guest editorial

Girish Behal and Kimberly Laing

global hydropower

current developments and future innovations

HYDROPOWER HAS BEEN UTILIZED ubiquitously in various forms throughout human history. In its most rudimentary form, it has been used to grind flour, to irrigate fields, and for many other purposes. In the last 140-plus years, it has been used increasingly as a source of electric power. Globally, large dams have been used to tame fast-flowing rivers, create large reservoirs for public use, and generate hydropower. These large dams have caused a significant impact on societies, economies, and the environment. Hydropower has also been used as a mechanism to store energy (often generated by nuclear plants) for peak use.

The future looks interesting for hydropower to utilize new technologies, reduce environmental impact, improve sustainability, and support the integration of renewable resources. Most recently, hydropower has been growing globally as a renewable and sustainable resource by modifying existing infrastructure for power generation. In addition, several countries are looking to complete projects that have long been delayed due to political and social factors.

With an eye toward discussing where hydropower currently stands globally and what we can expect in the near future, we invited authors from across the globe to give an overview of the past and expected future of hydropower in their respective regions. It should not come as a surprise to our readers that, in nearly every region of the world, hydropower is being looked at as a large storage asset, thus enabling the integration of renewables and playing a major role in reducing carbon emissions in the coming years.

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In This Issue

Our first article in this issue of *IEEE Power & Energy Magazine*, by Satish Kumar Sharma and Vinod Batta, discusses the development of hydropower in India and its role in meeting the Indian government's growth and sustainability goals. Since the 1970s, hydropower development in India has been limited due to government policies, high costs, and regulatory hurdles. Hydropower is now being revitalized as a means to integrate renewables and create a more sustainable and energy-secure future for India. The potential benefits of additional hydropower include flood control for the monsoon season and its use as a peaking power source, in addition to the traditional benefits of black start and long economic life of the asset. The authors suggest various policy measures to encourage a renewed growth of hydropower, including the declaration of hydropower as renewable power, the development of support infrastructure, and the introduction of new financial incentives.

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In the second article, Tom Tellefsen, Jan van Putten, and Ole Gjerde look at hydropower from a Norwegian perspective. Thanks to favorable geography, the creation of reservoirs as early as the 1800s, and subsequent developments after World War II, Norway currently possesses more than half of Europe's hydropower storage capacity. The transmission links between Norway and continental Europe enable energy arbitrage and the faster integration of renewable resources. The NorNed project is cited as an example of the various policy and energy market development concepts that have helped integrate Norwegian hydro (and other) assets into the larger grid. The mitigation of environmental and social impacts of Norwegian hydropower projects is outlined. The authors conclude with a discussion of the continued development of Norwegian hydropower.

The next article, by Daniel Flores, Andrew Bridgeman, Francois Welt, Juan Jose Aveiro, Delfín Benítez, and José Vallejos, is a case study on the life extension and modernization studies of Acaray generating station, one of the largest hydro power stations in Paraguay. The authors begin the article with a historical introduction of hydropower generation in Paraguay and at

Acaray. They then detail a comparative analysis of plant-modernization options developed in collaboration with the utility. Both power generation planning and asset-management models were considered. Various pieces of data and information were collected and added to the model, including hydrological data, unit efficiency information, environmental impact, and load projections. The model allowed for an ideal modernization option to be selected using risk-based capital expenditure optimization.

The last hydropower-themed article is by Peter Donalek. The article begins with a history of hydropower and pumped storage in particular, with a special focus on the Rocky River plant (completed 1928), the first of its kind in the United States. The author details how hydro storage units may be converted to pumped storage. A reversible motor/generator and pump/turbine on a common shaft at Hiwasee Unit 2 is cited as an example, along with solid-state variable frequency converter inverters. The synergies between pumped storage and nuclear generation are described. The technologies related to efficient, adjustable-speed pumped storage turbines are outlined. The author then discusses the experiences of Japanese utilities using adjustable-speed machines to provide frequency regulation. The article concludes with a discussion of doubly fed induction machine-pumped storage units and an overview of new pumped storage technologies under development.

The "In My View" column, written by Girish Behal, provides a view on how current developments in hydropower will shape its future growth. The current status of large-scale hydropower development is outlined. New small-scale hydropower technologies are featured, including closed-loop projects on existing impacted sites, small-scale storage development, the conversion of existing dams for power generation, and modular construction technology for distributed hydropower. We anticipate that future development of large-scale hydropower generation will slow down, but there will be significant growth in pumped storage and small-scale hydropower.

This issue contributes to the discussion of the current state of hydropower and the future path that it can possibly take. I would like to thank the authors for their time and dedication and the articles provided, which shed light on the developments and innovations happening around the world. We would like to give special thanks to the IEEE publications staff, our authors, John Paserba, and former editor-in-chief, Michael Henderson, for all the assistance rendered to these novice guest editors.