Growing Expectations of Dynamic Simulators for Achieving Systems with Resilience

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Chemical plants, nuclear power plants, and large-scale engineering systems including railways and aircraft must be operated at least safely enough so as to not affect the surrounding environment. Furthermore, it is apparent that even only one accident or problem becomes the target of fierce criticism from the general public, as seen in the response of people to the accident of the Fukushima I Nuclear Power Plant of the Tokyo Electric Power Company and the problems with Boeing's 787 jetliners. Of course, those industries in which a high level of safety in operations is required have been making continuous efforts in order to improve safety. Failures in components have drastically decreased thanks to higher-performance, higher-quality materials, proper design and manufacturing of parts and components, and elaborate maintenance and inspection. Human errors have also been steadily decreasing by making operating and working environments more appropriate, developing tools, preparing operation and maintenance manuals, and enhancing education and training. Accidents sometimes will occur, however. They can be reduced, but not eliminated.

As interactions between people become more intensive thanks to the development of greater transportation means, and as advanced technology societies mature, manuals are prepared for human behaviors in addition to various regulations and rules, and these serve as the basis for offering homogeneous services. However, some people point out that uniform and inflexible services tend to be offered, since manuals are considered to be an obligatory code of conduct. A self-satisfied mindset is becoming rampant, such that a person will make no mistakes nor will responsibility fall on his shoulders as long as he follows the manuals. As a result, a lack of vitality of organizations and society can be seen everywhere in today's Japan.

The chairman of the Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of the Tokyo Electric Power Company found such circumstances in the accident and expressed his concern in the "Chairperson's Remarks" section in the final report [(1)] as follows; "(7) It is vital to be conscious of the importance of seeing with your own eyes, thinking with your own head, making decisions and taking action, and vital to cultivate such faculties." He notes that we need resilient thinking and actions that flexibly adapts and responds to different situations. Because a code of conduct such as rules and manuals is set up for assumed situations and exemplifies only the standard actions, it will not work properly under extaordinary circumstances. The significant way of thinking is to spontaneously work out an appropriate action and carry it out while recognizing the nature of the code of conduct.

To generate resilient thinking and actions, while following rules and manuals to the extent that they can be applied, what constitutes an extraordinary situation needs to be understood, and the ability to recognize such situations needs to be developed. When the situation is recognized to be an extraordinary one, the courage to act exceeding rules and manuals is required while understanding their original purposes and goals. In addition, thinking and planning abilities to flexibly set up countermeasures to improve the situation or at least not to make it worse, and developing the ability for timely executing them are important.

For improving safety in large systems, resilience engineering [(2)] has been attracting attention in recent years after the era of improving hardware reliability, and the next era of improving human reliability. Previously, the basis for securing safety was to define possible abnormal states and set up preventive measures not to lead to abnormal states, prepare measures responding to actual abnormal states, and then implement those measures as necessary. Thus, the point to be focused on for improving safety was abnormal states. On the other hand, resilience engineering has shifted its viewpoint to normal states on the basis of the recognition that there is no boundary between abnormal states and normal states, but that those states continuously vary. Thus, by studying why the state is considered normal, the knowledge for flexibly responding to abnormal states is being gradually obtained. For this, the four abilities of responding, monitoring, learning, and anticipating are crucial. Although the responding ability is thought to be primary among them, the author considers the anticipating ability most important because responding does not work at all without resources, tools, or intention for action. The author also believes that the preparing ability based on anticipation is required as well.

Here, what is necessary for developing and improving the anticipating ability is discussed. The author believes the following are required: in-depth knowledge about the object, rich experience in managing the object, and prediction ability based on the model for the object. In chemical plants, in-depth knowledge includes knowledge about plant structure, constituent materials, operating principles, and operating preconditions and ranges; the rich experience includes empirical knowledge obtained through long-term involvement in the specialty department for operations, maintenance, management and so on, as well as an understanding of activities in the inexperienced specialty departments. Of course, these abilities are important even during normal operations where productivity and economical efficiency are required.

For ensuring resilient thinking and action at the occurrence beyond the scope of assumption, predicting ability based on the model of the object is required more so than knowledge and experience. This ability consists of two sub-abilities: object modeling ability and inference ability based on a model.

Even for the same object, various models can be built. Modeling has roughly three aspects: detailing, scope and viewpoint. Detailing determines whether to model the object simply or in detail, and scope determines which part of the object is modeled. Viewpoint is related to which viewpoint the object is modeled from among structure, behavior, function, and others. By modeling the object considering these three aspects, the coverage and applicability of the results of the inference based on the model can be evaluated.

Dynamic simulators based on physical laws are a strong tool for predicting behaviors of systems. However, in a dynamic simulator accompanying numerical calculation, a more detailed model does not always leads to precise results. From the author's past experiences, though not many, such as in transient response analysis in nuclear plants and numerical analysis of multi-phase flow, simple models often delivered a better comprehensive explanation of phenomenon in complex systems. Because parameters and variables increase in a detailed model, it is a big problem to set them appropriately. As in the case of the frame problem which has long been discussed in the field of artificial intelligence, the boundary of the model should be investigated enough. It is evident that there is no need to model the whole earth or universe for a weather forecast to decide the necessity of taking an umbrella when going out. It is important to select a model appropriate to the intrinsic purpose and target of the numerical calculation.

Among various methods for model-based inference, the dynamic simulator will apply the numerical calculation best. Fully enjoying the benefits of the drastically improved calculation capability of recent computers, the results of a calculation which was previously impossible can be obtained in a short time. By reducing the size of a computational mesh and the time increment, and by extending data length for expressing variables, problems in numerical calculation are being mitigated. However, it is necessary to verify the results more carefully than before because detailed modeling produces a huge amount of calculation results.

We have obtained an excellent tool, a dynamic simulator, to precisely predict future behaviors of engineering systems such as chemical plants. The dynamic simulator, which models the target system according to its structure and responsiveness, and the physical laws it follows, and then calculates its behaviors, is expected to be made full use of in various applications in the operations of engineering systems. Although human beings tend to rely too heavily on convenient systems or tools once they have obtained them, what is important next is how to interpret the calculation results from dynamic simulators, and how to use them for prediction. The author hopes that the dynamic simulator will evolve into an effective tool not only for improving the productivity and management efficiency of chemical plants but also for taking resilient measures against unexpected contingencies.

REFERENCE

(1) Final Report on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (main Text), Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2012, pp. 528

(2) Erik Hollnagel, Nancy Leveson, et al., Resilience Engineering: Concepts and Precepts, Ashgate Publishing Limited England, 2006