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# Procedure development of drone risk analysis

Yong-Tae Kim, Yun-Seon Chung*, Geum-Yong Lee, Woo-Sik Jung
Quantum and Nuclear Engineering, Sejong University, 209 Neungdong-ro, Gwanggin-gu, Seoul, Republic of Korea
**Corresponding author: yschung@sju.ac.kr*

## 1. Introduction

Drone, originally developed for military purpose, integrates various cutting-edge technologies such as aviation, cameras, and sensors, with ever wider still targeted applications made possible by innovative technologies, inventions, and designs to deal with needs from industries and objectives. About drone sabotage, incidents such as the appearance of drones, collisions and explosions at national critical facilities in Korea and overseas keep occurring, and so might be in the future.

Recognizing and in need of a systematic approach to address the potentially detrimental or sometimes disastrous impacts on national security and social interests, Korea began a conceptual study on the detection and blocking system for drone sabotage, from the very first moment setting the basic national plan for drone industry promotion [1].

There is a very large difference between aircraft and drones in terms of threat analysis. Unlike airplanes, drones have the advantage of being used as a terrorist weapon because they can be used more secretly for smaller targets with unmanned and remote control, and can be widely abused because they are easier to obtain, transport, and modify than airplanes. Therefore, it is timely to study drone attacks rather than aircraft crashes.

However, research on the threat assessment of actual drone collisions and explosions has not been pursued, and there are no studies or documents on the drone threat or drone attack assessment procedure for nuclear power plants, some surprise when considering the nuclear power plants constitute major facilities important to general security and welfare of Korean citizen.

It is a legal requirement [2] to evaluate threats to nuclear materials and nuclear facilities every three years (or if necessary) and to establish Design Base Threat (DBT). DBT forms the ground for designing and evaluating Physical Protection System (PPS). Firstly, identified and endorsed in 2016 [3] were the threats from small unmanned aerial vehicles (multi-copter and drone) and from explosives mounted on them.

## 2. Scopes and Limitation

Nuclear facilities follow the physical protection design procedure [4,5] shown in Fig. 1, and for the physical protection design of nuclear power plants, a vital area is selected, and a physical protection system is designed to protect the vital area. In this paper, to determine the target set in Phase 1 of the physical protection system design, risk analysis is conducted with the drone threat as an example among many threats regardless of the vital area.

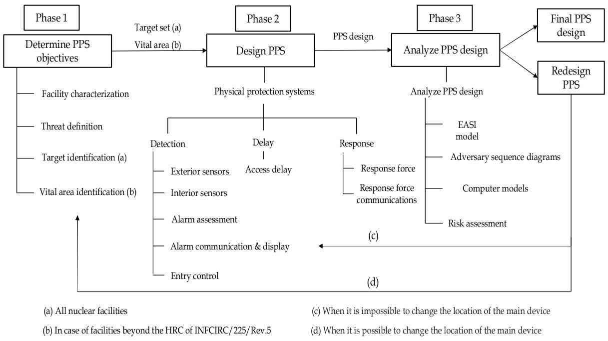

Fig. 1. Design and evaluation process for physical protection systems [4,5]

As delineated in Fig.2 and given the detailed descroption in Section3, the analysis procedure suggested in this paper for drone threat assessment consists largely of four stages, (1) drone model selection (2) selection of the drone threat targets in a nuclear power plant (3) calculation of the drone collision and explosion (4) component damage assessment for which we applied FEA to have as real a result as possible.

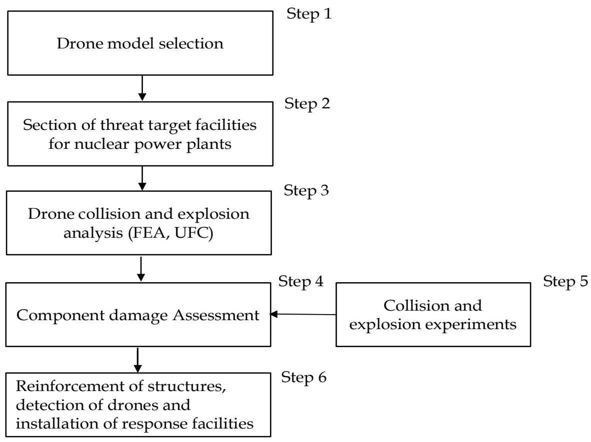

Fig. 2. Summary of the proposed drone threat assessment procedure

## 3. Drone threats assessment procedure

Summarized in Fig.2 was the proposed procedure to finally have FEA results showing the damage caused by the drone threat attack. In this section, more detailed explanation is given with respect to how to choose inputs and to execute each steps. Fig. 3 is the expansion of Fig. 2 to reveal the points made to reach the final results form the first stage of selecting the drone model, irrespective of the understanding that the steps would allow more sophisticated and alternative feeds when approached in different viewpoints.

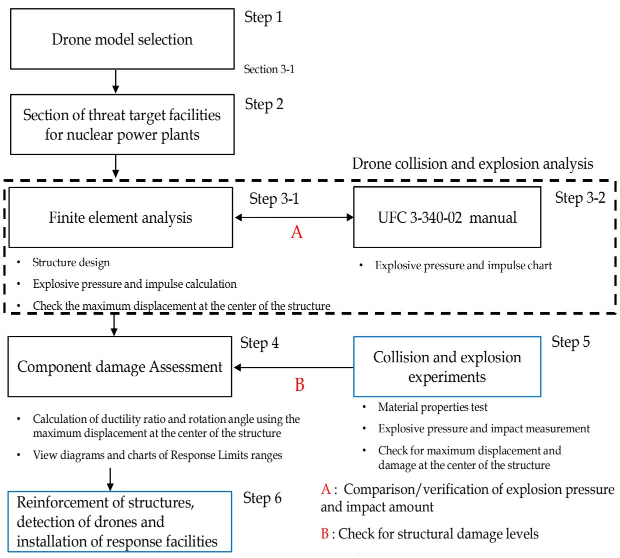

Fig. 3. Drone threat assessment procedures in detail[7]

In the first step of selecting a drone model that has a significant potential to impose actual threats to domestic nuclear power plants, we considered a lot of models available in market for the very purposes, but a risk of being random isn't taken by having the drone model with the past attack history as our drone for this study.

In the second step, we selected the drone-target facilities at the site of nuclear power plant, i.e. ones subject to damage when attacked by drones, and we have chosen four steps, i.e. (1) facilities 1: enclosed room, (2) facilities 2: walls of internal and external facilities, (3) facilities 3: external water tank, and (4) facilities 4: externally exposed piping [8].

Table I: Threat target Structures

| Target model | | Remark |
|---|---|---|
| Inside | Enclosed room | 18inch concrete wall |
| Outside | Wall and ceiling | 18, 13inch concrete wall |
| | Water tank | RWST size tank |
| | Piping | Various diameter piping |

In the third step, a drone collision explosion analysis of the selected facilities is performed. In this paper, the explosion pressure and impact amount values in finite element analysis were verified using the method of calculating the explosion load parameter as specified in the UFC 3-340-02[6] manual document.

Collision and explosion effects analysis requires both FEA and experiments. We used the ABAQUS program was for FEA. As mentioned earlier, the FEA is covered in the paper [7]. The figure 4 below shows an example of the FEA.

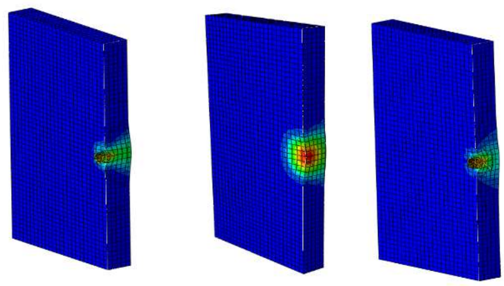
Fig. 4. Example of the FEA [7]

Finally, when assessing the damage to the component, the approximate degree of damage can be predicted by the explosion pressure and the amount of impact. However, in order to assess, the damage of the structure in consideration of the properties of the material and the shape of the structure, the maximum displacement and material property information at the center of the structure should be used to determine the degree of damage. The level of damage to the structure is divided into five levels, from a high level to blowout, hazardous failure, heavy damage, moderate damage, and superficial damage.

## 5. Conclusions

It is our finding that most of the drone research conducted and relevant reports published in Korea could be safely deemed about countermeasures such as drone terrorism, overseas drone research cases, and drone defense and improvement measures. No domestic research has been conducted on the threat assessment of actual drone collisions and explosions, and, as a corollary, no studies and the relevant publications deal with the drone attack damage assessment critically required to provide inputs for the purpose of designing blast resistant physical protection systems for domestic nuclear power plants. This is the first paper in Korea just for that purpose in that drone threat and the damage assessment is presented with actual targets eligible in nuclear power plants, along with references related to drone collision explosion.

There will be sequels for this study, progressing as we read this paper, but with foci on the physical attack targets set and Prevention set for a nuclear power plant.

## ACKNOWLEDGMENTS

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