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Induced Pulsation Attack Against Kalman Filter Driven Brushless DC Motor Control System

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Abstract : We use modeling and simulation tools, to introduce a novel bias injection attack, named the ’Induced Pulsation Attack’, which targets Cyber Physical Systems with closed-loop controlled Brushless DC (BLDC) motor and Kalman filter driver in the feedback loop. This attack involves engaging a linear function with a constant gradient to distort the coefficient of the injected bias, which falsifies the Kalman filter estimates of the rotor’s angular speed. As a result, this manipulation interaction inside the control system causes periodic pulsations in a form of asymmetric sine wave of both current and voltage in the circuit windings, with a high magnitude. It is shown that by varying the gradient of linear function, one can control both the frequency and structure of the induced pulsations. It is also demonstrated that terminating the attack at any point leads to additional compensating effort from the controller to restore the speed to its equilibrium value. This compensation effort produces an exponentially decaying wave, which we call the ’attack withdrawal syndrome’ wave. The conditions for maximizing or minimizing the impact of the attack withdrawal syndrome are determined. Linking the termination of the attack to the end of the full period of the induced pulsation wave has been shown to nullify the attack withdrawal syndrome wave, thereby improving the attack’s covertness.

Keywords : cyber-attack, induced pulsation, bias injection, Kalman filter, BLDC motor, control system, closed loop, P-controller, PID-controller, saw-function, cyber-physical system
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