EARTHQUAKE PERFORMANCE OF A VOLTAGE TRANSFORMER

by

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ABSTRACT

This paper deals with theoretical and experimental studies of dynamic behaviour of a 220 KV Voltage Transformer (VT). The properties of the porcelain have been obtained from static tests. Dynamic analysis of VT has been carried out by two methods. In one, it is treated as a Timoshenko beam and analysed as an assemblage of beam elements. In this, instead of the actual shape of the petticoat an equivalent shape had to be assumed. In the second, axisymmetric finite element technique has been used where actual shape could be preserved. The results of these two types of analysis have been compared.

Earthquake withstand tests on the VT have been carried out on a shake table. A new criterion of earthquake withstand tests has been evolved based on realistic dynamic response during a postulated design earthquake rather than adopting a specified percentage of acceleration due to gravity to be applied at the base sinusoidally as proposed by some standards like IEEE,(4).

INTRODUCTION

Power plants are important utilities for communities. With rapid industrialisation such systems have to be located in various parts of a country. Damage survey of past earthquakes, particularly in Western USA (1), Chile (2), Japan and Koyna (3) in India, has indicate that power station equipments made of porcelain like circuit breakers, lightening arresters, current and voltage transformers, etc. have suffered damage. It is therefore, necessary that all such equipments should be designed and tested to withstand the postulated earthquake for the site.

The methods of earthquake withstand tests on full scale prototype equipments as suggested by Novoa (2) and IEEE(4), do not take fully the principles of earthquake engineering into account. The proposed method adopted in this study takes into account the response of the equipment due to postulated earthquake.

SIMULATED EARTHQUAKE

During earthquakes, it is now well established that resonance of the type due to steady state sinusoidal excitation does not occur. For example, if a linear single degree of freedom system is considered and damping is assumed to be five percent, at resonance the dynamic magnification factor of amplitude would be ten. However, due to earthquake motion this factor may have a maximum value of about three at some frequency ranges and usually much

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less at most of the frequencies. Hence, only quasi-resonance should be deemed to occur during earthquakes.

It is, therefore, obvious that if sinusoidal type excitations are used to conduct shake table tests, the peak acceleration of the table should be considerably less than that of peak design ground earthquake acceleration. The criterion of simulation should be to achieve, by experiments, the peak response acceleration, evaluated at critical location (usually, at top) and this level by maintained for only few cycles (say about ten).

METHODS OF ANALYSIS

The following two types of analyses were done:

1. Timoshenko Beam Analysis

The VT shown in Fig.1 was treated as a Timoshenko beam and analysed as an assemblage of such beam elements. An equivalent shape of the petticoat as shown in that figure was assumed instead of the actual shape. Beam element is a 2 noded element with translation and rotational degrees of freedom per node, Fig. 2(a).

2. Finite Element Analysis

Advantage of the axisymmetric shape of the VT was taken in analysing it using axisymmetric finite elements of paralinear type (5),(Fig.2b). Thus, the actual shape of the petticoat was retained.

METHOD OF TESTING

The shaking platform on which the equipment is mounted could be driven by a function generator to give different types of motion to the platform. The function that can be easily generated is a sinusoidal type. Several mechanisms can be used for sinusoidal function generator (6). In the experimental study conducted, two types of mechanical drives were used. They were namely,(i) a double eccentric cam device which gives constant amplitude of motion and suitable for low frequency excitations, say 1Hz to 10Hz and (ii) a mechanical oscillator having two eccentric masses rotating in opposite directions and producing a sinusoidal force which is proportional to square of the exciting frequency and which can be used for high frequency excitations; say 5Hz to 40 Hz.

In order to carry out the forced vibration tests the VT was rigidly fastened to the shake table. The sinusoidal base motion was fed to the table. The table motion frequency was made to change very slowly in order to ensure that the response of the equipment corresponded to a stationary excitation. The vibrations were sensed with acceleration pick up mounted at the top of the VT. The signals from the pick up were fed to an amplifier and from the amplifier to a ink writing oscillograph which produced permanent and immediately readable records of the acceleration.

RESULTS

Table 1 shows the comparison between experimental and analytical results.

TABLE - 1

DESCRIPTION	EXPERIMENTAL	ANALYTICAL	
		BEAM ELEMENT	AXIS.FINITE ELEMENT
(1) Natural period	0.135 sec.	0.137 sec.	0.133 sec.
(2) Mode participation factor		1.3726	1.1795

It is seen that there is close resemblance between the experimental and analytical results.

The damping from free vibration tests was found to be about 5 percent. Fig.(3) shows the acceleration response spectrum corresponding to this damping for Koyna earthquake. The maximum response acceleration at the top was evaluated as a factor(greater than one) times the spectral acceleration corresponding to first mode period and damping for the Koyna earthquake.

CONCLUSION

The VT is analysed using 2D beam elements and axisymmetric finite elements. A very close similarity between theoretical and experimental results for the natural period is observed. Response acceleration at the top of the VT was derived by theory and experiment. The VT was tested for this response acceleration and found to be safe.

ACKNOWLEDGEMENT

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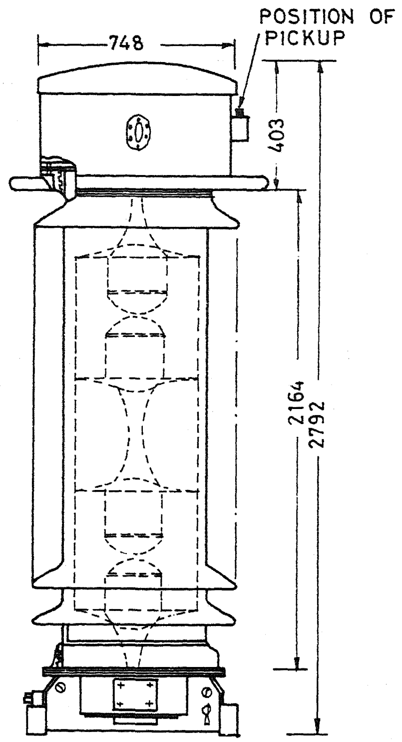

FIG. 1- 220kV VOLTAGE TRANSFORMER
(ALL DIMENSIONS IN mm)

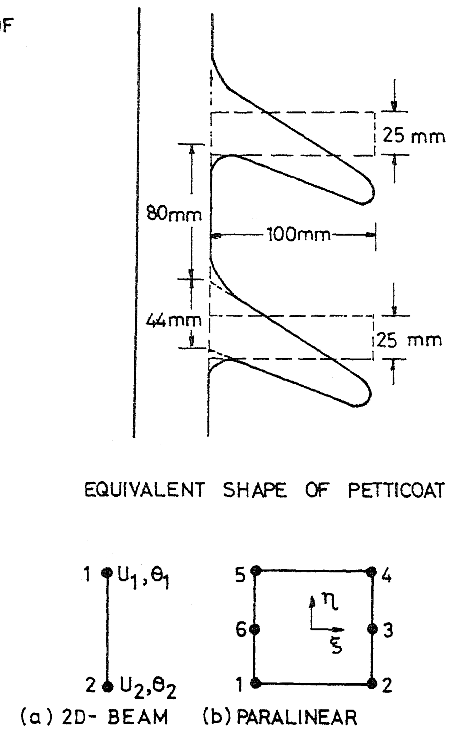

FIG. 2- FINITE ELEMENTS

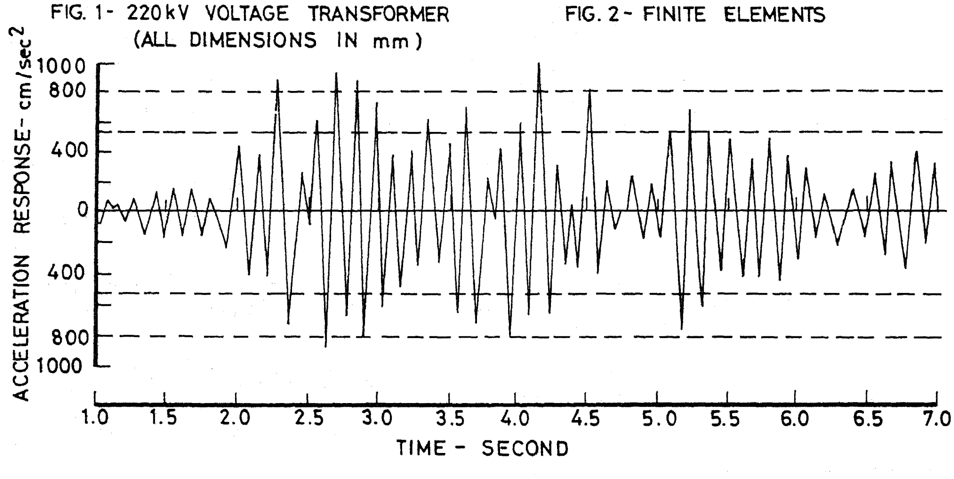

FIG. 3 - TIMEWISE ACCELERATION RESPONSE OF V.T.