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HydroFlex

AFC4HYDRO

NEWSLETTER OCTOBER 2020

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WELCOME

This is the first joint newsletter for the HydroFlex and AFC4Hydro Horizon 2020 R&D projects. The newsletter will present progress and results from the two projects in a popularized manner. One goal of the newsletter is to contribute to communication internally in the project and thus facilitate collaboration. With the more popularized form in comparison to the scientific publications, we hope that the newsletter also can be of interest to TSOs, regulators, power companies and other industries.

1 COLLABORATION

HYDROFLEX AND AFC4HYDRO

Both HydroFlex and AFC4Hydro are Horizon 2020 projects with research topics and objectives related to European hydropower. There are also overlap in the academic and industrial partners. Starting in June 2020, there has been regular dialog between the two projects on opportunities for collaboration. Communication and dissemination has been singled out as the most obvious area of synergy.

For the remaining time of the HydroFlex project, a joint newsletter, presenting results and progress from both projects will be issued. In addition, participants and stakeholders from both projects will be invited to public dissemination events. Depending on the development of the pandemic, it is hoped that there will be opportunities for joint physical meetings and also direct collaboration between researchers. As an immediate action, PhD students and post docs from ACF4Hydro was invited and encouraged to participate in the "Popular Science Writing" training course organised by HydroFlex in collaboration with the Languange Center and Uppsala University.

HydroFlex

The HydroFlex project aims to develop new technology permitting highly flexible operation of hydropower stations. Flexibility of operation here means large ramping rates, frequent start-stops and possibilities to provide a large range of system services.

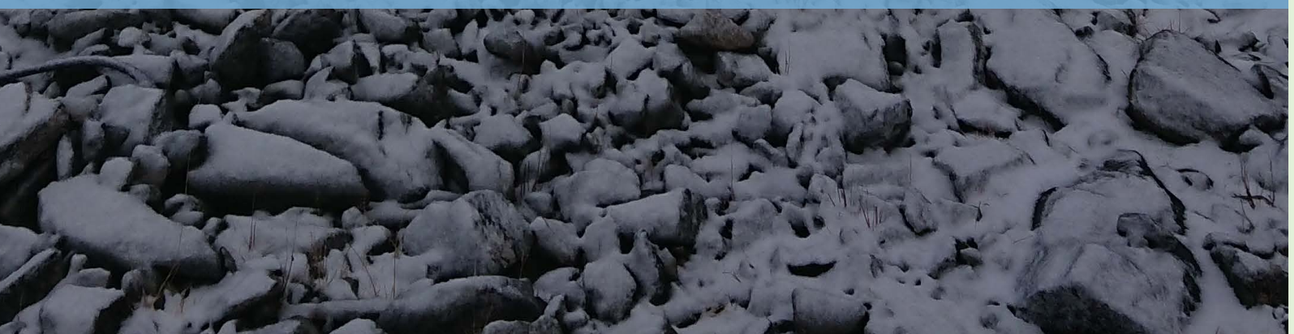
AFC4Hydro

The main goal of AFC4Hydro research project is to design, implement and validate in full-scale water turbine an active flow control system that permit to increase efficiency and reduce the dynamics loads on the structure at any off-design operating conditions and during transient operations.

GREETINGS

FROM AFC4HYDRO COORDINATOR XAVIER

Europe is currently facing the ever-increasing development of global warming. The earth's capacity to absorb greenhouse gas emissions is exhausted and humankind must face this challenge by promoting a long-term structural change of the energy system. In this sense, hydropower plays a central role in the context of EU energy transition into renewable power generation.



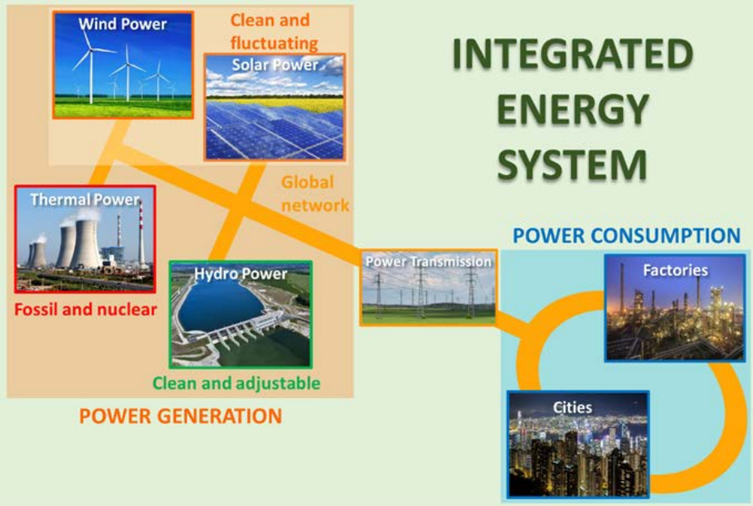
AFC4HYDRO
afc4hydro.eu

Therefore, there is a need to develop solutions to reduce the cost and increase the performance of hydropower which we are going to address thanks to the AFC4Hydro project. Hydraulic turbines are today limited in their operating range, this is why a novel component will be developed to allow efficient utilization also in off-design operation as well as during ramp up and ramp down phases.

Specifically, AFC4Hydro aims to design, implement and validate a novel Active Flow Control for Hydropower system to improve the performance of large-scale prototype hydraulic turbines of any size, capacity or design.
Thanks to AFC4Hydro we will achieve very important goals, such as:

1. **ACCELERATE THE INTEGRATION OF RENEWABLE ENERGY TECHNOLOGIES IN THE ENERGY SYSTEM.**
2. **REDUCE THE COSTS OF EXISTING HYDROPOWER UNITS.**
3. **PROVIDE A SECURE SUPPLY OF HYDRAULIC ENERGY TO THE GRID**
4. **REDUCE THE NEGATIVE IMPACTS OF THE CLIMATE CHANGE.**

Hydropower in the context of the European integrated energy system with the main generation and consumption actors.



In order to achieve so, we have built an international consortium comprising two universities, Universitat Politècnica de Catalunya-BarcelonaTech and Luleå Tekniska Universitet, two large energy companies, Vattenfall and Statkraft, and a small-sized enterprise, Flow Design Bureau. The work plan consists of a series of experimental and numerical tasks to develop the AFC4Hydro design at various scales.

For example, the validation in laboratory will be performed in a certified state of the art facility at Vattenfall Research and Development in Älvkarleby (Sweden), which allows for testing hydraulic turbine models under steady and transient operating conditions.
The complete system will also be tested on a 10 MW Kaplan turbine at the Porjus power plant in Sweden, and on a 200 MW Francis turbine at the Oksla power plant in Norway.

I hope that, thanks to the collaborative effort of all the partners, we will see in the near future how the existing hydraulic turbines can work safely and with reduced costs in a wider operational range , which will be extremely beneficial for the current European energy sector and for all the European citizens.

**Kind regards,
Professor Xavier
Escaler from
Universitat Politècnica
de Catalunya -
BarcelonaTech**

3 GREETINGS

FROM HYDROFLEX WP4 LEADER URBAN LUNDIN

In every newsletter we challenge each of the work package leaders to present their vision for the HydroFlex project. We hereby present the message from WP 4 : Flexibility of generator and converter.

Flexibility from Hydropower is an interesting topic. Everyone agrees that more flexibility will be needed in the power system in the future due to the additional requirement to balance, not only consumption but also, more of the intermittent electricity production. Hydropower has a unique position to act on the flexibility demand and also store very large volumes of energy in the reservoirs.
We often hear that there is no market for flexibility meaning that the plant owners do not get enough money in order to make the investments that will provide the additional flexibility that everyone understands will be needed. The crucial question is when the plant owners can start to earn money on being more flexible than what is possible with the technology they have installed today. This will trigger investments in new technology. Another question is what economical model they are using to conclude that they are not earning enough to make the investments. One might wonder, can they afford not to make investments to be more flexible? There is also a risk in not adapting to changes which can be foreseen.
At the same time as Hydropower is a very mature technology, innovations in the fields of simulations, measurements, sensors, digitalisation, and power electronics provides new tools that can modernize Hydropower. It opens up for the possibility to think in new ways and apply new tools to enhance the performance from what is already installed, and what can be achieved from new designs and solutions.

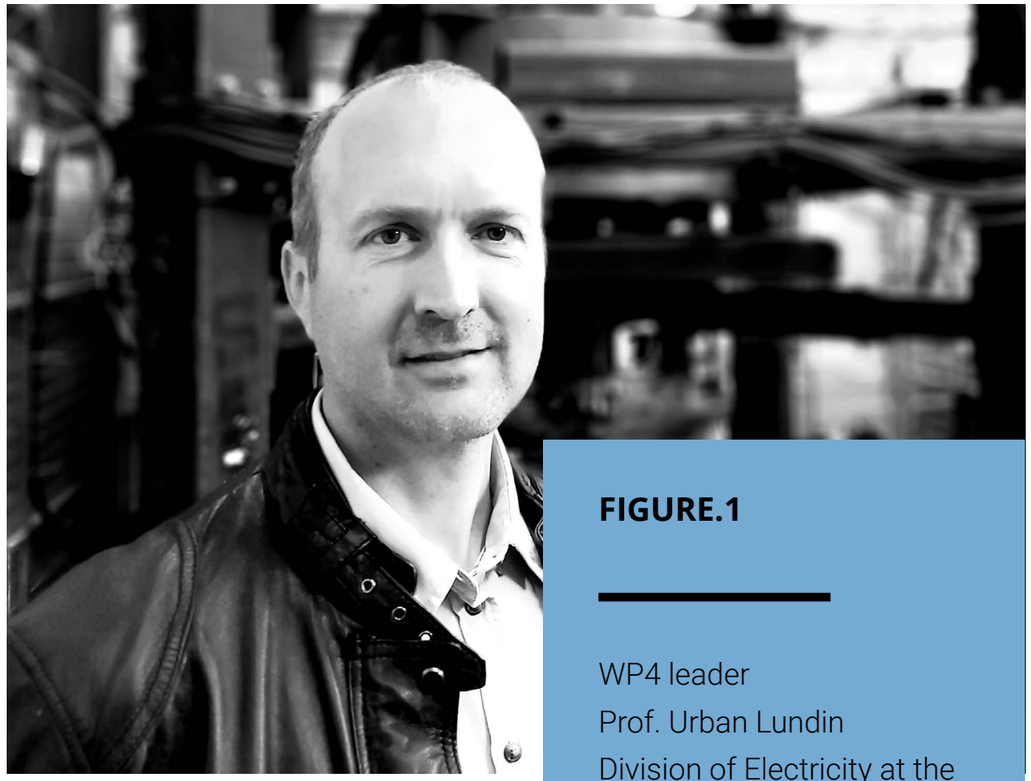


FIGURE.1

WP4 leader
Prof. Urban Lundin
Division of Electricity at the Department of Engineering Sciences,
Uppsala University.

One also has to understand that if extreme levels of flexibility will be needed in 10-20 years time, and the market development will be there as well, it is now that we have to invest in order to fulfill the need in 10-, 20-, 30-, 40- years time since the life span of the units is so high, and we live with technology 50+ years old providing what we need in the grid today.
In Hydroflex we want to show what flexibility is physically possible with technology at the latest development stage. Also identify what the challenges there are and potential ways to overcome them. We try to point in a direction of future possibilities. We develop the technology that will become needed in the future, both to fulfill the need of providing system services and keeping hydropower relevant on the flexibility markets. We are thus showing what is possible so that one can think and use the existing Hydropower potential in a more intelligent way, and maybe take the steps to invest in the potential solvers of the flexibility question.
All in the Hydroflex project are happy and proud to be parts in keeping hydropower relevant the next 100 years as well.

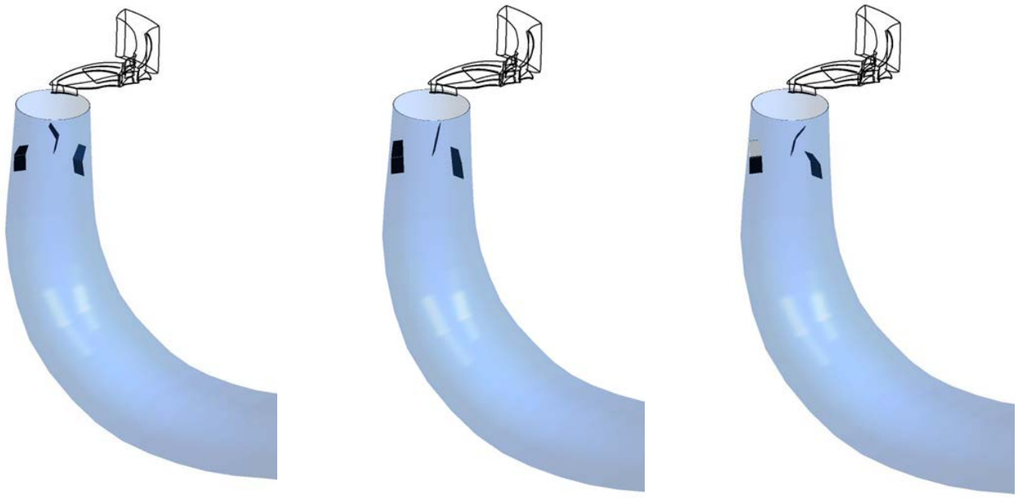
4 PHD CANDIDATE

JESLINE JOY

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

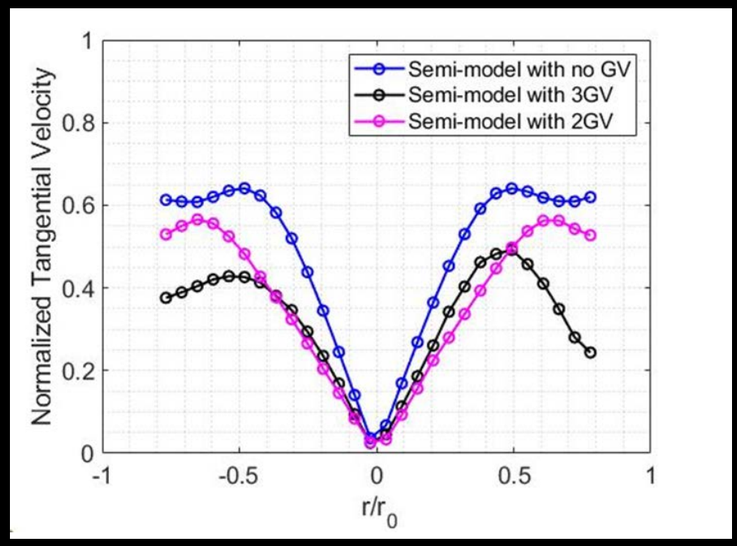
In past two years of my PhD, I have developed a guide vane system numerically that could mitigate rotating vortex rope (RVR) effectively at part load (PL) operating condition. These guide vane systems will be placed in the draft tube of the Francis-99 hydro-turbine at certain distance from runner exit.
A set of three guide vanes system is capable of reducing the presure pulsations upto 97% in the draft tube, thus, weakening the rotating vortex rope. The guide vane system show reduction in tangential component of the velocity as well, see figure 2.
These guide vane systems will be adjustable according to the flow conditions in the draft tube and thus, supporting the flexible operatin of the turbine, see figure 1.

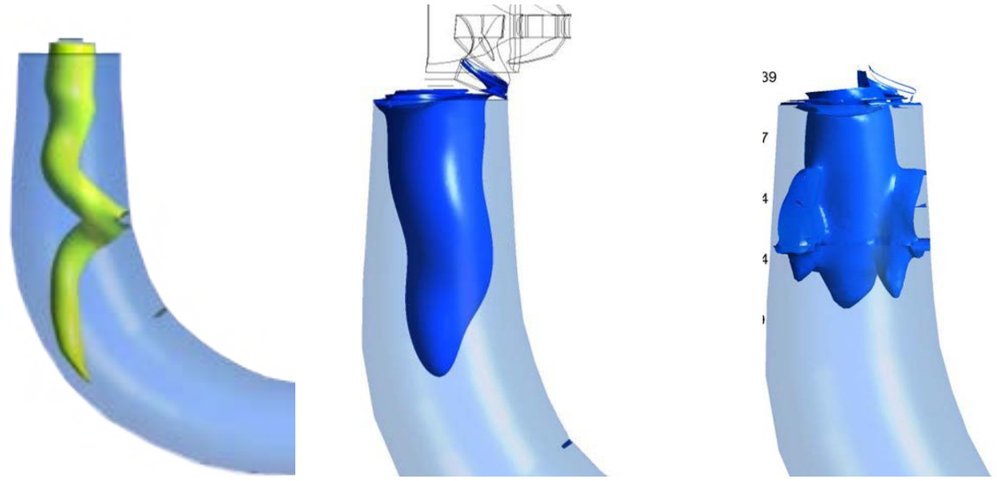
The thickness of the guide vanes will vary from 2 mm to 4 mm (from leading edge to trainling edge), thus giving it a hydrodunamic profile. The numerical and structural analysis results show that the guide vane system (3 guide vanes) with varting span of 25%-35% of runner radius and chord of 56% of runner radius can withstand the loads in worst case sceniors. The material considered for experimental analysis is structural steel. The future work focusses on manufacturing of draft tube cone and guide vane system. The experiment will be performed at Water Power laboratory at Norweigian University of Science and Technology, Trondheim, Nowray in Francis -99 test rig at the beginning of 2021.



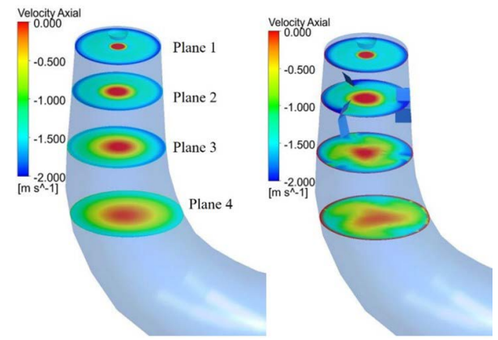
(a) at PL (b) at BEP (c) at HL

Figure 1. Guide vnes orientations at different operating loads
Figure 2. Reduction in tangential velocity by using a guide vane system with 3GVs (3 guide vanes) and 2GVs in the draft tube.





(a) (b) (c) with GVS



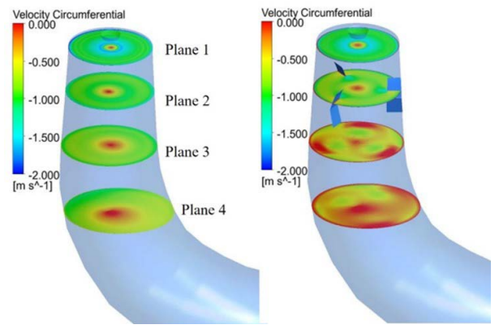


Figure 1. iso-surface of RVR
Figure 2. tangential velocity comparison
Figure 3. axial velocity comparison

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RAFEL ROIG BAUZÀ

PHD CANDIDATE

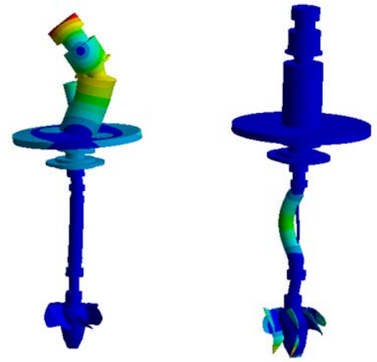
The overall objective of AFC4Hydro is to implement and validate an active flow control system that permits the improvement of the machine performance and the reduction of the dynamic loads on the structure at non-optimal operating points as well as during ramp up and ramp down phases. To achieve such goals, it is necessary to design and validate a structural health monitoring (SHM) system to assess the condition of the turbine and evaluate its performance during operation, which is the specific objective of WP3.

WP3

Structural Health Monitoring

In the frame of WP3, I'm conducting research on task 3.2 with the aim of developing numerical models to investigate the dynamic response of Kaplan turbine reduced scale models and prototypes. It is hoped that the results of the numerical simulations together with experimental data and the expertise of the team will enable the design of the SHM system.

More specifically, the numerical simulations will allow the prediction of the natural frequencies and the mode shapes of the turbine unit within the range of frequencies in which it is expected to have the main excitations. Previous studies on the dynamic behavior of hydraulic turbines have proved that neither natural frequencies nor mode shapes of this type of machines depend on added stiffness. Other two common assumptions to predict the vibration response of the hydraulic turbines are to consider that the added mass is not affected by the flow velocity and that the damping coefficient has a minor impact on natural frequencies.



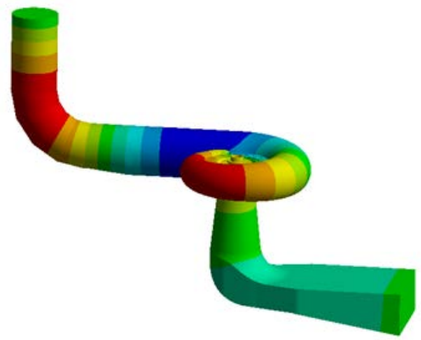


Figure 1. Mode shapes of the Vattenfall Turbine Test Stand.

Figure 2. Mode shape of the hydraulic circuit of the Vattenfall Turbine Test Stand.

Figure 3. Phd candidate Rafel Roig Bauzà.

Consequently, we will consider that it is accurate enough to predict the natural frequencies and the mode shapes by means of acoustic structural modal analyses without accounting for hydrodynamic and structural damping effects.

Based on the previous description, the topic of my PhD is directly related to my tasks in AFC4Hydro. With the objective of understanding the dynamic parameters of rotating systems in which there are fluid structure interactions, I will intend to develop numerical models to predict the evolution of systems in which rotating structures are submerged in a heavy fluid under excitations at both resonant and non-resonant conditions. The first step in my research will be to study and improve the available methods and models which describe fluid and structural dynamics parameters.

Experimental methods will be assessed in the reduced scale test rig implemented at Universitat Politècnica de Catalunya (UPC). The results from the tests will be compared with the numerical ones. The test rig consists on a disk rotating inside a casing filled with water. It has been built with the aim of being used to validate the new technologies which will be implemented for the SHM system. The second step in my research will be to extrapolate the knowledge, which has been gained in the simplified model at UPC, and apply it to turbines with the aim of studying experimentally and numerically the added parameters of turbine models and prototypes as well as investigating the similarity laws which permit their transposition.

INTRODUCTION TO

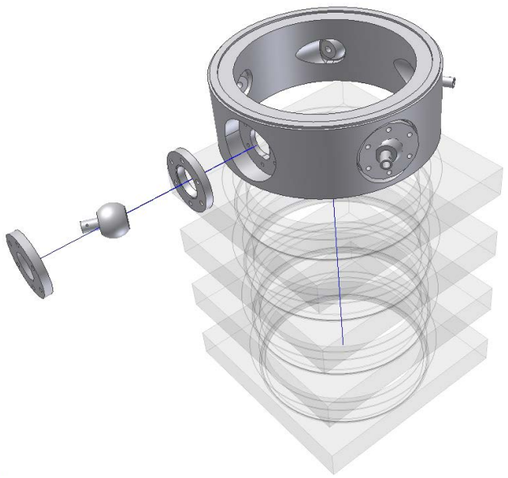
6

FLOW CONTROL

AFC4Hydro is short for Active Flow Control system for improving Hydraulic turbine performances at off-design Operation.

The name of the project therefore suggests a focus on active flow control and for a specific type of flow system. The active part of AFC4Hydro also reflects a focus on quantifying the deleterious effects, or the monitoring of structural health (SHM), of unwanted or secondary flow fields in the hydroturbine and using this quantification to direct an appropriate response by the flow control techniques exploited. The techniques cover active Flow Control through an injection of pulsating momentum or jet (IPM). The semi-active Flow Control involves the injection of continuous momentum or jet (ICM). For reference also a passive Flow Control solution, using rods extending into the flow field, will be applied by the project. SHM, IPM and ICM form separate WPs in the AFC4Hydro project but they will merge in a fourth WP when applied and validated on turbine units in the project.

Fiugres 1 - 2 - 3:
H. Francke's PhD work at NTNU (2010) inspires one of the Flow Control solutions (ICM) included in the AFC4Hydro.



FACTS

4y RIA H2020 project. Start up June 2019.Coordinator: Prof. Xavier Escaler (UPC)

Partners: Universitat Politècnica de Catalunya-BarcelonaTech (ES), Tech U of Luleå (LTU) (SE), Flow Design Bureau (NO), Vattenfall (SE), Statkraft (NO), Porjusstiftelsen (SE)

Web page: afc4hydro.eu
Project info: cordis.europa.eu/project/id/814958

7 THE ROLE OF FLEXIBILITY IN THE POWER SYSTEM

Flexibility is the ability of the power system and its components to respond to changes.

The first law of power systems is that there must be a balance between power production and consumption. If the load is higher than the input, the grid frequency will decrease. Conversely, as surplus in production will cause a frequency increase. Due to transmission limits, there are also spatial balancing requirements. The transmission system operator (TSO) is responsible for maintaining the frequency within specified, predefined limits. If not properly handled, the frequency deviation may cause a cascading failure as protection in the grid will be activated. In the worst case, the imbalance may lead to complete blackout as experiences in both North America and southern part of Europe in 2003.

Reservoir hydro and pumped storage hydro can provide many of the services needed in a highly renewable future.

Historically, when most or all the power plants in the system were dispatchable, the main cause of variability were due to changes in consumptions and sudden loss of production due to a failure in some production unit. By correlating historical data, very good models for predicting expected consumption as function of day of the week, season, weather as well as economic factors (e.g. market price of aluminium) and social behaviour (e.g. sauna hour is Finland) were developed. Accordingly, the main dimensioning capacity for reserve capacity was based on sudden outage of one or a few large production units.

The increased share of intermittent power sources, such as wind and solar have introduced additional challenges for the power system operators. Currently the error in 24-hour production forecast for wind or solar is of the order 10%-15%. With increased fraction of the power production from intermittent sources, the need for intraday reserve capacity will increase. The natural diurnal variation of solar power does not always match the consumption profile and the seasonal variations requires the ability to shift energy production in time. In practice this implies some means of energy storage. Reservoir hydro and pumped storage hydro can provide many of the services needed in a future, highly renewable or zero CO2 emission power system. However, there are also several competing technologies and future technical development as well as market design and regulation will determine the actual power system composition in 2050 and beyond.

THANK YOU

EUROPEAN COUNCIL

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UPC

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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

VATTENFALL

Statkraft

Multiconsult

ABB

EDR MEDESO

IAEW Institute of Power Systems and Power Economics

RWTH AACHEN UNIVERSITY