Fayoum University

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Sensorless Advanced Control Techniques Applied to Renewable Energy Applications

A thesis submitted in partial fulfillment

of

The requirements for the degree of

Doctor of Philosophy (PhD)

Electrical Power and Machines Engineering

Electrical Engineering Department

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2025

ABSTRACT

This thesis focuses on variant advanced Sensorless control techniques applied to renewable energy applications. The research is divided into three main areas:

1- **Efficient sensorless speed predictive control without weighting factors for PMSM drive based on MRAS Estimator**: a simplified accurate technique for sensorless direct speed predictive control (DSPC) for the permanent magnet synchronous motor (PMSM) based on the model reference adaptive system (MRAS) is presented. The suggested (DSPC) approach utilizes an innovative method that uses all electrical and mechanical variables in a single control law to determine the best switching vector for the inverter during the following sampling interval. The proposed cost function is simple without weighting factors due to the employment of a sliding term containing the speed/current tracking. A fair comparison between the suggested DSPC and the conventional current predictive control (CPC), which employs a PI controller in the outer speed loop, is provided to clarify the aspects of the proposed method. the response for different dynamic operating points is examined using MATLAB M-file/Simulink simulation. According to simulation comparison results between the suggested DSPC and conventional CPC, the proposed DSPC exhibits much better transient and steady state performance.

2- **Finite Speed-Set Model Reference Adaptive System Based on Sensorless Control of Permanent Magnet Synchronous Generators for Wind Turbines**: a novel finite speed-set model reference adaptive system (FSS-MRAS) based on the current predictive control (CPC) of a permanent magnet synchronous generator (PMSG) is presented in wind energy turbine systems (WETSs). The mathematical models of wind energy systems (WESs) coupled with a permanent magnet synchronous generator (PMSG) are presented in addition to the implementation of the CPC of PMSGs. The proposed FSS-MRAS is based on eliminating the tuning burden of the conventional MRAS by using a limited set of speeds of the PMSG rotor that are employed to predict the rotor speed of the generator. Consequently, the optimal speed of the rotor is the one resulting from the optimization of a proposed new cost function. Accordingly, the conventional MRAS controller is eliminated and the main disadvantage represented in the tuning burden of the constant-gain proportional-integral (PI) controller has been overcome. The proposed FSS-MRAS observer is validated using MATLAB/Simulink at different operating conditions. The results of

the proposed FSS-MRAS have been compared with those of the conventional MRAS, which proved the high robustness and reliability of the proposed observer.

3- **Maximum Power Point Tracking based on Finite Voltage-Set MPC for Grid-Connected Photovoltaic Systems under Environmental Variations**: This part presents a model predictive control (MPC)-based approach for optimizing the performance of a photovoltaic (PV) system. The proposed method employs a finite voltage-set maximum power point tracking (FVS-MPPT), ensuring precise duty cycle adjustment for a boost converter in the PV system considering the environmental changes in irradiation and temperature. Additionally, MPC is implemented for the grid-side converter to determine the optimal switching vector, ensuring precise control of active power via $i_{d\,ref}$ and the elimination of reactive power by setting $i_{q\,ref}$ to zero. This approach optimizes the converter's performance, maintaining a stable DC-link voltage while ensuring efficient grid integration. To ensure proper synchronization with the grid, a Phase-Locked Loop (PLL) is utilized to provide the necessary grid voltage angle for dq frame transformation. Simulation results demonstrate the effectiveness of the proposed MPC strategy, with the PV-side converter showing a robust response by dynamically adjusting the duty cycle to maintain optimal performance under varying irradiation and temperature conditions. Furthermore, the grid-side converter ensures precise control of active power and eliminates reactive power, enhancing the overall system's stability and efficiency during grid interactions. a comparison of simulation results between the conventional P&O algorithm and the FVS-MPPT approach is presented, demonstrating the enhanced performance of the proposed technique over the conventional method.