Renewable energy power systems

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This chapter provides an introduction and overview of the electrical power system. It covers the major components of a power system and reviews the various renewable energy sources (RES) that constitute today"s energy mix. This chapter also discusses operations, control strategies for a power system and the concept of a smart grid. Allied to this is the concept of power system deregulation, which is discussed as well.

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Policies and ethics

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We introduce a spatially distributed integrated river basin and power system simulation and design framework. It aims to help analysts and stakeholders to identify power system designs and hydropower operations that minimize adverse environmental impacts and intersectoral conflicts when addressing the challenge of integrating intermittent renewables. The approach minimizes conflicts and maximizes intersectoral complementarities across time and space in multisector systems. The proposed framework, shown in Supplementary Fig. 1, has two components: an integrated river basin and power system simulator and a multi-objective artificial intelligence-based optimized design process.

The second framework component is a multi-objective artificial intelligence-based search algorithm used to perform WEFE trade-off-informed design, considering many performance dimensions and spatiotemporal scales of the integrated river basin and power system simulator. The approach helps planners and stakeholders to identify performance trade-offs, synergies and co-benefits the performance trade-offs of the most efficient (that is, approximately Pareto optimal) and resilient portfolios of synergistic water-energy interventions and their spatial layouts. Further technical details on the framework are provided in the Methods.

We use Ghana as a case study to demonstrate the integrated river basin and power system simulation and design framework on a national scale. Ghana"s total electricity generation comprises a mix of hydropower, gas and oil sources (47%, 30% and 23%, respectively)34. The Ghanaian national policy targets large-scale development of intermittent renewables, and hydropower could be used to provide flexible services35. The Akosombo Dam, the largest electricity generation plant in the country, with a capacity of 1,020 MW, regulates the world"s largest man-made reservoir based on surface area--the Volta Lake36--and currently provides ancillary services (for example, voltage and volt-ampere reactor support, and reserve) to the Ghanaian power system37.

The map shows the existing electrical transmission network and the locations of existing and planned storage dams, solar photovoltaic (PV), solar PV with storage, wind power plants, irrigation and public water supply diversions, and flood recession activities in the Volta River basin included in the integrated water-energy simulation.

This study highlights the need to balance river ecosystems and multisector responses to the re-operation of hydropower plants aiming to support the integration of intermittent renewables, as detailed below. We evaluate the effects on sub-daily river flow alteration and the water resource sector produced by increased hydropeaking and changes in seasonal reservoir releases.

Comparing historical hydropower operations with those optimized via the framework presented here allows evaluation of changes in sub-daily hydrological alteration and agricultural yields. The drivers of those changes are the variability at different timescales of intermittent renewables and electricity demand, which hydropower attempts to offset alongside other interventions.

The figure shows the increased hydropower generation variability under intervention strategy one with high hydrological alteration (RB index 0.22), compared to the hydropower generation in the compromise solution (Fig. 2c, black line).