DISCUSSION BY F. NOVOA M.

to the Paper N° 67, An Assessment of the Earthquake Resistant Design of Electrical Power Transmission Facilities.
by M.S. Agbabian and C.C. Diemond

1) From our experience in Chile (1), there are 3 factors, each one capable to bring the equipment to failure:
   a) lack of consideration of the dynamic response of an oscillating element;
   b) oversight of the coupling between an oscillating element and some oscillating support;
   c) oversight of the relative displacement response between different oscillating elements which are tied or interconnected together.

   Do have factors b) and c) been observed by the authors?

2) The failure of the lightning arresters per fig. 7 could be attributed to the different displacement responses, of the busbar on its high supports on one side, and of the arrester column on the other. Has this possibility been verified? Experience in Chile has led to exclude rigid busbars and connections for using only cables. Has this possibility been considered?

3) The bracing solution as per figs. 8a and 8b is described as "eliminating cantilever action". Do have been considered the different displacement responses of the capacitor racks and the bracing frame structure? The oscillatory displacement of the frame could transmit via insulator diagonals a most unexpected cantilever force to the racks. Do have been incorporated elastic tension elements to the insulator diagonals to limit this force? Do have been discussed damping tension elements there? Fig. 8a implies that about the same lengths of insulating diagonals could have been applied to brace the rack directly from ground: Why was this solution excluded? The insulator diagonal oscillation cannot be disregarded: do has been considered the possible coupling between this oscillation and those of the racks? The oscillation of the beams supporting the capacitors in the racks can become coupled with some of the flexional or torsional modes of the racks: do have been this coupling possibilities taken into account?

4) The columns of the 220 kV circuit breakers described, considered alone, should give rise to a maximum response of at most 1.2 g in the Zone B and 1.8 g in the Zone C. If a maximum ground acceleration of 0.4 g is accepted for the San Fernando earthquake (2), the higher estimated factor of safety in Table 1 would imply a cantilever strength of 1.2 g for them.

   a) Does the lower estimated factor of safety in Table 1 correspond to consideration of some magnification factor of the response?
   b) An amplification by coupling between the columns of a single pole, or between one column and the three poles, of the type described in (1), fig. 5, could be feared, in the amount of about 3.5 times or more, if the natural frequencies are unfavorable. Do the platforms devised for either scheme 1 or 2 exclude the possibility of such a coupling?

5) If the results of the yielding of a common support for a group of columns are to be judged (scheme 1), it is important to take into account all the columns on the common support. This, on the simple basis that the damping cannot be effective for a column but after the common support yields. As this yielding is an effect of the oscillation of all the columns combined, has very little to do with the oscillation of each column, and its effectivity can be very small. Do has this been taken into account on analysing the effectivity of scheme 1?

6) Scheme 2, on account of the low natural frequencies it provides, corresponds more closely to the concept of isolating the breaker from the ground vibration. It is, however, to be noticed:
   a) that every damping needed for the stabilization will only be acting against an effective isolation;
   b) that the scheme makes the arrangement of the equipment most cumbersome, complicates the maintenance and should be supposed considerably expensive.

   This are, in fact, the objections we made against such a scheme in (3), page 15, point 8).

   To allow for a comparison, following information should be considered:

   In 1966 we got the columns of our 220 kV airblast circuit breakers, with about the same 1.2 g cantilever strength (stressed by air pressure on operating conditions and the porcelain loaded to the minimum breaking modulus in cantilever, that means $m = \mu - 3\sigma$) where μ is the mean and σ is the standard deviation of the fracture stresses), provided with additional elastic dampers under each of the 3 columns in a pole, to obtain a natural period of 1.2 s and a damping factor of about 6.6 %. These circuit breakers, each of their poles arranged upon 2 rigid (see ref. 1) pillars, have an estimated safety factor about 1.5 against an earthquake with 0.5 g maximum ground acceleration. They have been in service from mid 1969, and passed already the 7.5 magnitude earthquake of 1971, with a registered maximum ground acceleration of 0.17 g, without the least interference. The arrangement in the field can be seen in ref. 3, figs. 9 and 10. The additional elements represent less than 8 % of the price of the normal circuit breaker.

7) As regards to the seismic specifications for new equipment, we have thought it necessary to make them much more comprehensive (4), under principles refered to in (5).

References.

(1) F. Novoa M. : Earthquake Analysis and Specification of the HV Electrical Equipment, 5 WCEE Paper N° 69.

(2) Reimer, Clough and Raphael: Evaluation of the Pacoima Dam Accelerogram, 5 WCEE Paper N° 293.

(3) F. Novoa M. : Earthquakes and the Substation Equipment Arrangement and Specification, CIGRE 1970, paper 23-02.

(4) ENDESA : Earthquake Specifications for the HV equipt. up to 220 kV, Ed. 1971, rev. Ed. 1972, english version.

(5) F. Novoa M. : 5 WCEE, discussion to Paper N° 283, by Newmark and Hall.