

Question 1.1 :

What are design challenges for transformers installed in a nacelle with high range of vibration, shock, and special requirements? What are the best solutions for volume and pressure changes inside transformer considering hydro-compensator, N2 Tank, expander, and open breathing system?

Answer :

25 MVA silicone liquid immersed transformer was developed for offshore floating platform with satisfying the special requirements such as influence of swaying, limited and enclosed installation, and environmental issue in case of liquid leakage. Those special requirements were satisfied by application of additional support on active parts, bolt tightening on core lamination, application of silicone liquid for cooling medium, and heat distribution calculation surrounding the transformer. In addition to design application, actual product verification was performed by an inclination test.

Fig.1 shows the overview of this floating offshore substation.

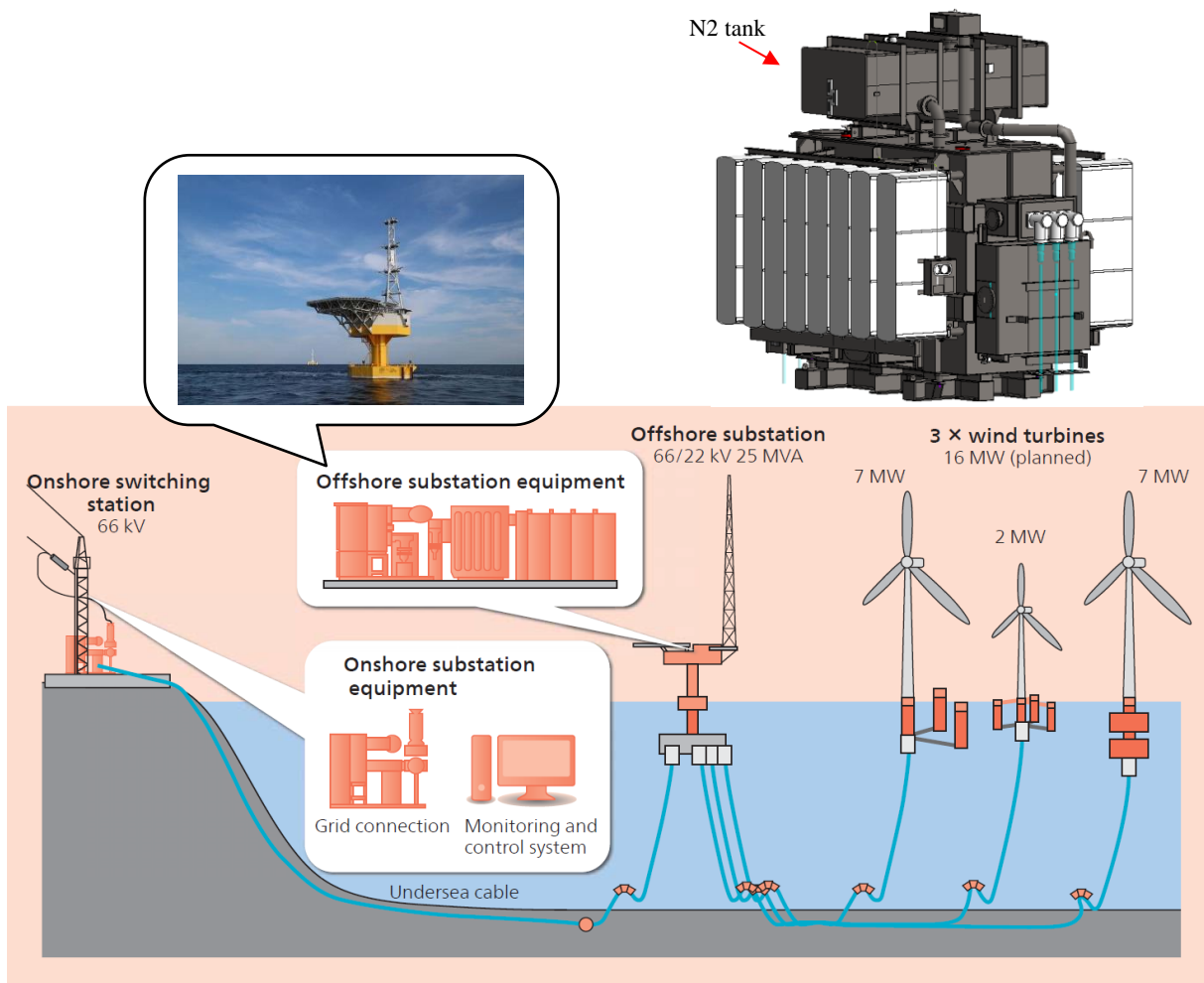


Figure 1 overview of floating offshore substation

Requested specifications and their solutions

The transformer to be installed in this special environment was required to meet the following special requirements: (1) performance against swaying (very low frequency, 0.1Hz, and high inclination, 11.8 degrees), which is not expected for a ground-based transformer; (2) response to limited and enclosed installation space; and (3) environmentally friendly in case of liquid leakage. Detail specifications and solutions are explained below.

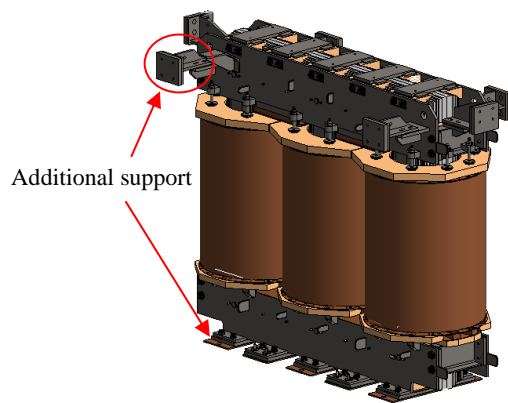
(1) Special swaying requirement

Table 1 swaying specification was required and in order to satisfy those requirements additional supporting is applied such as fixing between active parts and tank, fixing insulation material in the winding as shown in Figure 2, and bolt tightening on core lamination, and in addition to additional physical support aforementioned, deterioration of conservator rubber membranes due to swaying is prevented by applying N2 gas sealing system with a separate N2 tank. The risk of bubble generation due to turbulence was evaluated by checking the pressure drop and saturated vapor pressure at the lowest ambient temperature.

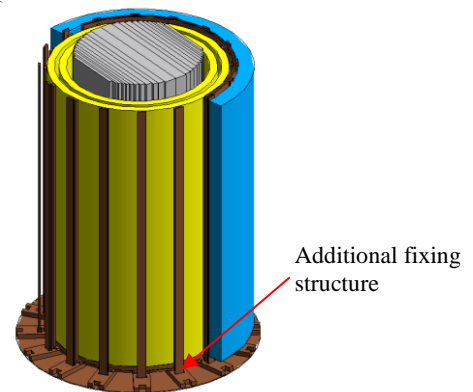
Finally, an inclination test was performed as shown in Figure 3 and verified the design and the product has a suitable structure against special swaying requirements.

Table 1 swaying specification

Item	Requirement for the transformer	Seismic requirement as reference
Frequency (Hz)	0.1 (Very low frequency)	1 ~ 10
Inclination (°)	Less than 11.8	-
Vertical Acceleration (G)	0.1	0.25
Horizontal Acceleration (G)	0.56	0.5



(a) additional supporting for active parts



(b) fixing enhancement on winding

Figure 2 additional support for active parts and winding



Figure 3 Inclination test of the transformer

(2) Limited and enclosed installation area

The transformer is planned to install at limited space and enclosed room, therefore, low viscosity silicone liquid which is superior to the heat transportation and contribute efficient heat release from the active parts. By application of low viscosity silicone liquid, reduction of installation area can be achieved approx. 70% less than mineral oil immersed transformers.

Furthermore, to confirm heat circulation surround the transformer in enclosed area CFD was performed as shown in Figure 4.

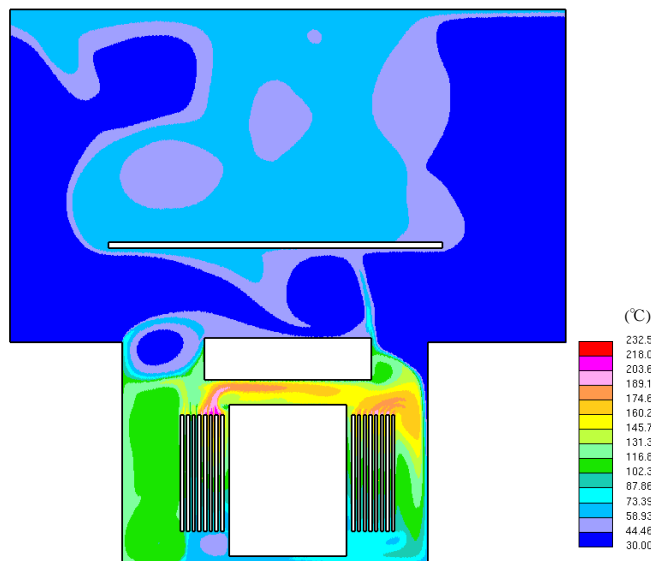


Figure 4 Temperature distribution surrounding the transformer

(3) Environmentally friendly

Since this transformer will be installed on offshore platform, low environmental impact liquid of silicone liquid is applied. Compared to mineral oil, silicone liquid has superior flame resistance, heat resistance, and electrical characteristics. It is also environmentally harmless because it is chemically inert and decomposes into silica rock, carbon dioxide, and water, which exist in nature, through hydrolysis, photolysis, and biodegradation.