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Digital Twin for a Floating Solar Energy System with Experimental Data Mining and AI Modelling

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Abstract : The integration of digital twin technology with renewable energy systems offers an innovative approach to predicting and optimising performance throughout the entire lifecycle. A digital twin is a continuously updated virtual replica of a real-world entity, synchronised with data from its physical counterpart and environment. Many digital twin companies today claim to have mature digital twin products, but their focus is primarily on equipment visualisation. However, the core of a digital twin should be its model, which can mirror, shadow, and thread with the real-world entity, which is still underdeveloped. For a floating solar energy system, a digital twin model can be defined in three aspects: (a) the physical floating solar energy system along with environmental factors such as solar irradiance and wave dynamics, (b) a digital model powered by artificial intelligence (AI) algorithms, and (c) the integration of real system data with the AI-driven model and a user interface. The experimental setup for the floating solar energy system, is designed to replicate real-ocean conditions of floating solar installations within a controlled laboratory environment. The system consists of a water tank that simulates an aquatic surface, where a floating catamaran structure supports a solar panel. The solar simulator is set up in three positions: one directly above and two inclined at a 45° angle in front and behind the solar panel. This arrangement allows the simulation of different sun angles, such as sunrise, midday, and sunset. The solar simulator is positioned 400 mm away from the solar panel to maintain consistent solar irradiance on its surface. Stability for the floating structure is achieved through ropes attached to anchors at the bottom of the tank, which simulates the mooring systems used in real-world floating solar applications. The floating solar energy system's sensor setup includes various devices to monitor environmental and operational parameters. An irradiance sensor measures solar irradiance on the photovoltaic (PV) panel. Temperature sensors monitor ambient air and water temperatures, as well as the PV panel temperature. Wave gauges measure wave height, while load cells capture mooring force. Inclinometers and ultrasonic sensors record heave and pitch amplitudes of the floating system’s motions. An electric load measures the voltage and current output from the solar panel. All sensors collect data simultaneously. Artificial neural network (ANN) algorithms are central to developing the digital model, which processes historical and real-time data, identifies patterns, and predicts the system’s performance in real time. The data collected from various sensors are partly used to train the digital model, with the remaining data reserved for validation and testing. The digital twin model combines the experimental setup with the ANN model, enabling monitoring, analysis, and prediction of the floating solar energy system's operation. The digital model mirrors the functionality of the physical setup, running in sync with the experiment to provide real-time insights and predictions. It provides useful industrial benefits, such as informing maintenance plans as well as design and control strategies for optimal energy efficiency. In long term, this digital twin will help improve overall solar energy yield whilst minimising the operational costs and risks.

Keywords : digital twin, floating solar energy system, experiment setup, artificial intelligence
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