

Maximum Wind Power Harvesting Using Interior Type Permanent-Magnet Synchronous Generator

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Wind energy is a renewable and highly efficient power source, capable of converting approximately 40–50% of the wind's kinetic energy into electrical energy. Wind energy extraction is primarily governed by two control stages: turbine control and generator control. In the turbine control stage, extraction efficiency depends on accurate Maximum Power Point Tracking (MPPT) under varying wind conditions. Conventional MPPT techniques rely heavily on precise turbine characteristics, which can lead to time delays and reduced dynamic responsiveness. This work proposes an artificial intelligence (AI)-based MPPT scheme that eliminates dependence on empirical equations and extensive simulations. The proposed approach directly predicts the optimal rotor shaft speed using an Artificial Neural Network (ANN). Furthermore, an AI-based wind forecasting model is incorporated to enhance predictive control and improve MPPT accuracy. In the generator control stage, an Interior Permanent Magnet Synchronous Generator (IPMSG) is employed to achieve high efficiency. The absence of rotor windings in the IPMSG eliminates rotor copper losses, thereby improving overall efficiency. Efficiency is further enhanced using a Maximum Torque Per Ampere (MTPA) control strategy, which minimizes stator current for a given torque demand and reduces stator copper losses. Field-Oriented Control (FOC) is implemented to achieve precise regulation of the stator current components in the d-q reference frame. Clarke and Park transformations are used to convert three-phase stator currents into d-q components and vice versa, enabling independent proportional-integral (PI) controllers for the d-axis and q-axis currents. A slower PI speed controller, operating at a bandwidth ten times lower than the current control loop, determines the required torque for speed regulation. The performance of the complete system is validated through computer simulations. In addition, a laboratory-scale prototype incorporating an IPMSG and a power electronic converter is developed to experimentally verify the power conversion in the system.

Keywords: Wind energy conversion system, Maximum power point tracking (MPPT), Interior permanent magnet synchronous generator (IPMSG), Maximum torque per ampere (MTPA) control