National Institute of Technology Rourkela

Defence Seminar

Seminar Title	: Advanced Control Strategies for Efficient Power Management in DC Microgrid with Hybrid Energy Storage Systems
Speaker	: Suchismita Patel (Rollno : 519ee1011)
Supervisor	: Arnab Ghosh
Venue	: EE-401
Date and Time	: 26 Mar 2025 (12:00 Noon)
Abstract	: The renewable energy sources (RESs) have recently been considered viable alternatives for conventional generation systems. RESs, such as wind and solar are feasible options for reducing greenhouse gas emissions. This work primarily focuses on developing suitable voltage controllers for the power management control loop that can effectively regulate the DC bus voltage in the DC microgrid (DCMG). The selection of control parameters is also challenging and time-consuming. Parameter selection ambiguity can diminish the dynamic response of power systems and lead to instability. Hence, soft computational methods are commonly employed to improve dynamic responsiveness under changing the load conditions. The limitation of PV-battery integrated DCMG is that the power supply may not be reliable due to the inherent intermittency of PV energy. Therefore, wind energy sources have been integrated with PV to improve the system's reliability. Another limitation is that the MSSA-optimized 2-DOF FOPID +PI controller-based PMS cannot effectively regulate the DC bus voltage during the initial transient portion. To address the above limitation, the three-degree of freedom integrated fractional order PID (3-DOF FOPID) controller is designed and implemented as a voltage controller in the PMS control loop, that can suppress the noise characteristic and improve the voltage stability. The modified sine cosine algorithm (m-SCA) algorithm is used to optimize the dynamic response of the 3-DOF FOPID controller and optimize its control parameters. A comparative study has been done between 2-DOF FOPID +PI controller-based PMS and proposed 3-DOF FOPID controller-based PMS in the MATLAB environment. There are multiple limitations associated with a single energy storage system. The batteries cannot rapidly supply energy during high-power demand applications due to their lower power densities. The excessive power requirements may cause more stress on batteries, resulting in accelerated deterioration and shortened lifespan. Therefore, a supercapacitor (SC) has been integrated with the battery, that can reduce the battery's stress levels and improve the system's reliability. To manage the power flow in a hybrid energy storage system (HESS) integrated DCMG, the multistage FOPID controller is proposed and implemented as a voltage controller in the PMS control loop. Harris' Hawks optimization (HHO) algorithm is used to optimize the control parameters of the multistage FOPID controller. The proposed PMS analyses with different cases are performed in the MATLAB environment and the real-time OPAL-RT platform. The multistage FOPID controller-based PMS could not effectively reduce the settling time of DC bus voltage, resulting in a slow response to load or power generation fluctuations. The hybrid adaptive fuzzy integrated multistage FOPID (HAFI multistage FOPID) controller is proposed and implemented as a voltage controller in the PMS control loop to alleviate this limitation. A hybrid chaotic HHO integrated PS algorithm is used to tune the parameters of the HAFI multistage FOPID controller to improve the system's dynamic response. The proposed hybrid adaptive fuzzy integrated multistage FOPID (HAFI multistage FOPID) controller-based PMS and multistage FOPID controller-based PMS is compared in the MATLAB environment. The HAFI multistage FOPID controller could not effectively regulate higher voltage variation during load or weather variations, potentially posing issues for sensitive equipment. Therefore, a hybrid artificial neural network-model predictive controller (hybrid ANN-MPC controller) based PMS is proposed to alleviate the above-mentioned limitations. The proposed PMS has a faster settling time, that can improve the reliability and stability of the system and provide superior load management. The proposed hybrid model predictive controller driven artificial neural network (MPC driven ANN) based PMS is compared with HAFI multistage FOPID controller-based PMS and multistage FOPID controller-based PMS in MATLAB/Simulink environment. An extensive robustness study of the DCMG system is conducted against the parametric uncertainty and real-time variation in solar irradiation, solar temperature, and wind speed. The efficacy of the proposed hybrid MPC driven ANN -based PMS has been evaluated by using computational studies and real-time OPAL-RT across different operating conditions.