

actuator parameter faults in the WT. It permits the detection and localisation by means of reconstruction of pitch angle sensor fault and any fault that implies a change in the dynamics of the pitch actuator system almost instantly. The performance of this observer was evaluated and we can confirm its efficiency. Finally, further work could be the practical implementation possibilities of this strategy.

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REFERENCES

[1] Piyali G, Akhtar K, Aladin Z.(2017). Optimum fuzzy logic control system design using cuckoo search algorithm for pitch control of a wind turbine. *Advances C* 72(4): 266-280.

[2] Arama FZ, Bousserhane IK, Laribi S, Sahli Y, Mazari B. (2018). Artificial intelligence control applied in wind energy conversion system. *International Journal of Power Electronics and Drive System (IJPEDS)* 9(2): 571-578. <https://doi.org/10.11591/ijped.v9n2.pp571-578>

[3] Fadil H, Elhafyani ML, Zouggar S. (2018). Enhanced three-phase inverter fault detection and diagnosis approach-design and experimental evaluation. *International Journal of Power Electronics and Drive System (IJPEDS)* 9(2): 559-570. <https://doi.org/10.11591/ijped.v9n2.pp559-570>

[4] Chen F, Fu ZG. (2016). Wind turbine failure risk assessment model based on DBN. *Advances C* 71(1): 110-124.

[5] Boumaiza A, Arbaoui F, Saidi ML. (2014). Diagnostic des défauts à base d'observateur dans un système éolien. *Mediterranean Journal of Modeling and Simulation* 1(1): 045-055.

[6] Park JH, Park GT. (2003). Adaptive fuzzy observer with minimal dynamic order for uncertain nonlinear systems. *IEEE Proceedings Control Theory and Applications* 150(2): 189-197. <https://doi.org/10.1049/ipcta:20030148>

[7] Shaker MS, Patton RJ. (2014). Active sensor fault tolerant output feedback tracking control for wind turbine systems via TS model. *Engineering Applications of Artificial Intelligence* 34: 1-12.

[8] Boussairi Y, Abouloifa A, Lachkar I, Hamdoun A, Aouadi C. (2018). Modeling and nonlinear control of a wind turbine system based on a permanent magnet synchronous generator connected to the three-phase network. *International Journal of Power Electronics and Drive System (IJPEDS)* 9(2): 766-774. <http://doi.org/10.11591/ijped.v9.i2.pp%25p>

[9] Edwards C, Spurgeon SK. (2000). Sliding mode observers for fault detection and isolation. *Automatica*. 36(4): 541-553. <https://doi.org/10.3182/20020721-6-ES-1901.00789>

[10] Tan CP, Edwards C. (2001). An LMI approach for designing sliding mode observers. *Int. J. Control*. 74:

1559-1568. <https://doi.org/10.1080/00207170110081723>

[11] Walcott BL, Zak SH. (1987). State observation of nonlinear uncertain dynamical systems. *IEEE Trans. Automat. Control* 32: 166-170. <https://doi.org/10.1109/TAC.1987.1104530>

[12] Ben Hamouda L, Bennouna OAM, Langlois N. (2013). Quasi-LPV model predictive reconfigurable control for constrained nonlinear systems. *Conference on Control and Fault-Tolerant Systems (SysTol)*, Nice, France.

[13] Odgaard F, Johnson K. (2013). Wind turbine fault detection and fault tolerant control – an enhanced benchmark challenge. *American Control Conference (ACC)*, 4447-4452.

[14] Dari H, Mehenaoui L, Ramdani M. (2015). An optimized fuzzy controller to capture optimal power from wind turbine. *4th International Conference on Renewable Energy Research and Applications*, Italy, pp. 815-820.

[15] Esbensen T, Sloth C. (2009). Fault diagnosis and fault-tolerant control of wind turbines. Master's Thesis, Department of Electronic Systems, Aalborg University, Denmark.

[16] Georg S, Schulte H. (2014). Diagnosis of actuator parameter faults in wind turbines using a takagi-sugeno sliding mode observer. *Intelligent Systems in Technical and Medical Diagnostics*. Springer, Berlin, Heidelberg, 230. https://doi.org/10.1007/978-3-642-39881-0_2

NOMENCLATURE

β_{dt}	The torsion damping coefficient [Nm / (rad / s)]
B_g	Viscous friction of high-speed shaft [Nm / (rad / s)]
B_r	Viscous friction of low-speed shaft [Nm / (rad / s)]
J_g	Inertia of the high-speed shaft [kgm ²]
J_r	Inertia of the low-speed shaft [kgm ²]
K_{dt}	The torsion stiffness [Nm / rad]
N_g	The drive train gear ratio [Nm / (rad / s)]
$T_a(t)$	The aerodynamic torque [Nm]
$T_g(t)$	The generator torque [Nm]
ω_r	The rotor speed [rad / s]
ω_g	The generator speed [rad / s]
$\theta_{\Delta}(t)$	Torsion angle of the drive train [rad]

Subscripts

DSMO	Decentralized sliding mode observer
Quasi-LPV	Quasi linear parameter varying
SMO	Sliding mode observer
VSWECS	Variable speed wind energy conversion system
WECS	Wind energy conversion systems
WT	Wind turbines