The Benefits of the Signature-Based Safeguards Approach

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3B. International Safeguards: The Integration of Emerging Technologies for Safeguards

For decades the workhorse of international safeguards has been the mass balance of nuclear material, particularly in bulk facilities. However, the emergence of new reprocessing, enrichment and reactor technologies, the development of advanced sensors and the availability of rapid computational and analytical techniques should stimulate new approaches to deterring the misuse of nuclear facilities that may reduce the burden of safeguards on both the host country and the International Atomic Energy Agency (IAEA). Signature-Based Safeguards (SBS) seeks to do this by synergizing the common interests of the IAEA and the host country. The IAEA needs to verify the peaceful use of nuclear technology and the host country needs to understand and optimize the operation of nuclear facilities. The monitoring of process signals, which the host country's operators and engineers would need to know for process control and optimization and the IAEA could use to extract key information about the use of a facility. SBS would use these process signals to infer the location of special nuclear material (SNM) and the probability of the misuse of a nuclear facility for non-peaceful application. This would be accomplished through a computational framework which would use process models, statistical techniques and/or multivariate analysis to understand and use the interdependence of sensors in the process network. By using *in situ* sensors and process signals, SBS could verify in near real-time the declared operation of a facility.

The power of SBS is best illustrated on an emerging reprocessing technology—pyroprocessing. Several attributes of pyroprocessing complicate the traditional approaches of nuclear material accountancy. First, the feed to the process includes inhomogeneous items—used nuclear fuel (UNF) assemblies. Second, its normal operation results in accumulation of SNM (U/TRU) in process equipment known as electrorefiners. Also, the process operates at high temperatures in a remotely operated environment. Thus, flush-outs, which are traditionally performed in aqueous reprocessing plants, would be counterproductive to the aims of the operators and complicated by possible freezing of process material to pipe walls. Lastly, it is a batch process that is a hybrid between a bulk and an item facility. Items are received into the process and in some case simply moved, dissembled or chopped. In other case, the composition of items fed to a process unit are altered and material tracking may be needed.

Manipulators

One simple process signal to track would be the movement and location of one or more manipulators. Because pyroprocessing is a batch process and handles highly radioactive UNF, it is all performed in a hot cell and manipulators are used to move items from one process unit to the next. Under normal operating conditions, these manipulators would perform (possibly

programmatically) a limited number of movements. Even, maintenance operations should be known and limited. A movement outside of the normal or declared operation could possibly indicate to the IAEA that misuse has occurred. Many SNM diversion scenarios would require the movement of an item out of the normal flow of items between units. Thus, the IAEA having knowledge of each manipulator's movements would provide a deterrent to such misuse.

Heater Power

Because of the high temperature nature of the process, vessels need to be heated, but some reactions are exothermic. Thus by monitoring the power fed to process unit heaters, the extent of key reactions involving SNM could be monitored [1].

Electrochemical Signals

Signals such as current and potential can be tied to the concentration of SNM in process units, particularly the electrorefiner. The use of electrochemical signals could be as simple as monitoring cell voltages and currents. More complicate techniques could be used to obtain greater accuracy, if needed [2,3].

Analysis

Multivariate techniques such as, Principle Component Analysis (PCA), could be trained to identify key variances in process signals and to determine how they relate to the amount of SNM or the declared operation of the facilities [4]. Additionally, the response of sensors could be re-constructed using PCA. If the process is operating abnormally, the re-constructed signals will have a high residual when compared to the actual response. The patterns of the residuals could give insight into the cause of the deviations. Additionally, process signals could be fed into process model which could determine whether the process is operating properly. If not, the process model could compare the process signals to a set of known diversion scenarios or failure modes for the facility and identify the cause.

Conclusion

SBS seeks to reduce the cost burden of safeguards to the IAEA and the host country without compromising the integrity of international safeguards. If accurate models and analytical techniques can be developed to predict or relate process signals to the flow of SNM through a process, then deterrence of misuse could be accomplished or the frequency of inspections and process interruptions could be decreased.

References

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