toe section. Employing Smartstone probes, a new technology in stone movement monitoring, laser measurement techniques and Particle Image Velocimetry (PIV) techniques, detailed description of failure mechanism in placed ripraps under overtopping conditions is presented within this study. Study findings demonstrate sliding as the underlying failure mechanism in placed ripraps with unsupported toes.

Hiriyanna Rao Ravindra, Ganesh; Gronz, Oliver; Dost, Bastian; Sigtryggsdottir, Fjola Gudrun. Description of failure mechanism in placed riprap on steep slope with unsupported toe using smartstone probes. Engineering structures 2020 ;Volum 221.



Fjola Gudrun
Sigtryggsdottir
Professor, NTNU

TECHNICAL COMMITTEES 2020

Work Package 1 Hydropower stuctures	Work Package 2 Turbine and generator	Work Package 3 Market and services	Work Package 4 Environmental design
WP Leader: Leif Lia, NTNU	WP Leader: Arne Nysveen, NTNU	WP Leader: Birger Mo, SINTEF	WP Leader: Torbjørn Forseth, NINA
Anne Marit Ruud, Energi Norge	Arne Småbrekke, BKK Produksjon	Andreas Kleiven, NTNU	Ana da Silva, NINA
Bibek Neupane, NTNU	Bernt Lie, USN	Arild Helseth, SINTEF Energi	Arne Anders Sandnes, Statkraft
Christian Bernstone, Vattenfall	Bjarne Børresen, Multiconsult	Arnt Ove Eggen, SINTEF Energi	Atle Harby, SINTEF Energi
Erlend Bårgard, Sognekraft	Carl Andreas Veie, NVE	Atle Frøland, Tafjord	Audun Ruud, NINA
Fjóla G. Sigtryggsdóttir, NTNU	Carl Maikel Högström, Vattenfall	Bendik Torp Hansen, SINTEF Energi	Bendik Torp Hansen, SINTEF Energi
Geir Helge Kiplesund, NTNU	Celine Faudot, NTNU	Bjørn Austrud, Agder Energi	Berik Köhler, NINA
Grethe Holm Midttømme, NVE	Einar Kobro, Energi Norge	Christian Oshaug, NTE	Bjørn Høgaas, NTE
Halvor Kjærås, NTNU	Eivind Kjerpeset, SKL	Frode Vassenden, TrønderEnergi Kraft AS	Bjørn Otto Dønnum, Hafslund Eco
Hanne Nøvik, Multiconsult	Geir Helge Kiplesund, Multiconsult	Geir Kildal, Skagerak Energi	David Aldvên, Vattenfall
Helge Martinsen, Glitre Energi Produksjon	Halvor Haugsvold, NorConsult	Hans Olaf Hågenvik, SINTEF Energi	Eilif Brodtkorb, NVE
Henki Ødegaard, NTNU	Hans Simen Fougner, Hydro Energi AS	Hans Ole Riddervold, Hydro	Eirik Bjørkhaug, NVE
Kaspar Vereide, Sira-Kvina	Harald-Knut Kvandal, Statkraft	Jakop Bjelland, SKL	Erling Otterlei, SKL
Krishna Panthi, NTNU	Henning Lysaker, Rainpower	Kjell Johnny Kvamme, Sunnfjord Energi	Frank Jørgensen, NVE
Livia Pitorac, NTNU	Inge Lines, Agder Energi Vannkraft	Kjetil Trovik Midthun, BKK Produksjon	Frode Fossøy, NINA
Magne Wraa, Skagerak Energi	Ingunn Granstrøm, Skagerak Energi	Lennart Hagen Schönfelder, SINTEF Energi	Halvor Kjærås, NTNU
Mats Billstein, Vattenfall	Inrid Vilberg, SINTEF Energi	Linn Emelie Schäffer, NTNU	Hans Petter Fjeldstad, SINTEF Energi
Morten Skoglund, NVE	Jan Petter Haugli, Statkraft	Magnus Korpås, NTNU	Harald Holm, TrønderEnergi Kraft AS
Nils Rüther, NTNU	Jane Berit Solvi, Skagerak Energi	Magnus Landstad, Lyse Produksjon AS	Håkon Sundt, NTNU
Nirmal Acharya, NTNU	Jørgen Ramdal, Statkraft	Marte Fodstad, Statkraft	Ingeborg Palm Helland, NINA
Oddmund Brevik, Hafslund Eco	Kari Haugan, Sweco	Siri Mathisen, SINTEF Energi	Jo Halvard Halleraker, Miljødirektoratet
Ola Haugen Havrevoll, NTNU	Kjell H. Sivertsen, Rainpower	Stein-Erik Fleten, NTNU	Julie Charmasson, SINTEF Energi
Per Vidar Halsnes, BKK Produksjon	Kjell-Tore Fjærvold, Statkraft	Sven Per Lønne, Glitre Energi Produksjon	Knut Alfredsen, NTNU
Ragnhild Hoel, Tafjord	Kjetil Uhlen, NTNU	Thea Bruun-Olsen, Statkraft	Lars Jakob Gjemlestad, Sira-Kvina
Roger Olsson, NGI	Lars Lone, Hydro Energi AS	Tor Halvor Bolkesjø, Hafslund Eco	Leif Lia, NTNU
Siri Stokseth, Statkraft	Linda Haugvaldstad, Lyse Produksjon AS		Lennart Schönfelder, SINTEF Energi
Tom Jacobsen, Sedicon	Line Drange Ruud, Glitre Energi Produksjon		Line Sundt-Hansen, NINA
Øyvind Pedersen, Multiconsult	Magnus Glomnes, Sweco		Marcell Szabo-Meszaros, NTNU
	Martin Aasved Holst, EDR Medeso		Marie-Pierre Gosselin, Multiconsult
	Ole Gunnar Dahlhaug, NTNU		Mathilde Berg, Skagerak Energi
	Olve Mo, SINTEF Energi		Nils Henrik Johnson, TrønderEnergi Kraft AS
	Pål Teppan, Andritz		Per Ivar Bergan, Sweco
	Pål-Tore Selbo Storli, NTNU		Per Øyvind Grimsby, Sira-Kvina
	Stig Falling, Tafjord		Ragna Flatla Haugland, SFE
	Sverre Dahl Knutsen, Hafslund Eco		Roy M. Langåker, Miljødirektoratet
	Thomas Øyang, USN		Sissel Mykletun, BKK Produksjon
	Tor Inge Reigstad, NTNU		Stein Øvstebø, Hydro
	Torbjørn K. Nielsen, NTNU		Svein Haugland, Agder Energi Vannkraft
	Tore Johan Flåm, NTE		Tor Håkon Bakken, SINTEF Energi
	Tormod Kleppa, Hafslund Eco		Trond Erik Børresen, Lyse Produksjon AS
	Øystein Gjerde, Voith Hydro		Trond Taugbøl, Eidsiva Energi
	Øyvind Linnebo, ABB		Trygve Øderud, Glitre Energi Produksjon
	Åsulv Haugatveit, Otra Kraft		Vegard Pettersen, EnergiNorge

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Office address:
HydroCen
The Waterpower Laboratory
Alfred Getz vei 4
Trondheim
Norway

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