Earthquake calculation on tap-changer types VUCL

General
The transformer and its foundation is assumed to be rigid but not stiff, so the ground acceleration $a_{HG}$ is considered to be amplified through the transformer tank to the tank cover with the amplification factor $K$, which is prescribed to be 1.5 (IEC 61463).

Static calculation on a somewhat flexible structure, taking into consideration the response factor $R$ as an alternative to the method by dynamic analysis, gives a simple and at the same time a more conservative method for calculation.

The bending moment $M_s$ in the critical cross-section on the part of the tap-changer under consideration is then calculated from an equivalent acceleration $a_{MP}$ of the center of gravity of that part:

$$M_s = a_{MP} \cdot h \cdot m_p$$

The acceleration $a_{MP}$ is calculated from the cover acceleration $a_{HC}$ by multiplication with a coefficient $S_c$ and the response factor:

$$a_{MP} = a_{HC} \cdot S_c \cdot R$$

The value of $S_c$ depends on the natural frequency of the mounted part and if no value is known, the conservative value $S_c = 1.5$ should be used. This coefficient aims to take into account the effects of both multi-frequency excitation and multimode response. $R$ can be assumed to be equal to the conservative value 1.74 when information for frequency and damping of the tap-changer on a transformer is not available. This value corresponds to the frequency range 2.4 Hz to 9 Hz and 5% damping ratio.
Calculation VUCL selector III
For tap-changer VUCL/III the following is valid:
\[ m_p = 445 \text{ kg} \times 9.81 = 4365 \text{ N} \quad h = 1.5 \text{ m} \quad K = 1.5 \quad R = 1.74 \quad S_c = 1.5 \]

Assume the strongest type of earthquake with a ground acceleration level \( a_{HG} = 0.5g \) (Richter scale $>7.0$) which gives that:
\[ a_{HG} = 5 \text{ m/s}^2 \quad a_{HC} = K \cdot a_{HG} \quad a_{MP} = a_{HC} \cdot S_c \cdot R \quad \Rightarrow a_{MP} = 1.5 \cdot 5 \cdot 1.74 = 19.575 \]

The bending moment \( M_s \) in the critical cross-section will be:
\[ M_s = a_{MP} \cdot h \cdot m_p \quad \Rightarrow M_s = 19.575 \cdot 1.5 \cdot 4365 = 12,82 \cdot 10^3 \text{ Nm} \]
Bending tests has been made on a VUCL/C, which show that a bending moment of about 47 kNm does not give any problem with leakage or damage. As this moment is much greater than the calculated moment \( M_s \), the tap-changer is capable to withstand even the most severe earthquake.

**NOTE:** The mass \( m_p=445\text{kg} \) does not include the top-section flange bolted to the transformer cover but only the mass below the top-section flange (cylinder, active insert parts, bottom flange and the tap selector).

*(Ref.file for calculations:earthucg.mcd)*

Calculation VUCL selector F
For tap-changer VUCL/F the following is valid:
\[ m_p = 545 \text{ kg} \times 9.81 = 5345 \text{ N} \quad h = 2.5 \text{ m} \quad K = 1.5 \quad R = 1.74 \quad S_c = 1.5 \]

Assume the strongest type of earthquake with a ground acceleration level \( a_{HG} = 0.5g \) (Richter scale $>7.0$) which gives that:
\[ a_{HG} = 5 \text{ m/s}^2 \quad a_{HC} = K \cdot a_{HG} \quad a_{MP} = a_{HC} \cdot S_c \cdot R \quad \Rightarrow a_{MP} = 1.5 \cdot 5 \cdot 1.74 = 19.575 \]

The bending moment \( M_s \) in the critical cross-section will be:
\[ M_s = a_{MP} \cdot h \cdot m_p \quad \Rightarrow M_s = 19.575 \cdot 2.5 \cdot 5345 = 32,62 \cdot 10^3 \text{ Nm} \]
Bending tests has been made on a VUCL/F, which show that a bending moment of about 47 kNm does not give any problem with leakage or damage. As this moment is much greater than the calculated moment \( M_s \), the tap-changer is capable to withstand even the most severe earthquake.

**NOTE:** The mass \( m_p=545\text{kg} \) does not include the top-section flange bolted to the transformer cover but only the mass below the top-section flange (cylinder, active insert parts, bottom flange and the tap selector).

*(Ref.file for calculations:earthucg.mcd)*