Earthquake calculation on tap-changer types VUCG

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 VUCG selector C
For tap-changer VUCG/C the following is valid:
\[ m_p = 360 \text{ kg} \times 9.81 = 3530 \text{ N} \quad h = 1.15 \text{ m} \quad K = 1.5 \quad R = 1.74 \quad S_c = 1.5 \]

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

The bending moment \( M_s \) in the critical cross-section will be:
\[ M_s = a_{MP} \cdot h \cdot m_p \]
\[ \Rightarrow M_s = 19.575 \cdot 1.15 \cdot 3530 = 7.95 \cdot 10^3 \text{ Nm} \]

Bending tests has been made on a VUCG/C, which show that a bending moment of about 20 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 \( m_p=360\text{kg} \) 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 VUCG selector III
For tap-changer VUCG/III the following is valid:
\[ m_p = 400 \text{ kg} \times 9.81 = 3925 \text{ N} \quad h = 1.5 \text{ m} \quad K = 1.5 \quad R = 1.74 \quad S_c = 1.5 \]

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

The bending moment \( M_s \) in the critical cross-section will be:
\[ M_s = a_{MP} \cdot h \cdot m_p \]
\[ \Rightarrow M_s = 19.575 \cdot 1.5 \cdot 3925 = 11.25 \cdot 10^3 \text{ Nm} \]

Bending tests has been made on a VUCG/III, which show that a bending moment of about 20 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 \( m_p=400\text{kg} \) 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 VUCG selector F
For tap-changer VUCG/C the following is valid:
\[ m_p = 500 \text{ kg} \times 9.81 = 4905 \text{ N} \quad h = 1.6m \quad K = 1.5 \quad R = 1.74 \quad S_c = 1.5 \]

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

The bending moment \( M_s \) in the critical cross-section will be:
\[ M_s = a_{MP} \cdot h \cdot m_p \quad \Rightarrow M_s = 19.575 \cdot 1.6 \cdot 4905 = 15.36 \cdot 10^3 \text{ Nm} \]

Bending tests has been made on a VUCG/F, which show that a bending moment of about 20 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 \( m_p = 500 \text{ kg} \) 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)