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Performance Validation of Model Predictive Control for Electrical Power Converters of a Grid Integrated Oscillating Water Column

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Abstract : This paper aims to experimentally validate the control strategy used for electrical power converters in grid integrated oscillating water column (OWC) wave energy converter (WEC). The particular OWC's unidirectional air turbine-generator output power results in discrete large power pulses. Therefore, the system requires power conditioning prior to integrating to the grid. This is achieved by using a back to back power converter with an energy storage system. A Li-Ion battery energy storage is connected to the dc-link of the back-to-back converter using a bidirectional dc-dc converter. This arrangement decouples the system dynamics and mitigates the mismatch between supply and demand powers. All three electrical power converters used in the arrangement are controlled using finite control set-model predictive control (FCS-MPC) strategy. The rectifier controller is to regulate the speed of the turbine at a set rotational speed to uphold the air turbine at a desirable speed range under varying wave conditions. The inverter controller is to maintain the output power to the grid adhering to grid codes. The dc-dc bidirectional converter controller is to set the dc-link voltage at its reference value. The software modeling of the OWC system and FCS-MPC is carried out in the MATLAB/Simulink software using actual data and parameters obtained from a prototype unidirectional air-turbine OWC developed at Australian Maritime College (AMC). The hardware development and experimental validations are being carried out at AMC Electronic laboratory. The designed FCS-MPC for the power converters are separately coded in Code Composer Studio V8 and downloaded into separate Texas Instrument's TIVA C Series EK-TM4C123GXL Launchpad Evaluation Boards with TM4C123GH6PMI microcontrollers (real-time control processors). Each microcontroller is used to drive 2kW 3-phase STEVAL-IHM028V2 evaluation board with an intelligent power module (STGIPS20C60). The power module consists of a 3-phase inverter bridge with 600V insulated gate bipolar transistors. Delta standard (ASDA-B2 series) servo drive/motor coupled to a 2kW permanent magnet synchronous generator is served as the turbine-generator. This lab-scale setup is used to obtain experimental results. The validation of the FCS-MPC is done by comparing these experimental results to the results obtained by MATLAB/Simulink software results in similar scenarios. The results show that under the proposed control scheme, the regulated variables follow their references accurately. This research confirms that FCS-MPC fits well into the power converter control of the OWC-WEC system with a Li-Ion battery energy storage.

Keywords : dc-dc bidirectional converter, finite control set-model predictive control, Li-ion battery energy storage, oscillating water column, wave energy converter
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