Experimental Study of Friction Pendulum System for Seismic Protection of Transformer

J. B. Jang,a J. K. Kim,a K. M. Hwang,a K. W. Ham,a J. W. Park,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

The large earthquakes have significantly damaged many electric power facilities that are important to the delivery of electric power in urban areas in recent. Also, substation facilities are expensive and key, and it is necessary to establish a way to protect them from those earthquakes. Especially, transformers represent crucial substation equipment and the loss of their functionality can be devastating to the entire power system. So, friction pendulum system is developed to prevent the damage of transformer from the large earthquakes and its seismic capacity is verified through the shaking table test.

2. Seismic Isolator

The seismic isolator technology has gained popularity in the recent decade as one of the rehabilitation measures for seismic protection of structures. The typical seismic isolator is divided into 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. But, the elastometric bearing is impossible to satisfy the design requirements such as buckling, breaking, creeping safety due to the light weight of transformer and the Friction Pendulum System(FPS) which has a properties of sliding bearing, is developed as seismic isolator of transformer in this study.

The figure 1 shows the developed FPS. The loading capacity of each FPS is 25 tonf and the body of FPS is made of SM 490 and Filled PTFE is used for the friction system. The restored period of FPS is 2 sec. and the radius of curvature is 1,000 mm.

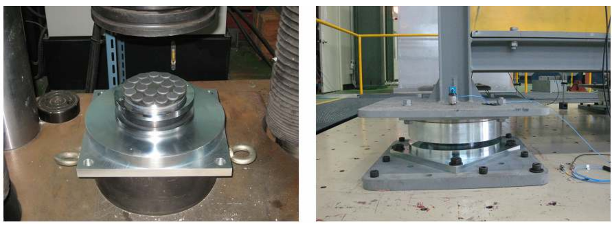
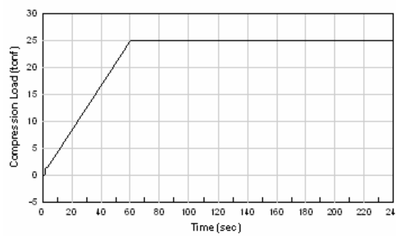


Figure 1. Friction Pendulum System

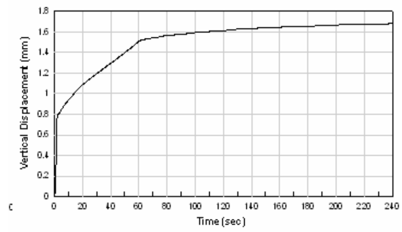
3. Seismic Test

3.1 Compressive Capacity Test

Compressive capacity test is carried out to judge whether creep and permanent deformation due to normal vertical load, are occurred or not. Test is carried out for 3 minutes under design load of 1.0 and 1.5 times. Both test results show that the deformation converges into the specific value as shown in figure 2.



(a) Compression Load



(b) Vertical Displacement

Figure 2. Compressive Capacity Test (1.0 Design Load)

3.2 Friction Test

In order to get the friction coefficient which prepares the damping function of FPS, friction test is carried out.

Figure 3 shows the results of friction test and minimum friction coefficient is 3.78% and maximum is 11.0%. These values are relatively larger than the existing commercial FPS but that is available considering transformer is connected with neighboring electrical facilities by cables.

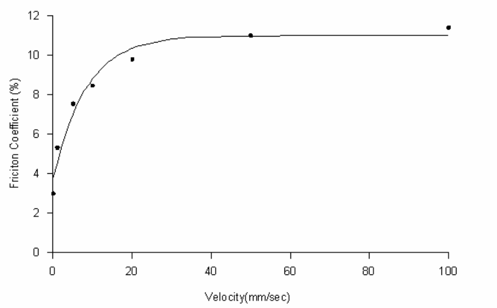


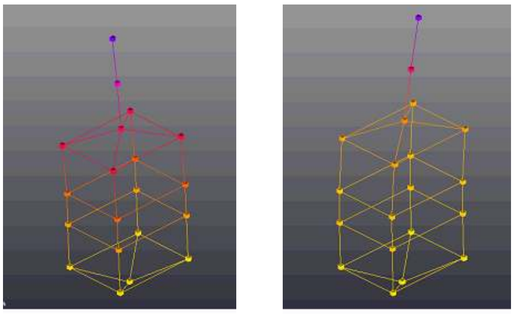
Figure 3. Frictional Test Result

3.3 Seismic Test

In order to analyze the acceleration response reduction effect of FPS compared with the existing anchorage type, seismic test intended for the large scale transformer model, is carried out as shown in figure 4.

(a) Anchorage Type (b) FPS Type
Figure 4. Large Scale Transformer Model

Before seismic test is carried out using the shaking table, modal analysis is performed to analyze the dynamic characteristics of transformer model using the impact hammer. As a result, 1st natural frequency is 8.8 Hz and figure 5 shows mode shapes.



(a) 1st (b) 2nd
Figure 5. Mode Shape

The shaking table motion is standard design response spectrum of electric facilities as shown in figure 6. As a result of shaking table test, maximum response acceleration by FPS type is reduced about 30% at bottom of transformer and 59% at top of bushing compared with the existing anchorage type as shown in figure 7 and 8.

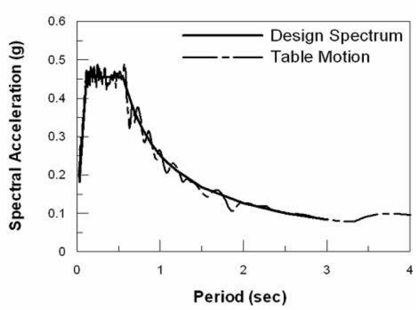
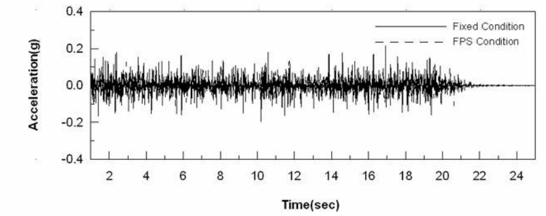
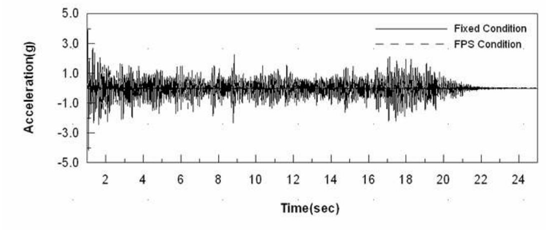


Figure 6. Standard Design Response Spectrum



(a) Bottom of Transformer



(b) Top of Bushing
Figure 7. Seismic Test Results

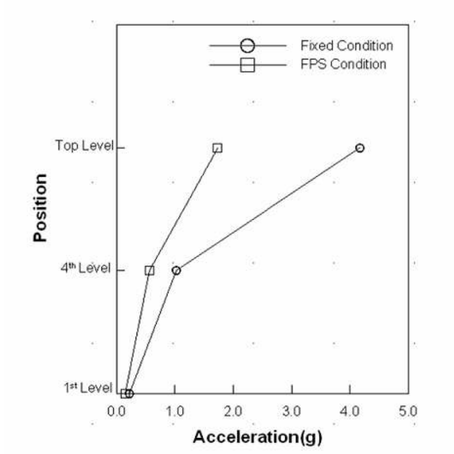


Figure 8. Maximum Response Acceleration

4. Conclusion

Transformer represents crucial substation equipment, and the loss of their functionality can be devastating to the entire power system. So, friction pendulum system is developed to prevent the damage of transformer from the large earthquakes and its seismic capacity is verified through the shaking table test.

As a result, maximum response acceleration by FPS type is reduced about 30% at bottom of transformer and 59% at top of bushing compared with the existing anchorage type. The developed FPS contributes to the stability of electric power service under the earthquake.

REFERENCES

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