To verify the performance of the proposed method even when the wind speed increases suddenly before the MPPT algorithm reaches steady-state, the simulation results in Fig. 14 are presented. As is shown in Fig. 14(a), the wind speed suddenly increases from 8 m/s to 11 m/s at t=0.003 s, before the generator speed reaches the optimal speed of 12.95 rad/s for the wind speed of 8 m/s. Even in this case, the generator speed is continuously increased until it reaches the optimal value of 17.74 rad/s for the wind speed of V=11 m/s, as can be shown in Fig. 14(b). This well proves the performance of the proposed scheme and theoretical analyses presented in the third case.

In addition, Fig. 15 shows the simulation results to verify the performance of the proposed method even when the wind speed decreases suddenly before the MPPT algorithm reaches steady-state. As shown in Fig. 15(a), the wind speed suddenly decreases from 11 m/s to 9 m/s at t=0.005 s, before the generator speed reaches the optimal speed of 17.74 rad/s for the wind speed of 11 m/s. Similarly, the proposed scheme reduces the generator speed to the optimal value of 14.78 rad/s for the wind speed of 9 m/s as can be seen from Fig. 15(b).

Table 1: Parameters of a PMSG

Parameters	Value
Stator resistance R_s	0.64 Ω
d-axis inductance L_d	0.82 mH
q-axis inductance L_q	0.82 mH
Number of pole pairs P	12
Inertia J	0.111 kgm^2
Viscous friction coefficient B	0.011 Nms
Flux linkage ψ	0.18 Wb

Table 2: Theoretical optimal speed of generator and tracking values obtained by the proposed MPPT algorithm

Wind speed V	Theoretical optimal speed	Tracking value of the proposed MPPT algorithm
8 m/s	13 rad/s	12.95 rad/s
9 m/s	14.5 rad/s	14.78 rad/s
11 m/s	18 rad/s	17.74 rad/s

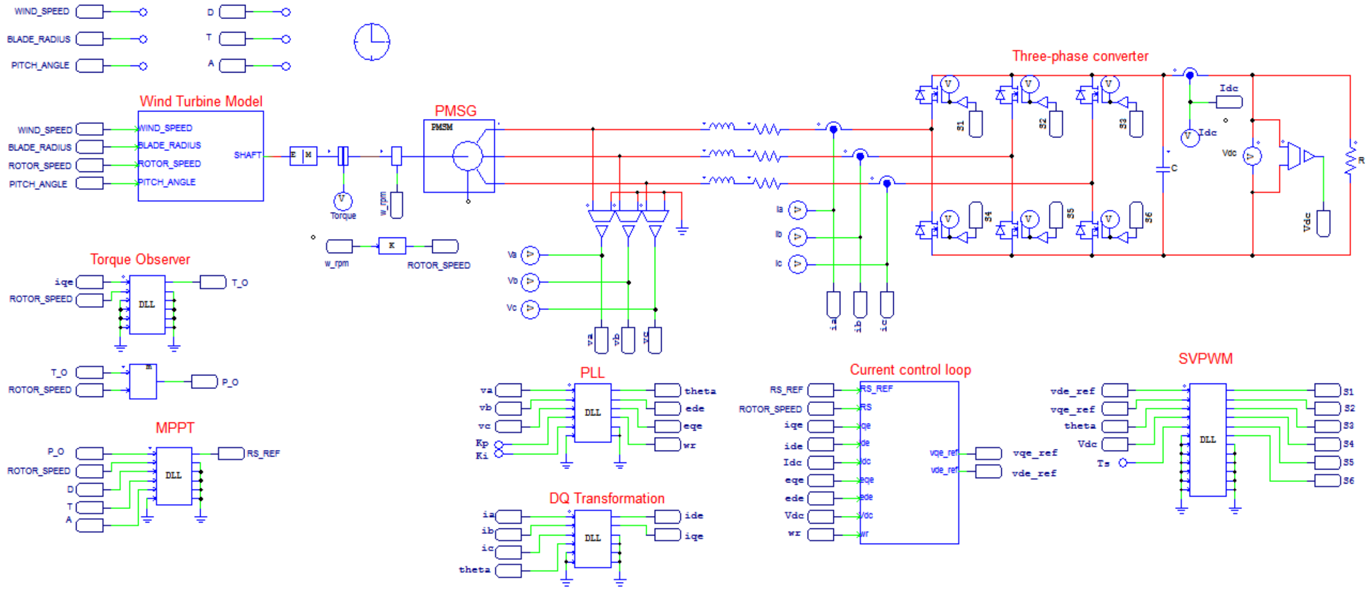
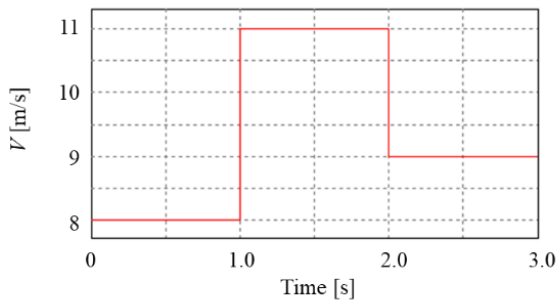
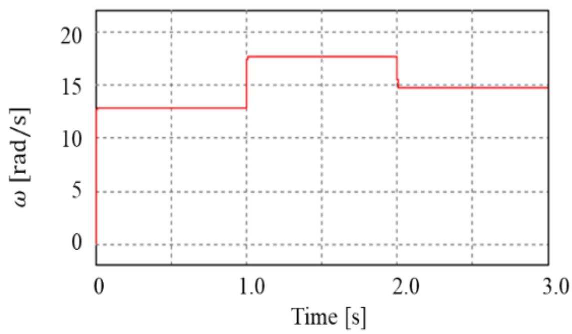


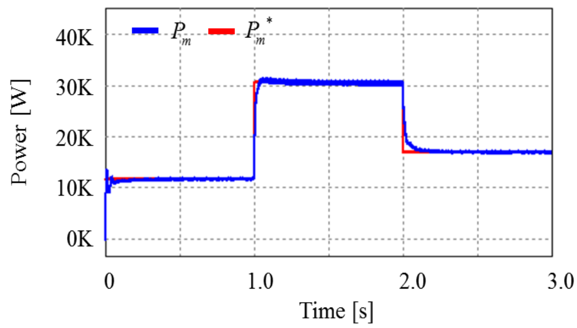
Figure 12. Simulation Configuration of the Proposed MPPT Algorithm based on PSIM



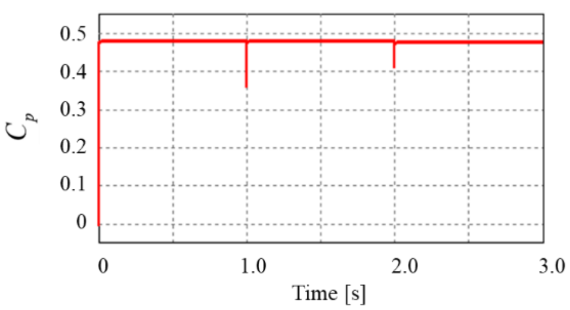
(a) Variation of wind speed



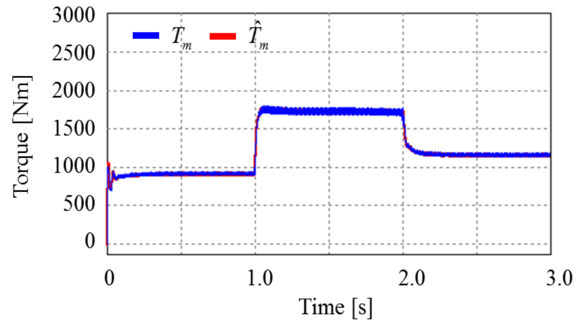
(b) Generator speed



(c) Desired maximum power and extracted power obtained with the proposed MPPT algorithm

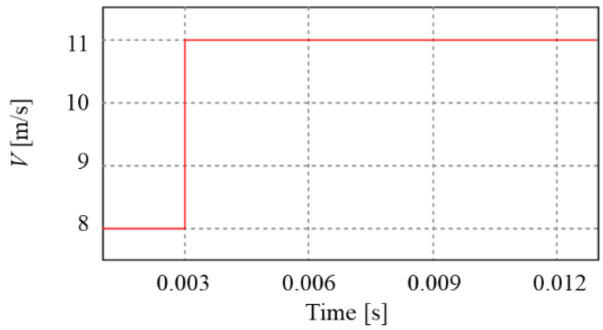


(d) Power coefficient

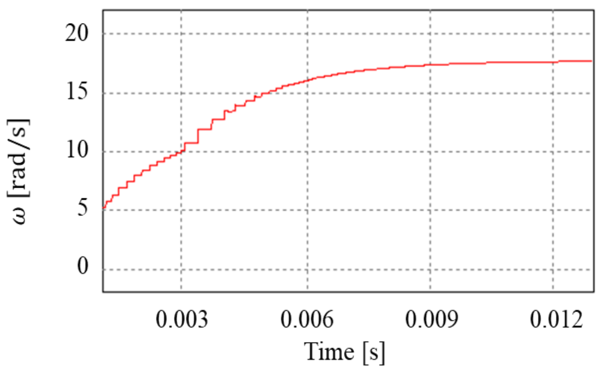


(e) Actual and estimated torque of wind turbine

Figure 13. Simulation Results of the Proposed MPPT Algorithm under Variation of Wind Speed at Steady-State of Tracking

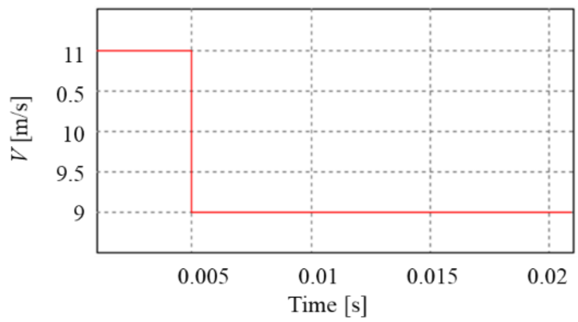


(a) Variation of wind speed

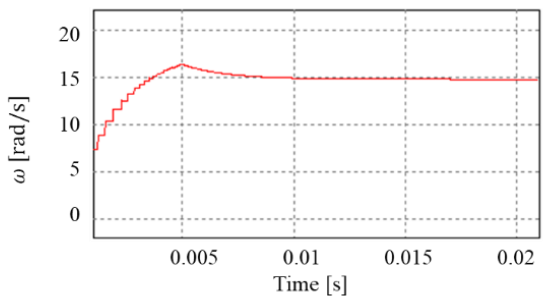


(b) Generator rotor speed

Figure 14. Simulation Results of the Proposed MPPT Algorithm When Wind Speed Increases Suddenly at t=0.003 s before a Steady-State of Tracking



(a) Variation of wind speed



(b) Generator rotor speed

Figure 15. Simulation Results of the Proposed MPPT Algorithm When Wind Speed Decreases Suddenly at t=0.005 s before a Steady-State of Tracking

CONCLUSION

In order to improve the efficiency of a wind power system, an optimal MPPT algorithm to extract the maximum available power from a PMSG-based WECS has been proposed in this paper. This proposed method does not require a wind speed sensor as well as the prior information such as the air density and wind turbine parameters. Furthermore, it provides an ability to track the MPP effectively even under a sudden change in wind speed. Conventionally, a torque sensor has been usually employed to measure the mechanical torque of wind turbine. However, using the torque sensor significantly increases the total cost of a WECS. For the purpose of eliminating the requirement for additional sensor in a WECS, a disturbance observer has been introduced in this paper to estimate the torque of wind turbine. To verify the feasibility of the proposed control scheme, integrated simulation studies have been carried out considering the whole variable-speed WECS based on PMSG and power conversion circuits. Theoretical analysis and simulation results have been provided to confirm the effectiveness of the proposed MPPT algorithm.

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