Development of Friction Pendulum System to Reduce the Seismic Force

J. B. Jang,a J. K. Kim,a K. M. Hwang,a H. O. Kwon,b C. W. Lee,c
a Earthquake Engr. Group, KEPRI, 103-16, Munji-Dong, Yuseong-Gu, Daejeon, 305-380
b VE Tech Co., Seohyeon-Dong, Bundang-Gu, Seongnam, Gyeonggi 463-862
c B&T Engineering Co., 164-1,Anyang-Dong, Manan-Gu, Anyang, Gyeonggi, 430-816

1. Introduction

Most of the damages in electrical facilities are occurred at transformer due to the great earthquake. The damage types of transformer are the failure of upper bushing of transformer, overturning of transformer due to geometry with high height, and the failure of anchorage of transformer.

The objective of this study is to develop the seismic isolator to prevent the damage of transformer due to earthquake considering the importance of transformer.

2. Seismic Isolator

In general, seismic isolator is divided by two types. One is the elastometric bearing using the damping and the shear stiffness of rubber, and the other is sliding bearing using frictional damping between the PTFE(Poly-Tetra-Fluor-Ethylene) and stainless plate and restoring device.

The seismic isolator was applied to the high voltage condenser system by combining the rubber bearing and steel damper and FPS(Friction Pendulum System) is being focused as seismic isolator with simple structure and without the influence of structural period recently.

The FPS is developed as seismic isolator of transformer in this study.

3. Friction Pendulum System

The dynamic stability and accuracy of manufacture of the developed FPS are improved by making the body of FPS with steel. The frictional surface is made of both PTFE and stainless steel and the reliability of FPS is enhanced. In addition, shear key is considered to prevent the uplift force. The multi frictional surface is considered to get the uniform bearing force.

The FPS with 25 tonf-capacity is made in this study and 4 units are installed at 154kV transformer and 8 units are installed at 345kV transformer.

The period due to restoring force of FPS is 2.0065 sec. and the frictional coefficient is 6 % under the earthquake. The figure 1 shows the developed FPS in this study.

4. Effectiveness of FPS

4.1 Numerical Analysis Model

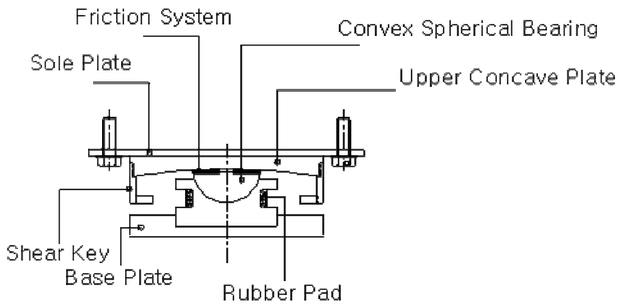


Figure 1. Friction Pendulum System

The numerical analysis is carried out to evaluate the seismic capacity of the developed FPS. The SAP 2000 is used as structural analysis program and the rigid motion is assumed to the body of transformer. The weight of transformer is 179 tonf and it is assumed that the inertia force is applied at the center of gravity of transformer. 8 units FPS with 25 tonf capacity are considered for numerical analysis and the figure 2 and 3 show the artificial time history and the numerical analysis model respectively.

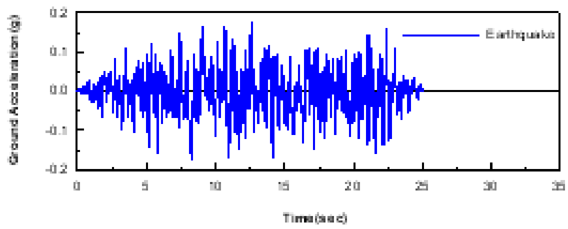
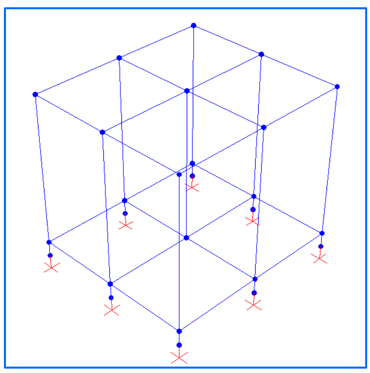
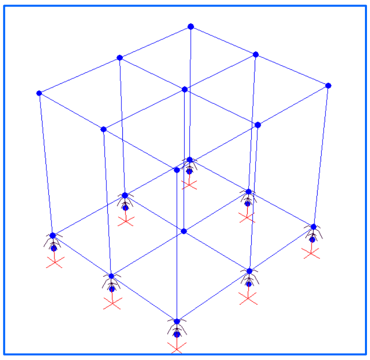


Figure 2. Artificial time history



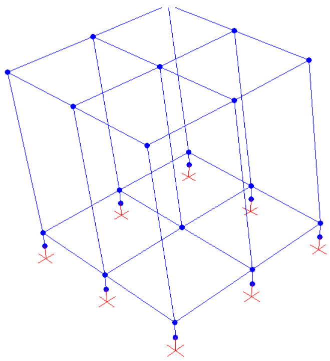
(a) The existing anchorage type



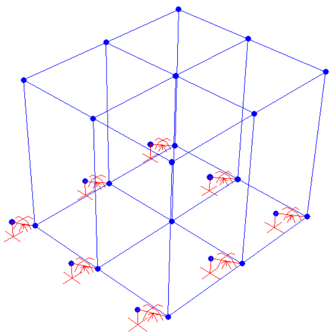
(b) FPS type
Figure 3. Numerical analysis model

4.2 Numerical Result

From the modal analysis as shown in figure 4, the period of transformer with the existing anchorage using the anchor bolt is 0.0333 sec. and this shows the rigid motion and the period of transformer with FPS is 1.09sec.



(a) The existing anchorage type



(b) FPS type
Figure 4. Mode shape

From the time history analysis, FPS makes the period longer and energy reduce as shown in figure 5. Also, base shear of transformer with FPS is 61 % smaller than the existing anchorage and body acceleration of transformer is 62 % smaller than the existing anchorage. If the FPS is applied to the transformer, the entire stability is enhanced and acceleration of upper bushing is reduced.

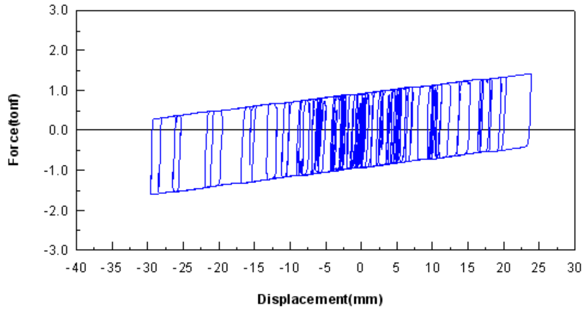
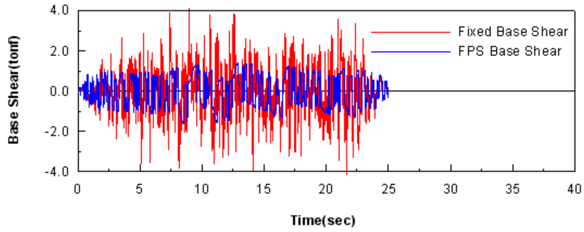
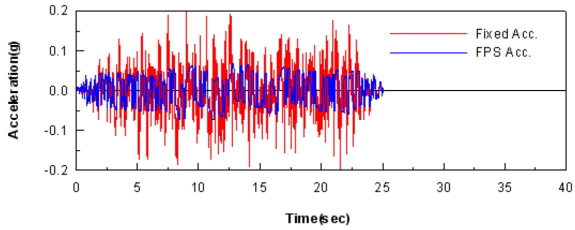


Figure 5. Load-displacement curve



(a) Base shear



(b) Body acceleration
Figure 6. Numerical analysis result

5. Conclusion

Both the base shear and body acceleration are reduced by applying the FPS to the transformer and additional reduction is possible by adjusting the frictional coefficient.

Therefore, the developed FPS can prevent the upper bushing of transformer from failure and the transformer from overturning effectively under the earthquake.

REFERENCES

[1] Eggert, H., Kauschke, W., Structural Bearings, Ernst & Sohn, 2002.
[2] American Association of State Highway & Transportation Officials, Guide Specifications for Seismic Isolation Design, 1999.
[3] Highway Innovative Technology Evaluation Center, Guidelines for the testing of seismic isolation & Energy Dissipating Devices, 1996.
[4] CEN(European Committee for Standardization), EN 1337-2: Sliding Elements.
[5] CEN(European Committee for Standardization), EN 1337-7: Spherical & Cylindrical PTFE-Bearings.