Security Analysis for Process Control Systems

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ABSTRACT

We present security analysis of process control systems (PCS) when an attacker can compromise sensor measurements that are critical for maintaining the operational goals. We also develop model-based detection methods that can be tuned to limit the false-alarm rates while detecting a large class of sensor attacks. By taking example of a well studied process control system, we discuss the consequences of sensor attacks on the performance of the system and important implications for designing defense actions.

1. ATTACK MODEL

A general model for the observed signal is the following:

$$\tilde{y}_i(k) = \begin{cases} y_i(k) & \text{for } k \notin \mathcal{K}_a \\ y_i(k) + \lambda_i(k) & \text{for } k \in \mathcal{K}_a \\ y_i^{\min} & \text{for } k \in \mathcal{K}_a,\ y_i(k) + \lambda_i(k) < y_i^{\min} \\ y_i^{\max} & \text{for } t \in \mathcal{K}_a,\ y_i(k) + \lambda_i(k) > y_i^{\max} \end{cases}$$

The model can be used to represent many attacks such as additive injection, multiplicative scaling, replay & DoS.

2. MODEL-BASED ATTACK DETECTION

The anomaly detection module (ADM) of our attack detection system (Figure 1) compares the sequence $\tilde{y}(k)$ (received from the sensor and may have been attacked) with the sequence $\hat{y}(k)$ (obtained from the internal model). The ADM raises an alert if the deviation between the two sequences is significant. The nonparametric CUSUM statistic for sensor i is $S_i(k) = (S_i(k-1) + z_i(k))^+$, $S_i(0) = 0$.

Our response strategy (shown in Fig 1) can be summarized as follows: For sensor i, if $S_i(k) > \tau_i$ (the threshold selected for sensor i), the ADM replaces $\tilde{y}_i(k)$ with $\hat{y}_i(k)$. Otherwise, it treats $\tilde{y}_i(k)$ as the correct sensor signal. We use the Tennessee-Eastman process control system (TE-PCS) model (Figure 2) to verify our approach.

3. EXPERIMENTS

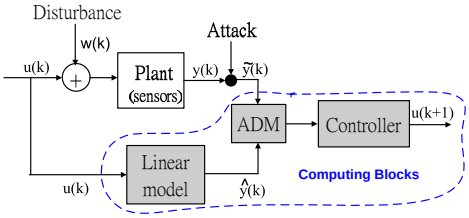


Figure 1: The proposed detection module.

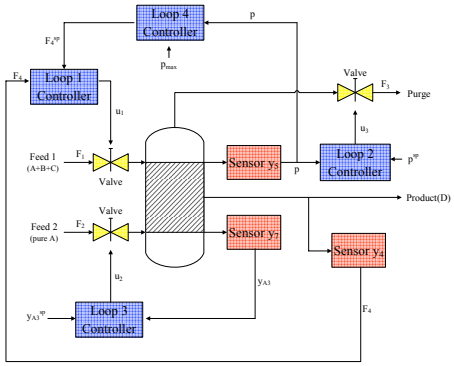
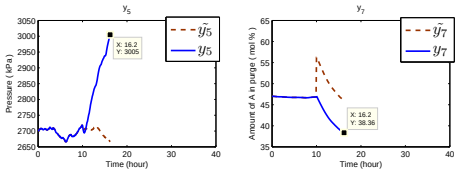
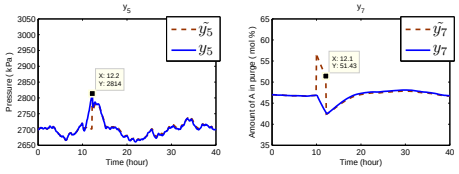


Figure 2: Architecture of the Simplified TE Plant



(a) without ADM the pressure grows past safety levels.



(b) The statistics for y_5 and y_7 independently detect the attack.

Figure 3: $\tilde{y_5}(t) = y_5(t-10)$ **&** $\tilde{y_7} = y_7 * 1.2$