VIRTUAL ASSESSMENT OF CUSTOMIZED (NON-STANDARD) SUBSTATION SOLUTIONS FOR RENEWABLE APPLICATIONS

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ABSTRACT

The trend toward the development of customized equipment is leading manufacturers to a new philosophy in the design, manufacture and assessment of new products. As equipment is not standard (special customer requirements, due to local climatic conditions and regulatory standards) it is not economically feasible to physically test every customized solution.

Simulation technologies, such as FEM[1] and CFD[2], along with the development of regulation that standardizes the simulation methodologies (to increase confidence in the results), allows virtual testing of solutions as a complement or alternative to physical testing (as long as the virtual model results have been compared, contrasted and fine tuned with a physical test).

INTRODUCTION

Any electric substation has to comply with standards where it is placed in order to guarantee a secure, efficient and reliable solution. For example, in the case of container substations, each has to fulfill the structural requirements set out by local standards such as live and dead loads (container structure and the equipment placed inside), wind and snow loads, and expected earthquake excitations (in most cases loads must be coupled).

Besides, ventilation of the equipment inside the container must be assessed in order to reduce the working temperature to extend equipment life (especially electronic devices), thus reducing maintenance and replacement rates (promoting a higher ROI). In order to address the environmental requirements each solution has been eco-efficiently designed to reduce the use of forced ventilation or climatisation (auxiliary consumption), thus reducing the carbon foot print and increasing both the lifetime and reliability of the cooling systems.

1 Finite Element Method.
2 Computational Fluid Dynamics.

CUSTOMIZED SUBSTATION

As stated in [1], the prefabricated substation product standard [2] cannot cover all the checks required for the functions expected. Moreover, as modifications of the design are often made, it is advisable to perform type test for the worst working conditions. Numerical simulations can be used for the assessment of mechanical and thermal performance for other configurations.

As an example, a customized substation for renewable applications was designed and assessed using advanced simulation methodologies in order to achieve both customer and local standard requirements, allowing a rapid deployment of the customized turn-key solution.

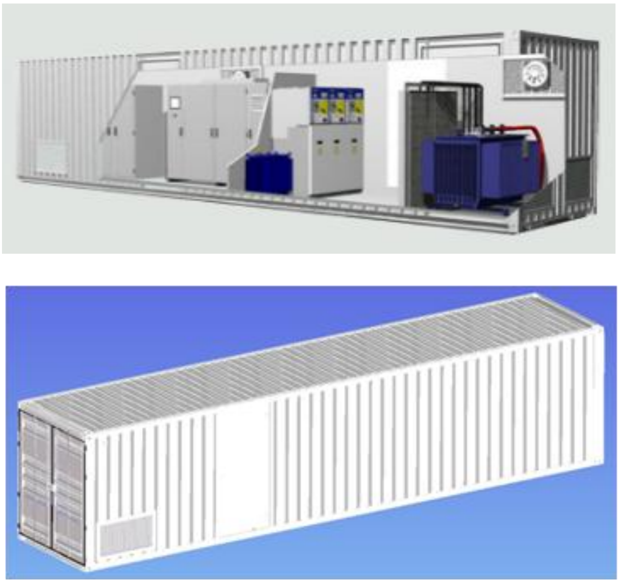

Fig. 1: Customized substation for renewable applications.

STRUCTURAL ASSESSMENT

The substation has been installed in Peru, where the National Building Code (NBC) [3] applies and compliance is mandatory.

According to this NBC the substation must withstand the following load combinations (LC) in order to assess its structural behaviour:

LC 1	1,4.D
LC 2	1,2D + 1,6L + 0,5S
LC 3a	1,2D + 1,6S + L
LC 3b	1,2D + 1,6S + 0,8W
LC 4	1,2D + 1,3W + L + 0,5S
LC 5	1,2D + 1,0E + L + 0,2S

Table 1: Load combinations according to [3]; where D= container load, L= equipment load, S= snow load, W= wind load, E= seismic load.

As the physical structural testing of any building is cumbersome and expensive or impossible (especially under combined loads), the NBC allows the justification of the requirements by means of calculation. Simulation technologies allow both the assessment of the maximum deflection and the maximum stress in the container substation (see an example of load combination in Figures 2 and 3)

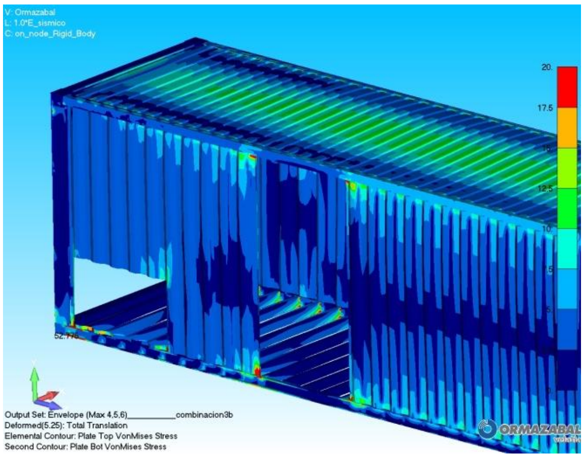

Fig. 2: Maximum stress - Combined load: container load + snow load + wind load

The worst load combination simulated for the mechanical stress is the combination: LC 2 = 1.2D + 1.6L + 0.5S, where 154.9MPa are calculated, far below the 345MPa limit needed for the yield of the steel.

The substation fulfils the requirements of structural resistance, in all the possible load combinations, according to the NBC [3].

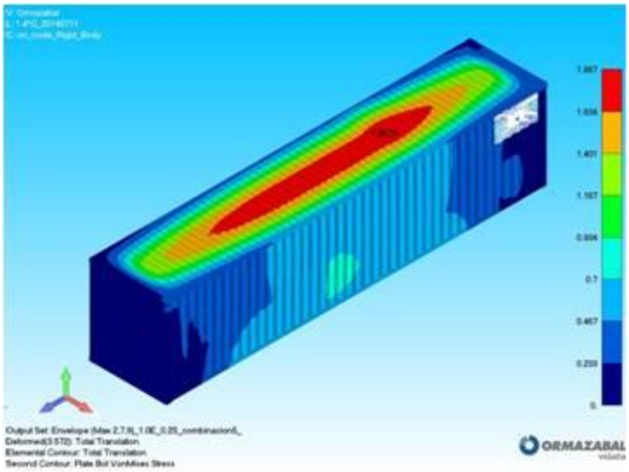

Fig. 3: Maximum deflection - Combined load: container & equipment load + snow load + seismic load

None of the load combinations show a deflection able to compromise the structural stability of the substation.

On the other hand, the internal equipment can be assessed individually. For example, the MV switchgear seismic assessment can be done be means of a virtual test [4] according to the new IEC/TS 62271-210 [5] that gives basic guidelines for the use of numerical analysis models, such as the Finite Element Method, to assess the seismic response of high voltage metal enclosed switchgear and controlgear assemblies.

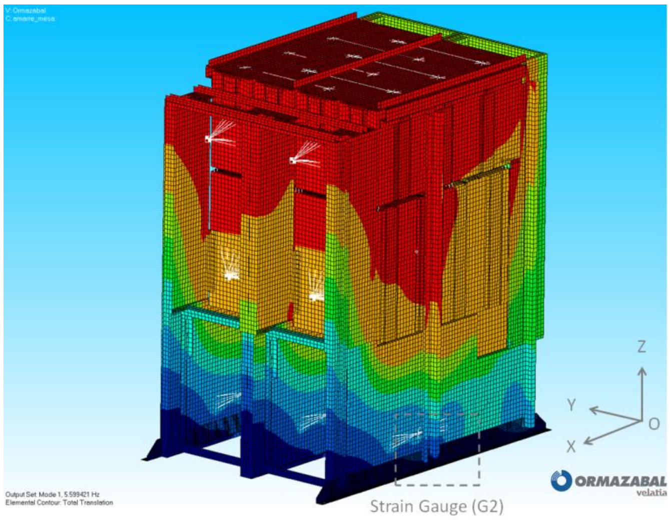

Fig. 4: Switchgear modal response

As described in [4], once an accurate virtual model correlation with both modal and seismic measurements is achieved, a reliable qualification of the switchgear family is possible by combination of testing and analysis.

THERMAL ASSESSMENT

Simulation has proven to be an efficient technology to study the ventilation of transformer substations, allowing the improvement and optimization of the designs from a thermal point of view [6-10].

All renewable energy systems rely on electronics to convert, invert, connect, transmit, track, regulate and monitor the system. However, the electronics are often the weak spot of the renewable facilities.

In the case of PV farms, as transformers and inverters are the main source of heat inside the substation and their power requirement and/or manufacturers can change from one substation to another, the thermal assessment of the solution is of special importance. A correct design of the ventilation system is vital for the reliability of the substation because an increment of the temperature quickly reduces the expected working life of any electric, and (particularly) electronic devices such as the inverter.

In the case of wind farms, the substation has to evacuate heat especially when the wind mill is at full power, i.e. when the wind is blowing at high speed. This fact is remarkable because natural cooling depends on wind velocity. However, the ventilation louvers are designed to surpass a temperature rise test inside a building with no wind.

As a consequence ventilation louvers can be oversized, leading to lower protection of the substation equipment against sea spray, speeding up the corrosion phenomena. According to [1], if wind is taken into account, in a simulation model, the ventilation area can be reduced by a factor of three, thus minimizing the risk of overexposing the equipment to sea spray.

Fig. 7: Metal-enclosed substation

Furthermore, during low wind velocity cycles, the impact of solar radiation should be considered because air renewal is limited.

CFD simulations are performed in order to assess the temperature rise class of the enclosure, which is often between 5 and 20 K.

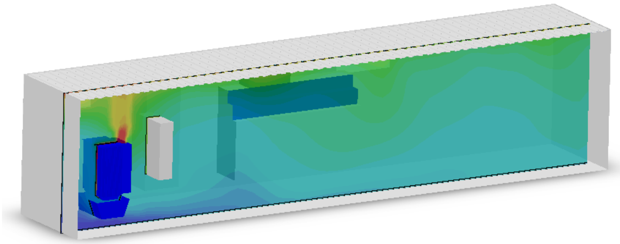

Fig. 5: Temperature profile

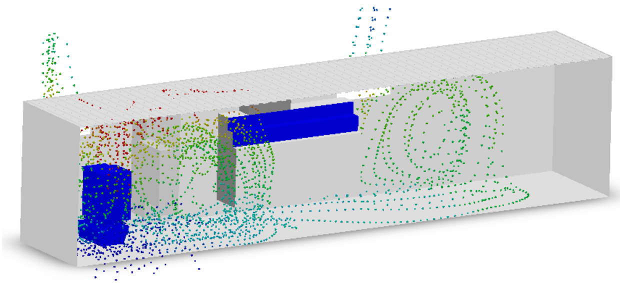

Fig. 6: Air flow trajectories

Supercomputing

Nowadays, wind power facilities can be designed with the help of supercomputing[3], especially at locations featuring complex terrain due to flow separation and anisotropic turbulence. This High Resolution Wind Power Simulations allow to position the wind turbines in the locations with the best potential for producing energy by performing an analysis that takes the entire life cycle of the facility into account. This wind flow profiles could also be used by utilities to correctly locate the substations in the wind farm enhancing its ventilation performance, i.e. extending its working life, and by substation manufacturers to develop customized solutions.

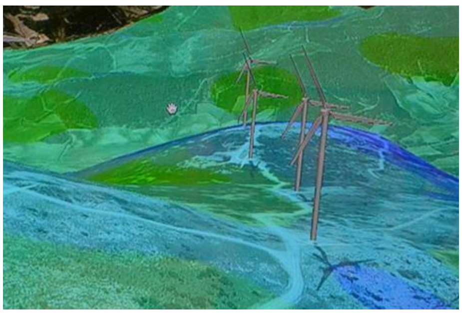

Fig. 8: Wind farm simulation

3 http://www.iberdrola.es/press-room/press-releases/national-international/2013/detail/press-release/130726_NP_01_SupercomputingSedar.html

CONCLUSIONS

A thoughtful use of simulation technologies can promote the development of reliable, cost effective and efficient customized solutions for renewable applications (OPEX reduction) and streamline the development cost by means of performing just the necessary physical tests to verify and validate any virtual model (CAPEX reduction).

Therefore simulation technologies are fostering the development of renewable energies, with the aim of extending its operational life to be competitive without public funding.

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