Resilience Engineering of Industrial Processes: Principles and Contributing Factors

In process safety area, many efforts have been focused on studying methods to prevent the transition of the state of the system from the normal state to upset and/or catastrophic state, but many unexpected changes are unavoidable even under good risk management and the incidents still occur.

In response to the need to improve the safety of the chemical process or plant, there is a need to study research in which left transition (green) (Figure 1) is carried out easily and as soon as possible; that is Resilience.

The aim of this work is to propose the principles and contribution factors of resilience of chemical process which can be applied to develop a systematic approach in evaluating resilience of chemical processes or units using multi-factor multi-level approach and hierarchical framework.

Three system states can be distinguished in operation of an industrial process: normal, upset and catastrophic (Figure 2). It is desired to maintain the process systems at normal-state region. However, unwanted disturbance always exist and tend to force system...
state out of the normal-state region and may go to upset or catastrophic state. A resilient system can prevent these unwanted transitions and bring it back to normal by appropriate design, technology, human and management activities which can be called measures. If the measures between disturbance and upset states are effective, system goes back to normal. If the measures fail and upset still occurs, there will be protective measures which prevent harm to human and equipment loss. A modeling concept here is that those measures not only can prevent loss but also bounce-back the state to normal operation. This model also reveals another new concept, that is: resilience is a family of many different measures, not a single one. These different measures work and tie together which will improve the ability of the system to tolerate and to bounce back from disturbances instead of being broken.

From the general definition, resilience strategies are identified and developed. Resilience strives to control the situation by minimizing the probability of failure, the consequences and the restoration and recovery time which can be considered as three resilience strategies. Then, to achieve the resilience strategies, there are the following basic principles of a positive resilience: Flexibility, Controllability, Early Detection, Minimization of Failure, Limitation of Effects, and Administrative Controls/Procedures.

Figure 3. Development of resilience strategies, principles, and primary contribution factors

Next, the top-level factors to contribute to Resilience are developed from the resilience principles. The factors must affect the associated principles directly. The primary contribution factors are Design, Detection Potential, Emergency Response, Human, and Safety Management.