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hydropower generation

overcoming system limitations

HYDROPOWER HAS BEEN UTILIZED for generating mechanical energy for more than 3,000 years and, subsequently, electrical energy in the last 140-plus years. At the end of 2019, there was more than 1,308 GW of hydropower generation installed globally, as shown in Figure 1. That 1,308 GW includes the 16 GW of new capacity (Figure 2) brought online in 2019. A large portion of the existing hydropower fleet across the world consists of large storage reservoirs followed by run-of-the-river hydropower generation assets. Pumped storage units were built to store energy during low load periods and reutilize the energy during peak periods.

Recently, there has been a large increase in the amount of variable energy (i.e., wind and solar) supplied to the grid. This has enhanced the need for a

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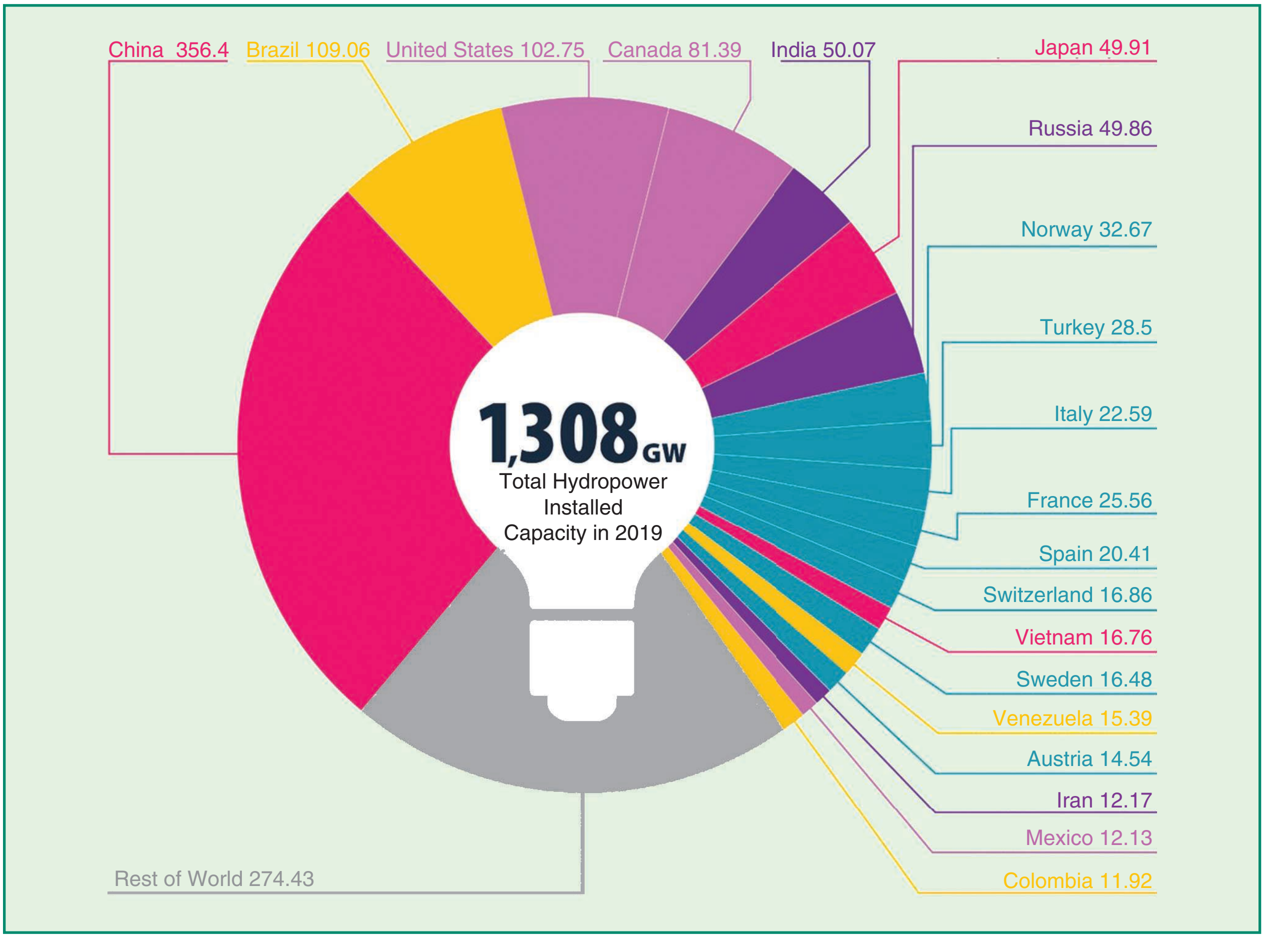

figure 1. The total global hydropower generation installed at the end of 2019. (Source: "2020 HydroPower Status Report," International Hydropower Association; used with permission.)

resource that can act as a storage mechanism and provide energy on an on-call basis. Hydropower generation currently plays that role in several markets. The need to integrate hydropower generation with variable resources is creating a unique opportunity for innovative hydropower generation ideas.

Large-Scale Hydropower Generation

Large-scale hydropower generation projects (>1 GW) are becoming a bit more challenging from a social-impact perspective in a number of regions around the globe. Several current projects under development are under social and political pressure. In addition, the effects of the most-recent global recession and the current COVID-19 pandemic are expected to hamper the implementation of proposed projects even more in the near future. Although there is long-term potential for the further growth of large-scale hydropower, the overall picture is quite uncertain.

There have been significant efforts aimed at improving the performance of hydropower plants that have been in operation for many years. The implementation of new technologies involving upgraded control systems, the replacement of existing fixed-speed turbines with variable-speed turbines, and the relining of existing penstocks to improve water flow is improving the generation output of existing facilities.

Hydropower generation currently plays that role in several markets.

Pumped Storage Development

Pumped storage that can act as a large-scale storage device for intermittent resources is attracting interest globally. There are current plans in place to reuse mines that have been exhausted. Large-scale projects utilizing abandoned gold and iron ore mines have been proposed and are envisioned to be closed-loop projects. Closed-loop projects are favored by environmental agencies because they tend to eliminate negative impacts on river wildlife, resulting in a significantly reduced ecological impact compared to that of open-loop pumped storage facilities. Utilizing existing sites that have already had social and environmental impacts appears to be a more acceptable solution by various stakeholders than siting new locations for storage projects.

As for small-scale pumped storage, many technologies are currently being tested in various places around the world. One application utilizes large steel tanks with an elevational difference to create the head differential necessary to generate electricity. Shell Energy is working on a small-scale membrane design for innovative reservoir technology for closed-loop configuration in collaboration with Oak Ridge National Laboratory.

Small-scale projects do suffer from economic limitations; however, integrated storage solutions with renewable energy sources tend to produce better economic results. The implementation of resilient microgrids powered by a combination of a small-scale pumped storage solution with a renewable resource like solar can improve life in rural areas. For example, water can be pumped to an elevated tank during the day utilizing solar energy and then released in late evening and early morning for irrigation with integrated microturbines, which can generate electricity to power a rural village. This can eliminate the need for expensive batteries and create a more

figure 2. The global hydropower generation added at the end of 2019. (Source: "2020 HydroPower Status Report," International Hydropower Association; used with permission)

figure 3. "The French Dam concept." (Source: Office of Water Technologies-Energy Efficiency and Renewable Energy, French Development Enterprises; used with permission.)

sustainable lifestyle and more economic opportunities for the village.

Small-scale hydro or "microhydro" plants that can generate fewer than 100 kW utilizing existing water infrastructure are currently being installed in various developing nations. These installations are typically being used for energizing small homes or small communities and are also part of local microgrids, thereby adding to the resiliency of the electrical system in the region. Small units can also be installed inline with minimal modifications to the existing canal and pipeline infrastructures. Carefully designed and integrated microhydro systems are not only effective in delivering power to a community economically but also have little to no impact on the environment.

Nonpower Dams

There are many existing reservoir assets used for storing excess water during the rainy season or high flow season or as recreational facilities with managed outflows for irrigation and water supply uses. Because nonpower dams (NPDs) are already constructed, established, and functioning, adding the technology required to get these facilities to produce electricity is a great way to increase or expand the clean and renewable energy supply. In addition, when these assets are converted for electricity production and integrated into the local grid, they can partially fill the need to provide support for intermittent resources. Integration over a larger region could enable NPD conversion to serve as a grid-support tool. It is estimated by the U.S. Department of Energy that a conversion of the top 100 NPDs to power-producing assets in the United States alone could add 8 GW of additional hydropower to the grid.

Modular Construction Technology

The largest component cost for a small hydro is the on-site construction cost. Newer technological developments, in the modular construction of small and microhydro plants, can help these dams be constructed quicker and at a lower cost. The Water Power Technologies Office under the Office of Energy Efficiency and Renewable Energy has most recently supported the implementation of project(s) that utilize modular construction under the designation of "French Dam" based on the company that has brought this innovation to market (see Figure 3).

The Future of Hydropower

Looking in my crystal ball, the future outlook of hydropower is mixed in nature. New, large hydropower generation projects will continue to face significant challenges from environmental, social, and political perspectives. I anticipate continued growth in technologies that will enable better efficiencies from existing large hydro plants, resulting in continued growth, albeit small, from existing large hydropower dams.

On the pumped storage front, it can be expected that there will be significant growth in closed-loop projects. It is quite likely that projects utilizing existing infrastructure will move forward. Other technological innovations in small and microhydro plants, such as modular construction techniques, will continue the growth of smaller installations and conversion of NPDs, leading to the continuous growth of a clean and renewable energy source that can not only act as a stabilizing resource for the grid but also help integrate other renewable resources into the grid.