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A study on system identification of high voltage circuit breaker and lightning arrester with isolator and their aseismic behavior

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ABSTRACT: Two kinds of isolators for high voltage circuit breaker and lightning arrester were designed. The dynamic parameters of the two kinds of equipments with isolator were obtained from system identification, and the isolating effects under three kinds of site conditions were investigated.

1. INTRODUCTION

In order to prevent the high voltage (110kv) circuit breaker (CB) and lightning arrester (LA) from breaking down during strong earthquake, two kinds of isolators have been developed. The behavior of the isolators has been got through shaking table test, then dynamic parameters of the two structures have been obtained from system identification, and the isolating effects under three kinds of site conditions are predicted.

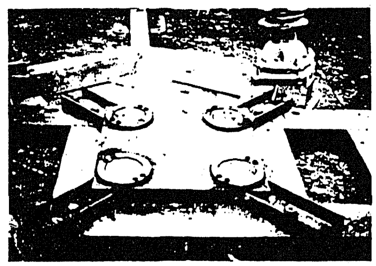

Photo. 2 Chasis and Pieces of Bearing of Isolator for Circuit Breaker

2. SHAKING TABLE TEST

Two kinds of isolators (see photo 1 to 6) were

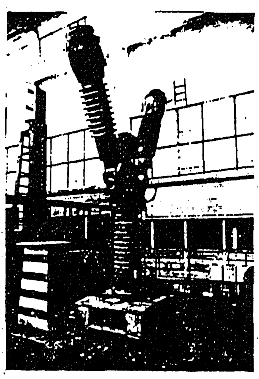

Photo. 1 Circuit Breaker with Isolator on Shaking Table

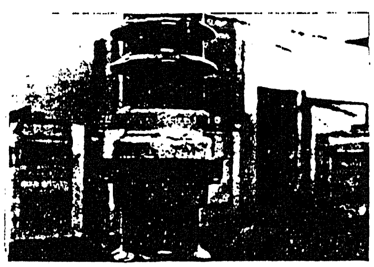

Photo. 3 The Connecting of Flange Plate of Porcelain Insulating Bushing of Lightning Arrester

designed for the two kinds of equipments in order to guarantee adequate aseismic capacity of the two equipments.

Isolating mechanism of the isolators mentioned above is as follows:

1. By making the structures flexible enough to avoid the predominant period of the soil.
2. By using damping rubber washer to absorb the energy.
3. Through the deformation of the connecting bolts

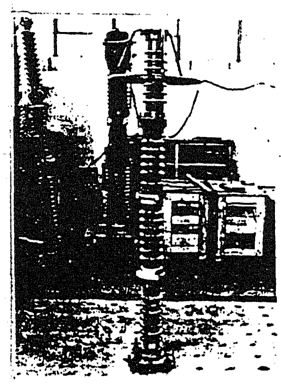

Photo. 4 Lightning Arrester with Isolator on Shaking Table

Photo. 5 Bearing Ball

Photo. 6 Neoprene Washer

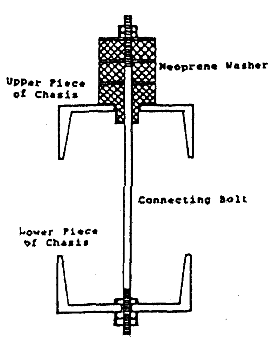

Fig. 1 The Connecting of Upper and Lower Piece of Chasis of Isolator for Circuit Bresker

Photo.6 Neoprene Washer

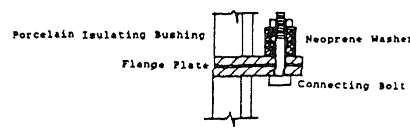

Fig. 2 The Connecting of Flange Plate of lightning Arrester

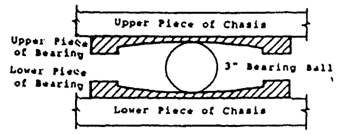

Fig. 3 Bearing Ball and Bearing Piecese

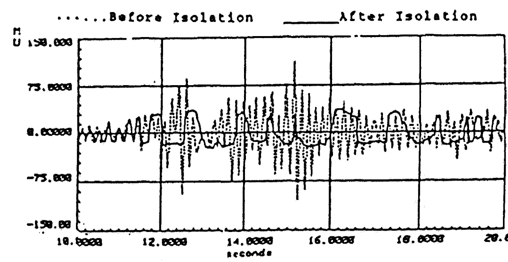

Fig. 4 The Acceleration on the Top of Lightning Arrester Excited by E-C with Peak Value of 0.3g

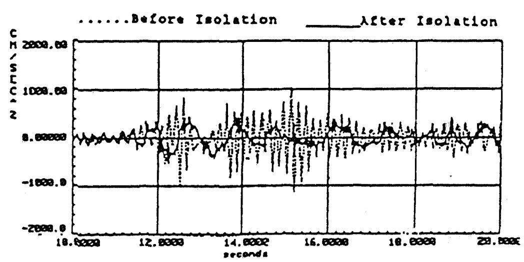

Fig. 5 The Stain at the Bottom of Lightning Arrester Excited by E-C with Peak Value of 0.3g

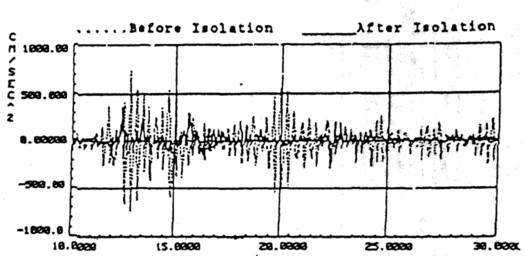

Fig. 6 The Acceleration on the Top of Circuit Breaker Excited by E-C with Peak Value of 0.3g

to absord the energy.

The installations of the two isolators is illustraied in Fig.1 to Fig.3. Shaking table tests have been undertaken to verify the behavior of the isolators. Foliwing are the test program, (1) the prototype test without installing isolators, (2) the isolating test, which include, (a) skimming with the equal amplitude and changing frequency sine wave, (b) inputting E-C (El-centro 1940 N-S record) as base acceleration.

The comparison of acceleration and strain responses before and after isolation excited by E-C with peak value of 0.3g is shown in Fig.4 to 7.

The frequencies before and after isolation are listed in Table 1

Table 1. Frequencies Before and After Isolation

Equipment	Circuit Breaker	Lightning Arrester
Before Isolation	3.7Hz	5.3Hz
After Isolation	1.0Hz	1.3Hz

The isolation efficiency of the isolators is defined as,

$$\eta = \frac{a_1 - a_2}{a_1} \times 100\%$$

in which a_1 and a_2 are response peak value before and after isolation, respectively.

The efficiency of isolators designed in this paper under the excitation of E-C with peak value of 0. 3g and 0.4g is shown in Table 2 and 3.

Table 2. Efficiency of Isolator for Circuit Breaker

Peak Value of Base Acceleration	Strain(μ) Before Isolation	After Isolation	Efficiency η s
0.3g	54.29	19.16	64%
0.4g	63.09	39.15	38%

Peak Value of Base Acceleration	Acceleration(cm/s_2) Before Isolation	After Isolation	Efficiency η a
0.3g	765.23	366.45	50%
0.4g	979.59	804.75	18%

As shown in Table 2 and 3, the isolating effciency of acceleration (η a) on the top of the structures and that of strain (η s) at the bottom of the porcelain insulating bushing of the two structures do not agree. This might be due to the high mode response of the two structures. Hence the reduction of damaging quantity of structures should be

Table 3. Efficiency of Isolator for Lightning Arrester

Peak Value of Base Acceleration	Strain (μ) Before Isolation	After Isolation	Efficiency η s
0.3g	112.63	36.88	67%
0.4g	166.65	50.78	70%

Pesk Value of Base Acceleration	Acceleration(cm/s_2) Before Isolation	After Isolation	Efficiency η a
0.3g	1113.70	753.25	32%
0.4g	1381.97	455.07	67%

regarded as the standard in judging the isolating efficiency. In this paper the strain (or stress) at the bottom is chosen as the standard.

3. ANALYSIS

The dynamic model of isolated lightning arrester and circuit breaker are shown in Fig.8 and 9.

Differential equation,

$$[M]\{X\} + [C]\{X\} + [K]\{X\} = -[M]\{I\}Xg$$

where [M] is the mass matrix; [C] and [K] are the damping and stiffness matrix of structures; {I} is a unit vector; Xg is the base acceleration; {X}, {X} and {X} are the vectors for relative displacement, velocity and acceleration of mass points, respectively.

The restoring force model of the connecting point of lightning arrester is shown in Fig.10, and that of sliding and rocking spring of isolater for circuit breaker is shown in Fig.11.

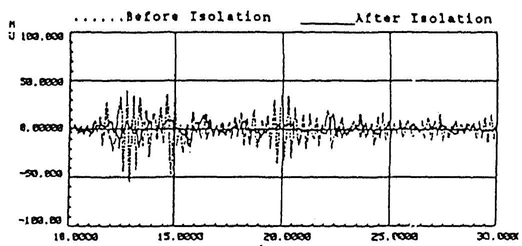

Fig.7 The Strain at the Bottom of Bircuit Excited by E-C with Peak Value of 0.3g

The following phenomena are found in the test, the unsymmetrical arrangement of flange plate bolts of lightning arrester can make the connecting point stiffness different in two directions; the static

Fig.8 Dynamic Model for Lihgtning Arrester with Isolator

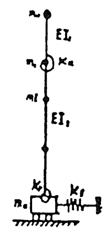

Fig.9 Dynamic Model for Circuit Breaker with Isolator

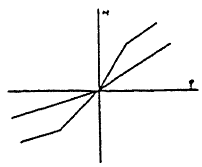

Fig.10 Restoring Force Model for Rocking Stiffness of Isolator for Lightning Arreater

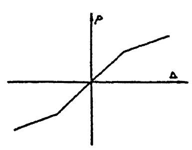

Fig.11 Restoring Force Model for Rocking and Sliding Stiffness of Isolator for Circuit Breaker

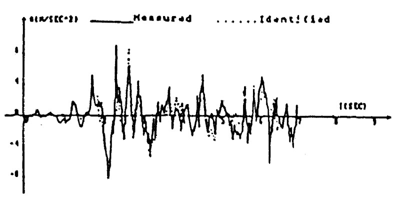

Fig.12 The Acceleration on the Top of Circuit Breaker Excited by E-C with Peak Value of 0.4g

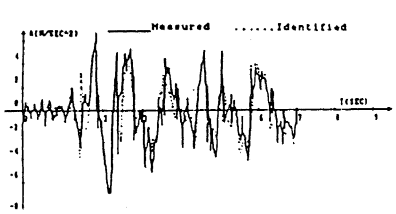

Fig.13 The Acceleration on the Top of Lightning Arrester Excited by E-C with Peak Value of 0.4g

Table 4. Predicted Efficiency of Isolator for Lighting Arrester

G1		G2		G3	
ηa	ηs	ηa	ηs	ηa	ηs
73	93	70	90	59	85

Table 5. Predicted Efficiency of Isolator for Circuit Break

Peak Value of Base Acceleration	G1		G2		G3	
	ηa	ηs	ηa	ηs	ηa	ηs
0.1g	51	49	46	46	29	30
0.2g	41	46	51	57	37	32
0.4g	56	60	58	67	34	32

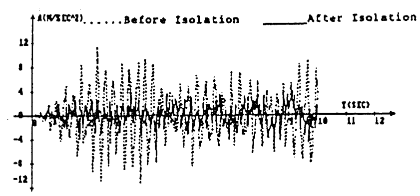

Fig.14 The Predicted Acceleration on the Top of Circuit Breaker Excited by G1 with Peak Value of 0.4g

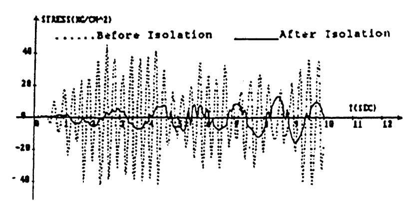

Fig.15 The Predicted Stress at the Bottom of Circuit Breaker Excited by G1 with Peak Value of 0.4g

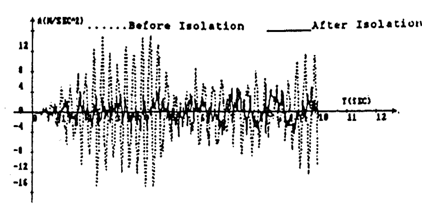

Fig.16 The Predicted Acceleration on the Top of Circuit Breaker Excited by G2 with Peak Value of 0.4g

friction between bolt and installing hole can produce a big initial stiffness, once the friction disappears, the stiffness will reduce obviously, then a "loss of stiffness" can be caused, which is not restorable and very helpful to isolation.

A computer program has been developed to identify the isolated system and to predicte the dynamic response for the isolated equipment, which has taken into account the phenomena mentioned above.

In the process of system identifiction a modified Powell method is used to identify the dynamic parameters of the structures.

The measured and identified time history of acceleation on the top of the structures are compared with in Fig.12 and 13.

After isolation, the dynamic responses excited by G1, G2 and G3 have been predicted by using the parmeters obtained from system identification. G1, G2 and G3 include the character of the ground motion in three kinds of site conditions, hard, moderate and soft, respectively. The predicted efficiency of the two isolaters is listed in Table 4 and 5.

Again, the efficiency of stress (η s) and that of acceleration (η a) do not agree, and the efficiency of stress is greater than that of acceleration. The phenomenon can be found either in shaking table test or in analysis.

The comparison of predicted response before and after isolation under the same seismic action are shown in Fig.14 to Fig.25.

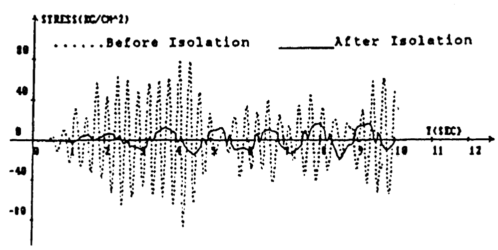

Fig.17 The Predicted Stress at the Bottom of Circuit Breaker Excited by G2 with Peak Value of 0.4g

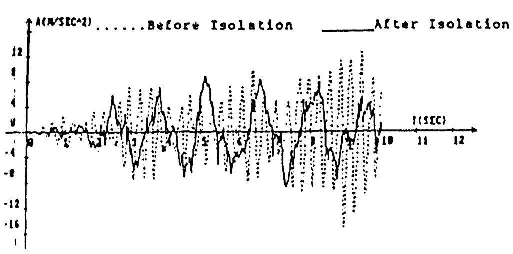

Fig.18 The Predicted Acceleration on the Top of Circuit Breaker Excited by G3 with Peak Value of 0.4g

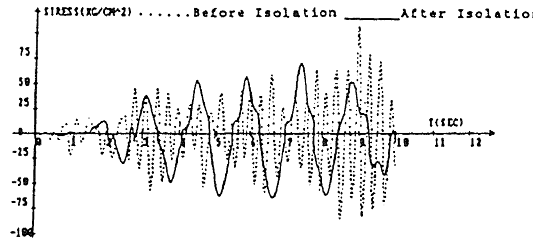

Fig.19 The Predicted Stress at the Bottom of Circuit Breaker Excited by G3 with Peak Value of 0.4g

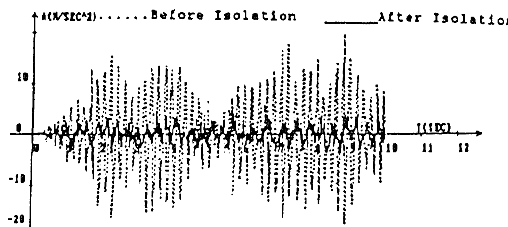

Fig.20 The Predicted Acceleration on the Top of Lightning Arrester Excited by G1 with Peak Value of 0.4g

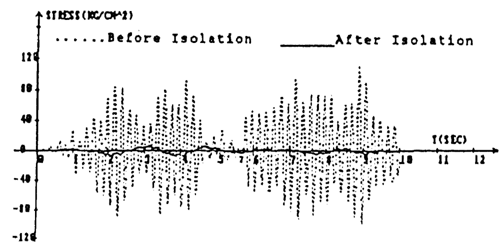

Fig. 21 The Predicted Stress at the Bottom of Lightning Arrester Excited by G1 with Peak Value of 0.4g

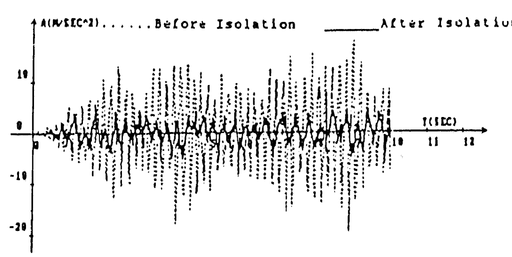

Fig.22 The Predicted Acceleration on the Top of Lightning Arrester Excited by G2 with Peak Value of 0.4g

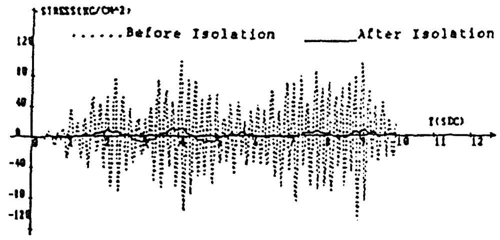

Fig. 23 The Predicted Stress at the Bottom of Lightning Arrester Excited by G2 with Peak Value of 0.4g

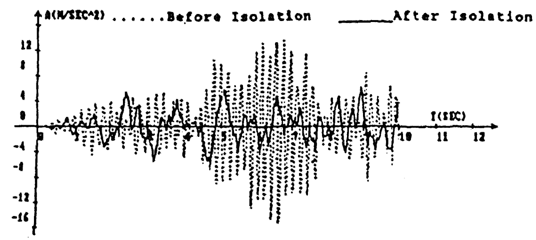

Fig. 24 The Predicted Acceleration on the Top of Lightning Arrester Excited by G3 with Peak Value of 0.4g

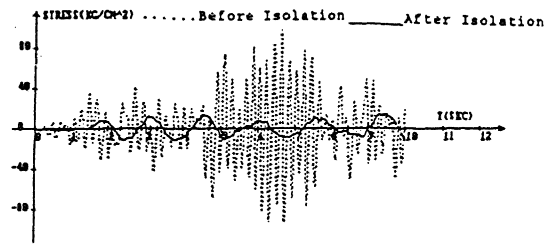

Fig. 25 The Predicted Stress at the Bottom of Lighning Arrester Excited by G3 with Peak Value of 0.4g

4. CONCLUSION

1. The isolators designed in this paper work well and can reduce seismic action by thirty percent to seventy percent.
2. The efficiency of isolation can be reliably predicted by using the dynamic parameters obtained from the system identification.
3. The efficiency of isolation should be defined as the reduction of damaging quantity of structres with isolators under the same seismic action.

5. REFERENCE

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