Study Committee B3

Substations and electrical installations

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Resilience reinforcement of substations in Japan

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1.Introduction

- In recent years, there has been an increase in the number of cases where rivers have swollen and burst their banks in a short period of time due to heavy rainfall or powerful typhoons. Fig. 1 and Fig. 2 are examples of this. In Typhoon Hagibis (No. 19), which landed in Japan in 2019, the rivers were flooded, and a substation was inundated with water at a height of > 2.0 m. This was a disaster that could not be dealt with by conventional countermeasures.
- The following sections show the efforts of national and local authorities and Japanese utilities in response to these situations.

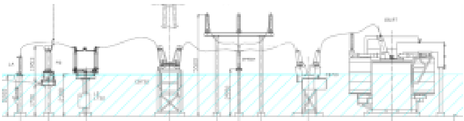

Fig. 1. Substation inundation level (GL+ 2100 mm)

Fig. 2. Picture of substation flooding

2. Review of flood damage assumption

- The national and local governments published hazard maps of the largest flood, inland waters, and storm surge inundation areas that are expected for the purpose of enhancing and strengthening evacuation systems. The Flood Control Act revised in 2015 widened the range of inundation area (Fig. 3).
- One utility company found that, based on new hazard maps, 141 of its 396 substations are expected to be flooded. This is an increase of approx. 100 substations over the previous assumption.

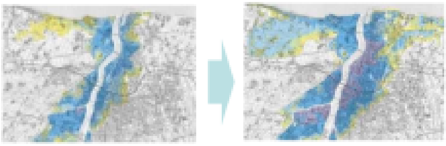

Fig. 3. Expansion of the inundation assumption area based on the revision of the Flood Control Act (https://www.mlit.go.jp/river/suibou/pdf/suibouhou_gaiyou.pdf)

- The utility company assessed the inundation impact on each equipment (Fig. 4). The company decided to take measures for equipment in substations where the expected depth is 2.0 m or less.

Equipment	Outside / Inside	Impact assessment LEVEL 1 Minimum	Impact assessment LEVEL 1 Maximum	Impact assessment LEVEL 2 Minimum	Impact assessment LEVEL 2 Maximum
Circuit breaker	Outside	0.5m	1.8m	1.8m	3.7m
Transformer	Outside	0.9m	1.8m	2.2m	12.0m
Gas insulated switchgear	Outside	0.5m	0.5m	N/A (Sealed tank)	N/A
Oil insulated switchgear	Outside	0.4m	1.3m	0.5m	0.8m
6kV switchgear	Outside	0.3m	0.3m	0.4m	0.4m
Disconnector	Outside	0.5m	0.8m	2.9m	3.3m
Shunt reactor	Outside	1.0m	1.0m	6.5m	–
Static capacitor	Outside	1.2m	1.2m	1.8m	4.1m
22kV switchgear	Inside	0m	–	0.1m	–
Protection Relay	Inside	0.1m	0.3m	–	–
Battery	Inside	0.3m	0.5m	–	–

LEVEL 1: power equipment becomes uncontrollable
LEVEL 2: power supply becomes impossible

Fig. 4. Inundation impact assessment for each equipment

3. Measures against flooding

3-1. Prioritization of substations to implement permanent measures

- One utility company found that several of their substations could be flooded by more than 0.5 m according to the new hazard map. However, the company was not able to take the uniform measures at all substations due to technical and cost limitations.
- Therefore, the company prioritized its substations to implement permanent measures using the flowchart shown in Fig. 5. This allows appropriate measures to be taken at the right time for each substation.

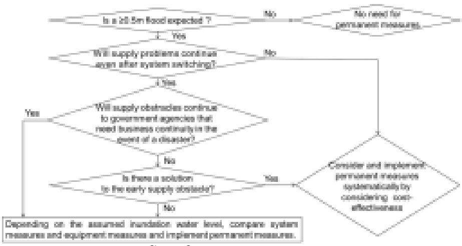

Fig. 5. Priority flow for permanent countermeasures against inundated substations

3-2. Early identification of inundation conditions in substation

- When typhoon or heavy rainfall is approaching to a substation, early identification of the local inundation situation can prevent disruptions to the electricity supply by switching the power system configuration before the substation equipment is damaged. The following are two examples of such efforts in Japan.

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- Fig. 6 shows an initiative to remotely and visually monitor inundation conditions by installing water level indicators at the substation where the industrial television (ITV) is installed.
- In substations without ITV, water level sensor systems were installed to inform the remote operator when the water level in the cable pits exceeded a certain level (Fig. 7).

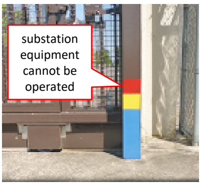

Fig. 6. Water level indicator

Fig. 7. Water level sensor

3-3. Measures to resolve power supply disruptions in the early stage

- If a substation is flooded and access from outside to the substation is stopped, maintenance personnel cannot get to the substation quickly and cannot assess the damage to the substation's equipment. This could lead to prolonged power supply disruptions.
- One solution to this is to deploy an inspection robot (Fig. 8). This robot can be operated from a remote maintenance office. The robot performs routine visual inspections of substation equipment during normal times. When a disaster occurs, the maintenance office can remotely monitor the local damage using the robot. This enables the office to plan restoration methods and prepare the necessary materials before going to the site. This reduces the time required to restore the power supply disruption.
- For substations where the flooded water level is high and most outdoor equipment is inundated, the use of mobile substation is an effective way to quickly resolve the power supply disruption. Fig. 9 shows an example of early recovery using a 66 / 6 kV mobile substation equipment for flood damage.

Fig. 8. Inspection robot

Fig. 9. Mobile substation

3-4. Permanent measures

- Measures to prevent flooding into substations (Fig.10,11)

Fig. 10. L-shaped watertight wall around a substation

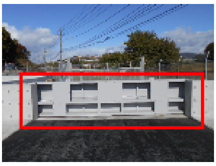

Fig. 11. Watertight gate at the substation entrance

- Measures to prevent flooding of the equipment inside substations (Fig.12-16)

Fig. 12. Raising foundation level of transformers

Fig. 13. Raising floor level of a main building

Fig. 14. Raising GIS support structure

Fig. 15. Watertight door of the main building

Fig. 16. Watertight wall around power equipment

4. Conclusion

- Inundation due to heavy rains and typhoons is becoming more frequent and severe in Japan. This is a big challenge for utilities to ensure stable supply of electricity.
- To prevent severe flooding damage to substations, it is important to review the conventional design of substations, identify the risks of flooding to substations and take appropriate measures according to the risks.

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