TECHNICAL PAPER
MAY 2023

HOW AMERICAN BASED HVDC AND OSS OFFSHORE WIND SUBSTATIONS CAN PROFIT FROM THE EUROPEAN LEARNING CURVE

LESSONS LEARNED FROM 15 YEARS OF EUROPEAN OFFSHORE WIND PROJECTS.

Written by:
A.B. Groeneveld, S.H. Gerssen, N.P. Hoogakker
InterDam, Netherlands

Abstract

The USA has committed to significant investments in offshore wind energy and is expected to quickly catch up with European investment levels. The federal government has committed to deployment of 30 gigawatts of offshore wind by 2030 [1].
Due to the nature of the energy function of offshore wind substations, risk assessments allow for different, generally less onerous, fire and blast ratings of architectural items as compared to the standards prevalent in the offshore oil and gas industry.
The most commonly used standard for offshore wind substations is DNV-ST-0145. This standard is regularly updated.

This paper is based on lessons learned from the design process utilized on a total of 55 European offshore wind substations and five USA offshore wind substations, all based on the DNV standard. Lessons learned are taken from the design of European substations over the past 15 years. The lessons learned are translated to meet American offshore norms and standards, allowing the architectural design and build of USA based substations to be executed swiftly and effectively. These lessons have been implemented in the architectural design of the first five American substations. A number of standard and USCG/DNV approved details are provided, including details of penetrations where architectural, structural, piping, HVAC and Electrical disciplines are aligned.

Conclusion: USA based offshore wind projects have ample opportunities to "leapfrog" the learning curve already realized by European projects and immediately adopt the resultant design philosophy for HVDC and OSS offshore wind substations. Provided local production norms and standards of transition of support steel to USA dimensions are incorporated in the design.
This results in an approved, standardized and economic architectural design model for the fabrication of USA based and produced substations. The application of this standard could shorten lead times and production times significantly.

1. Introduction

With the recently announced growth of investments in USA based offshore wind [1] and the start of production of the first offshore wind OSS substations in the USA, it is a good time to review the lessons learned from 15 years of European offshore wind projects. The USA based offshore oil and gas industry has a significantly longer history than offshore wind in Europe. Drilling began in 1896 off the coast of Summerfield California and has evolved into the industry it is today. Risk assessments have been standardized and updated based on events that occurred in the past, for example Piper Alpha in the North Sea in 1988 [2].

In this paper similarities and differences between offshore oil and gas platforms and offshore wind substations are discussed in further detail. For clarity two terms frequently used in this paper are explained:

Oss substations: also named offshore wind substations, or OSS; fixed offshore platforms where electricity generated from a windfarm at sea is bundled and directed to shore. This can either be Alternating Current for near shore windfarms, or also be transformed to Direct Current for windfarms further offshore. OSS substations also include HVDC, high voltage direct current platforms in this paper. These OSS substations typically operate unmanned.
Oil & Gas platforms: also named offshore oil and gas production platforms; fixed offshore platforms where oil and/or gas is produced from a major field. Oil & Gas platforms with focus on the larger, manned platforms including living quarters.

The safety assessment of offshore oil and gas production platforms is based on keeping the areas where
people are working and resting safe. These are often manned platforms, with living quarters separated from the hazardous production areas, using fire and blast resistant walls and doors. Due to the flammable nature and high energy content of the oil and gas being produced, the potential hazard is substantial. For this reason, several layers of protection are designed into oil and gas platforms and separation of hazards from "safe" areas is a key component of the architectural design.

On OSS substations, the primary design philosophy favors unmanned, remote operation. The main fire hazard is the cooling oil in the transformers, a limited supply of flammable material. The safety assessment is mainly based on the of keeping people away from operational high voltage areas and keeping the OSS operational in case one transformer fails. Therefore, only relatively light weight blast and fire walls are required to separate the transformers from other areas. For the external walls typically no fire resistance is required.
Fire suppression on most substations is provided by an inert gas system which leads to an overpressure when activated. The overpressure the architectural and structural systems require to withstand is between 0.05 and 0.08 bar, depending on the type of system used.
On oil & gas platforms, the key to keeping people safe is to keep the hazardous hydrocarbons contained in the process piping and equipment. Process areas are typically designed and built as open areas to allow faster dispersion of flammable gas in the event of a loss of containment. On OSS substations, the existence of these gases is minimal and thuswise the transformers can be enclosed, allowing for an oxygen reduction system to be activated effectively in case of an event. It also helps that these OSS substations generally are unmanned, reducing the risk to personnel from the fire suppression systems.

These primary differences between OSS substations and oil & gas platforms are elaborated on in the following chapters.

1.2. DNV-ST-0145

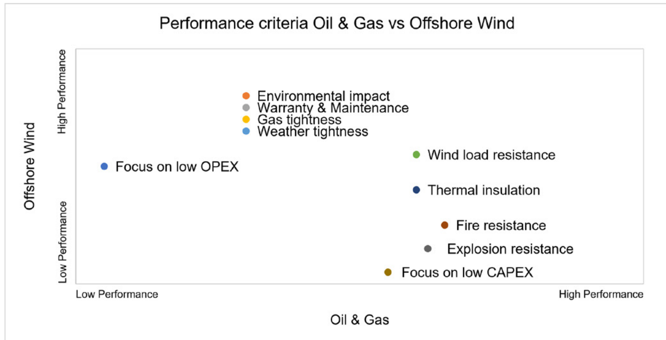
The internationally recognized standard for offshore substations that has been in place since November 2013, is DNV-ST-0145. This standard supersedes DNV-OS-J201. The current edition of the standard is from September 2021 [3].

'The objectives of this standard are to:
- provide an internationally acceptable standard for safe design of offshore substations
- promote a holistic, performance and risk-based approach to health and safety of personnel, environmental protection and safeguarding of the installation considering economic consequences
- define minimum design requirements for installations and supplement these with options for improving safety and reliability
- serve as a guideline for designers, suppliers, purchasers and regulators
- serve as a contractual reference document between suppliers and purchasers
- specify requirements for offshore substations subject to DNV GL verification and certification services.'

All best practices and reference drawings in this paper are fully in line with the DNV-ST-0145 standard. The focus in this paper is on the architectural items and application of secondary yard steel.

2. Performance criteria

For a better generic understanding of the differences in the importance of performance criteria between offshore oil & gas platforms and offshore wind substations, a graph is introduced and explained in more detail in the following paragraphs.



Graphic 1 'Generic" difference in relevance of performance requirements between OSS substations and oil & gas platforms.

2.1. Fire resistance

On offshore oil and gas platforms the passive fire resistance requirements are based on project specific risk assessments, derived from IMO directives. In the generally close quarters on an offshore oil & gas production platform, the fire resistance of the "barriers" (walls, doors and windows), required to separate the most hazardous processes from other areas, for example the escape routes, is Hydrocarbon rated, up to 120 minutes and sometimes even jet fire rated.
For the current OSS substation design DNV ST-0145 clearly defines the minimum requirements on fire resistance in Table 1.

However, currently some OSS operators specify a H60 fire wall as separation between transformers, instead of A60, to minimize collateral damage in case of an event where only one transformer is damaged. Large transformers can hold over 70 cubic feet of cooling oil. If this oil leaks and ignites, chances are that the resulting temperature will exceed the maximum temperature rating of an A60 rated separation wall. In this case H60 rating provides an additional safety measure, above the DNV norm [2].

2.2. Explosion resistance (over pressure)

In the offshore oil & gas industry explosion resistance is one of the key passive safety requirements of separation walls. These walls, including doors, are designed to separate operations where a potential explosion hazard is situated from people or other equipment. Due to the high amounts of energy contained in process areas, the explosion, if an event occurs, can be significant. Current designs for offshore oil and gas platforms regularly feature 1.0 bar overpressure blast walls.

In the earlier days of European OSS designs, the separation wall between transformers had to withstand 0.3 bar overpressure. Based on current risk assessments, the probability of an explosion occurring which results in this overpressure is very low and therefore not required to be taken into consideration during the design of the OSS substation.

With the current dominant design, most substations have active firefighting systems installed that exchange the air for an inert gas during a fire.
The overpressure, the architectural and structural systems require to withstand is between 0.05 and 0.08 bar, depending on the type of system used. Pressures above the specified overpressure

Space	Typical spaces on an offshore substation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. Control stations	Control and communication room, UPS, emergency diesel generator, SCADA and control room.	A-0	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-0
2. Corridors			C	B-0	B-0 A-0	B-0	A-60	A-0	A-0	A-0	*	B-0
3. Accomodation spaces	Public room, locker room.			C	B-0 A-0	B-0	A-60	A-0	A-0	A-0	*	C
4. Stairways					B-0 A-0	B-0 A-0	A-60	A-0	A-0	A-0	*	B-0 A-0
5. Service spaces (low risk)	Workshop, storage.					C	A-60	A-0	A-0	A-0	*	B-0
6. machinery spaces of category A	Diesel generator room (>375 kW), HV transformer room.						*	A-60	A-60	A-60	*	A-0
7. Other machinery spaces	Diesel generator room (<375 kW), rooms for LV HV.							A-0*a)*	A-0	A-0	*	A-0
8. Hazardous areas	Heli fuel skid, diesel tanks.								-	A-0	-	A-0
9. Service spaces (high risk)										A-0*a)*	*	A-0
10. Open decks	Walkways.										-	*
11. Sanitary and similar spaces												C

a) Where spaces are of the same numerical category and superscript 'a' appears, a wall or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a wall but a galley next to a paint room requires an 'A-0' wall.
* The divisions should be of steel or equivalent material,but are not required to be of A class standard. However, where a division is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations should be made tight to prevent the passage of flame and smoke and minimise the impact of the fire rating of the penetrated division.

Table 1 Fire integrity of walls separating adjacent spaces [2] are relieved by the use of pressure release venting areas. This means that all walls that enclose rooms that are equipped with this firefighting system have to be designed according to this overpressure. This can be met by incorporating this design load into the structural calculations [4].

2.3. Weather tightness

In the offshore oil & gas industry, weather tightness is mainly applicable for living quarters, since process areas are typically designed as open areas to reduce the risk of hazardous gases collecting in an enclosed area. For this reason, windshield cladding with open top and bottom is often used. The equipment behind this cladding does not require to be fully protected from the weather. The windshield cladding mainly functions as a windbreak for people working at the equipment or walking past.

Weather tightness is important when the humid and saline environment could deteriorate the longevity and uptime of the equipment. For this reason, the equipment of offshore wind substations is usually installed in a closed, weather-tight environment.

2.4. Wind load resistance

On any offshore installation wind load resistance has to be taken into consideration on all external walls and structures. There is a difference between maximum wind loads on the North Sea in Europe and hurricane prone areas, like the Gulf of Mexico. For offshore wind substations to be installed in hurricane areas, not all types of wall systems are advised, as significantly strengthened external walls are to be incorporated that are able to withstand the hurricane wind loads.

2.5. Thermal insulation, R value

Thermal insulation on offshore oil & gas platforms is important for the living quarters and offices where people are gathered for prolonged periods. A proper thermal insulation of these rooms allows for a comfortable climate to live in. Offshore wind substations are generally unmanned, reducing the thermal insulation requirements required to keep the climate comfortable for people. Also, the transformers generate heat that needs to be ventilated out. So, the R value of architectural items is of secondary importance for OSS substations.

2.6. Gas tightness

Gas tightness on offshore oil & gas platforms is important for living quarters and offices, to maintain overpressure and avoid ingress of toxic gas in case of an event. For offshore wind substations, basically the complete envelope should be gas tight and able to maintain its overpressure during an event where the active firefighting system is activated.

2.7. Warranty & maintenance

The offshore industry is used to relatively short warranty periods and accepts that all materials that are subjected to the harsh offshore environment require regular maintenance. For OSS substations however, operators demand 40 years design life, with minimal maintenance and minimal 6 years warranty. This is due to the agreed uptime with their clients, usually being over 99%, and the fact that the substations are normally unmanned. Key difference is that in the offshore wind industry the operator commonly has agreed to steep penalties in case of underperformance, whereas in the oil and gas sector contractual guarantees of high uptime are much less common.

2.8. Environmental impact

Most offshore installations that were built in the 1980's and early 1990's, were not designed with great thought on the environmental impact, when viewed from our current perspective. Carbon footprint and life cycle analysis were not common words back in the day, although more recent platforms have been built with more emphasis on total cost of ownership (TCO) and lowering the emissions per unit of hydrocarbon produced. The total offshore wind industry, however, exists primarily to lower mankind's carbon emissions.
Another key difference is that offshore oil and gas installations are designed for the expected lifetime of the energy reservoirs they are connected to. Although lifetime extensions are common, the resource being exploited is ultimately finite and the installations will be decommissioned. In contrast, offshore wind energy is in endless supply. The longer the offshore wind installation can be kept operational, the lower the relative environmental impact per unit of energy produced. To minimize the carbon footprint basic principles can be adhered to:

1. Minimize the materials used in construction as well as during the operation of the project.
2. Make use of reusable materials.
3. Maximize the use of green energy to produce materials. For example, electric melting of stone wool instead of using coal.
4. Minimize carbon intensive logistics, especially air transport of materials.

2.9. CAPEX vs OPEX

Offshore oil & gas projects usually receive a revenue stream based on the market price of oil & gas (energy). In the initial years of production, when reservoirs are still full, then ensuring maximum production volumes is key to ensuring that the high CAPEX is recouped and a healthy return on investment is achieved within a few years. In the early years of large projects, the OPEX is of secondary importance, since OPEX generally only is a small percentage of the revenue stream and production is the main priority. In late-life fields, OPEX can of course be a more important consideration.

Offshore wind projects on the other hand are just about viable without any subsidies. The payback period currently is 10 years+. When the grid/OSS operator is a different company from the windfarm operator, the contractual uptime commitment from the grid operator towards the windfarm operator usually is in the range of 99% or higher. This means that additional downtime can be very costly due to agreed penalties and must be avoided wherever possible. This translates into considerably higher attention to minimizing downtime by maximizing the longevity and quality of all materials used. This results in a higher CAPEX and lower OPEX for the OSS substation.

2.10. Acoustic insulation

Acoustic insulation is required to keep people protected from high noise levels. When living quarters are required, a proper acoustic separation is needed. Since most OSS substations are unmanned and the (relatively quiet) transformers are usually separated from temporary living quarters (emergency shelter) by more than one wall, for OSS substations this acoustic insulation requirement usually can be met without any cost increasing measures.

3. Types of wall systems

We have now established that the current design of external walls for OSS substations can be completely different from offshore oil and gas platforms as both the risk analysis as well as the performance criteria are different. Heatshield cladding and windshield cladding as well as blast walls are not required on OSS substations. The focus is on thermal and fire-insulated weather and gastight walls, being able to withstand the external elements and keeping the equipment safe.
Corrugated welded walls currently are not used by most European operators, as these walls require a relatively high maintenance regime due to the shape and number of the welds in this construction (see Figure 1). This design is only cost effective when high blast resistance is required. And that is not required on the current generation of OSS substations.

Figure 1 25 years old, patched up offshore fire and blast wall Generation II.

3.1 Five types of wall systems explained

1. Generation I welded stressed skin + insulation + liner panel
This type originates from the shipbuilding industry [2] as it was originally used as a ship's hull and bulkhead, starting in the 1940's. This wall type has a flat and clean outside surface and can be used as a structurally loadbearing wall. Insulation is applied on pins that are welded on the external steel skin. Internally a liner can be applied, or the insulation can be covered with an aluminum backing. Painting of the steel skin takes place after the welding of the wall to the primary steel and before installation of the insulation.

2. Generation II welded corrugated skin + insulation + liner panel
This type of wall system was copied from container design in the 1960's. This wall type has a corrugated surface, with a corrugation depth depending on the required span and loads. This wall can be used as a structurally loadbearing wall. Insulation is applied on pins that are welded on the external steel skin. Internally a liner can be applied, or the insulation can be covered with an aluminum backing. Painting of the steel skin is after welding of the wall to the primary steel and before installation of the insulation.

3. Generation III bolted build up wall system + insulation + liner panel
This type was copied from the onshore building industry in the late 1970's. This wall is a non-loadbearing wall and can only carry its own weight. All parts are bolted and no hot work is required. Insulation is partly applied in the internal steel liner boxes and partly on pins that are glued on the thin pre-coated external steel skin.

4. Generation IV bolted sandwich panels
This type of wall was copied from the onshore building industry in 2010 where it was used first as external and internal wall on a HVDC OSS substation in the German bight. Originally this type was chosen due to its low weight, combined with low CAPEX and low OPEX. This panel system is non-loadbearing and precoated, with the insulation factory glued to the steel internal and external sheets. The precoated internal steel sheet adds to the required 'clean room' look and feel, compared to aluminum foil finish of Generation I and II. This type of wall currently is the standard for internal walls and non-loadbearing and non-hurricane proof external walls.

5. Generation V welded stressed skin + bolted sandwich panels
This type of wall has been in use since 2015 for the OSS platforms and has become the standard for loadbearing external walls and hurricane proof external walls. It is a combination of Generation I and Generation IV.

Generation I - IV have been previously introduced to the industry [2]. In this paper Generation V is introduced as a generic name for a specific OSS substation external wall solution.

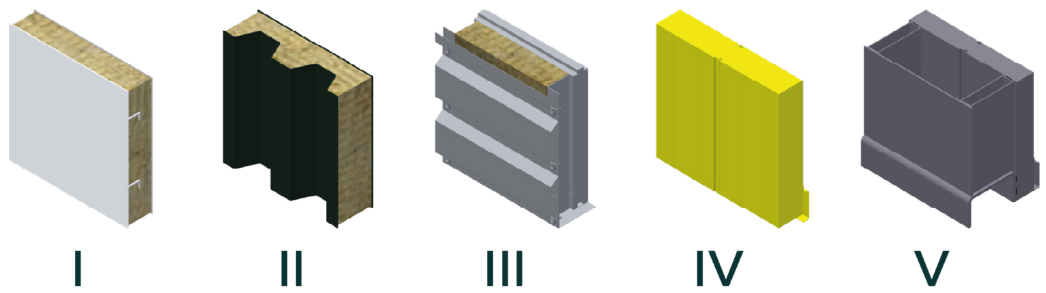


Figure 2 5 types of wall systems, from Generation I to Generation V.

Performance criterion	Gen I	Gen II	Gen III	Gen IV	Gen V
Low maintenance	o	o	+	++	+
Longevity	o	o	+	o	o
CAPEX (based on USA build, materials + labor)	-	-	-	++	-
OPEX (based on USA installed)	o	o	+	++	+
Ease of installation	o	o	o	++	+
Flexibility on sequence of installation of penetrations and walls	o	o	+	++	o
Cost of materials	+	+	-	o	-
Installtion manhours	o	o	o	++	+
Structural Loadbearing capacity	+	++	-	-	+
Certification of penetrations	O	o	-	++	++
Low weight	-	-	+	++	-
Gas tightness	+	+	o	+	+
Weather tightness	+	+	o	+	+
Acoustic insulation	+	+	o	o	++
Hurricane resistance	++	++	o	-	++
Explosion resistance	+	++	++	+	+

Table 2 Wall types vs performance criteria (- = not so competitive, o= on par with general requirements, + = better, ++ is way better than general requirements for offshore platforms in general.)

3.2. Wall types offset against performance criteria

In order to arrive at the conclusions and best practices, the five different types of walls are offset against a set of criteria in the following table (table 2). Also, a list of European and American OSS projects is presented, together with a set of graphs that present the used type of walls.

From this table it can be concluded that for OSS substations Generation IV is the default wall type, unless the walls need to be hurricane resistant. In this case Generation V is the best fit for purpose wall. Other types perform better on criteria, like explosion resistance that are not required for OSS substations.

3.3. List of projects that are taken into consideration

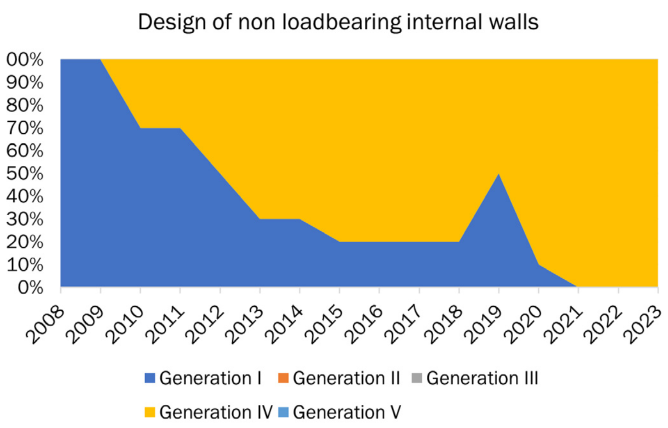
An assessment of the design of the 60 platforms mentioned in this list results in the following graphs.

2023 Orsted, Ocean Wind
2022 EMDT, Dieppe et le Tréport
2022 TenneT, HKW-B
2022 Orsted, Gode Wind 3
2022 Orsted, Borkum Rifgrund 3
2022 Orsted, Revolution Wind OSS1 + OSS2
2022 TenneT,Borwin 5
2022 Orsted, Southfork OSS
2021 TenneT, DolWin 5 HVDC
2021 Parkwind, Kaskasi OSS
2021 Orsted, GodeWind 3 OSS
2021 TenneT, Hollandse Kust West A HVDC
2021 TenneT, 380kV station Rilland
2021 EMF, Courseulles sur mer
2021 SBM Offshore, Provence GL OWF
2021 Parkwind, Arcadis Ost 1 OSS
2020 Innogy, Triton Knoll 1/2 OTM
2020 EDPR, Moray East 1/2/3 OTM
2020 TenneT, Dolwin 6 HVDC
2020 TenneT, HKZ Alpha & Beta HVDCs
2020 Iberdrola, Saint Brieuc OSS
2020 Iberdrola , Baltic Eagle OSS
2020 TenneT, Hollandse Kust Noord HVDC
2020 EDF, Fécamp OSS
2019 Otary, Seastar & Mermaid OSS
2019 Parkwind, Northwester 2
2019 EDF, Neart na Gaoithe OSS
2019 EDF, Saint Nazaire OSS
2018 Elia, Offshore Switch Yard Project (OSY)
2018 E-ON, Rampion OSP
2018 TenneT, BorWin 3 HVDC
2018 EnBW, Hohe See OSS
2018 Elicio, Norther OSS
2018 Northland Power, Deutsche Bucht OSS
2018 TenneT, Borssele Alpha & Bèta HVDC
2017 Scottish Power Renewables, East Anglia ONE Offshore Wind Substation
2017 Dong Energy, Race Bank 1/2 OSS
2017 Dong Energy, Walney 3&4 OSS
2017 Dong Energy, Hornsea Z11/Z12/Z13 RCS
2017 Dong Energy, Borkum Riffgrund 2 OSS
2017 Dong Energy, Merkur OSS
2016 Dong Energy, Burbo Bank OSS
2016 Eneco, Prinses Amalia OHVS
2016 Dong Energy, Godewind OSS
2015 Energinet DK, Horns Rev C substation
2015 Scottish Power, Wikinger OSS
2015 Vattenfall, Sandbank OSS
2014 TenneT, Dolwin Gamma HVDC
2013 Siemens, Nord See Ost OSS
2013 Dong Energy, Borkum Riffgrund I OSS
2013 TenneT, Helwin Beta HVDC

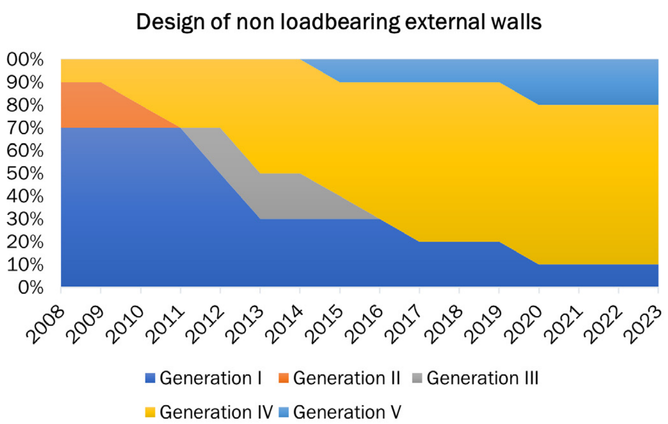
2012 VattenFall, Dan Tysk OSS
2011 EWE, Riffgat OSS
2011 TenneT, Dolwin Alpha HVDC
2010 ABB, Thornton Banks OSS
2010 Dong Energy, London Array OSS
2010 RWE Dea, Clipper South
2010 Dong Energy, MOCL Lincs
2009 Siemens, Greater Gabbard OSS
2009 E-ON, Nord
2008 Energinet DK, Horns OSS

3.4. Evolution of use of wall types on OSS substations

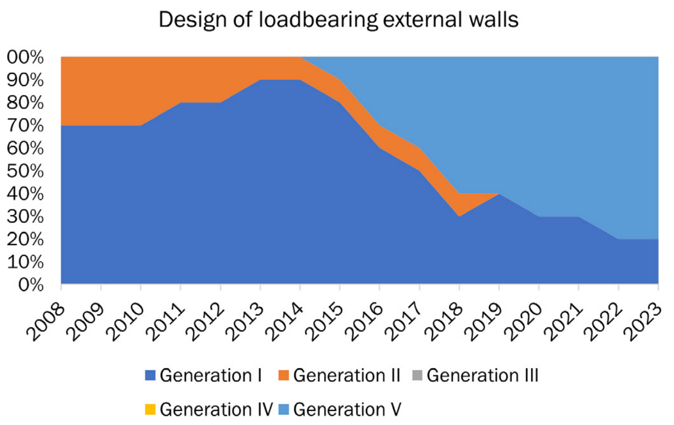
Graphic 2, 3 and 4 summarize the use of the different wall types on the projects mentioned in the paragraph above. These graphs demonstrate a shift from the more traditional oil & gas platform build solution wall types, Generation I and II, towards Generation IV and V which are more suitable for OSS substations.
Over the recent years these last 2 types have become the dominant wall types for OSS substations: Generation IV for non-loadbearing walls and Generation V for loadbearing or hurricane proof walls.



Graphic 2 Design of non-loadbearing internal walls, divided by Generation of wall type, from 2008-2023.



Graphic 3 Design of non-loadbearing external walls, divided by Generation of wall type, from 2008-2023.



Graphic 4 Design of loadbearing external walls, divided by generation of wall type, from 2008-2023.

When the above graphs are combined with the table of wall type vs performance criteria a few best practices can be drawn.

3.5. Conclusion, resulting best practices:

1. All non-loadbearing internal walls: Generation IV sandwich panels
2. Non-loadbearing, non-hurricane resistant external walls: Generation IV sandwich panels
3. Loadbearing or hurricane resistant external walls: loadbearing due to structural design philosophy to be of Generation V welded sandwich walls (welded stressed external skin + internal sandwich panel as insulation and finish).

Figure 3 Generation IV external sandwich wall panels on OSS substation including 2 windows.

Pictures and drawings of these solutions to follow in chapter 6 and 7.

4. External doors

For OSS substations, the standard for external doors is double-sealed hinged doors, preferably in Stainless Steel 316 (SS316) with CX coating system. For quite a few decades the common standard for external doors for large manned offshore oil and gas platforms is sliding doors.

Main reasons to use sliding doors for Oil & Gas platforms are:

- Fire separation zone from different hazardous areas that need to be separated during operation and opened during personnel or equipment transport;
- Escape route; doors slide away from route and form no obstacle when opened;
- Easy forklift access, especially on larger production platforms;
- Openable in a safe and easy way during high winds;

By default, a sliding door will require higher CAPEX as well as OPEX. Especially when pneumatic operating systems are required.

Since most OSS substations are unmanned and low OPEX is required, the standard for these substations is the hinged door, this is preferred due to:

- Minimal number of door openings on yearly basis
- Escape routes, designed to keep open door leaves out of escape routes. This is easier when the number of people working on OSS substations is minimal.
- Due to layout of OSS platforms, many external doors hardly need to be opened during operation, main function is as escape door, no other logistical use.

Figure 4 Double sealed hinged door including vision panel and panic bar inside, built into a Generation V wall, welded stressed skin outside and bolted sandwich panels on the inside.

SS316 with CX coating for external doors is used as a standard to minimize OPEX and maximize the longevity of these doors. The CAPEX compared to mild steel is higher, but this additional investment typically is paid back several times over the design life of the substation (40 years).

All external hinged escape route doors to be equipped with a panic bar on the inside, a storm chain and a vision panel, allowing people to see potential hazards on the other side before opening the door.

Another recent (2022) and not yet common addition to OSS door requirements is intruder protection. Some clients prescribe burglar class RC4 for external doors on all their newly designed OSS substations. RC4 resistance class has a resistance time of 10 minutes according to SN EN 1627-1630. This class is used when there are high security requirements.

When intruder protection is required on specific new USA platforms, class RC4 might be considered.

5. Installation of wall panels, clean room philosophy.

Offshore oil and gas platforms have a production sequence that differs from OSS substations on some key points. This is caused by the difference in the equipment to be installed.

The main equipment on oil and gas platforms, for example piping, process equipment, power generation etc., is usually all installed in an open structure at the construction yard. The EPIC is in the lead for the total project execution. Basically, these oil and gas platforms are produced as a multidisciplinary process in an open structure. This makes it more difficult and also less necessary to execute the installation of the architectural scope on room-by-room basis.

The main equipment on OSS substations are the transformers that are installed room by room after the transformer room is given free by the yards as a "clean room". The transformers typically are supplied by one of the global equipment suppliers like Siemens, ABB, Hitachi etc. This equipment is only allowed to be installed when the rooms are "clean" and lockable. During the installation of this equipment, it is allowed to install piping, HVAC and cabling, however all architectural works should be finished before this work starts. This sequence allows for room by room finishing by the architectural supplier, which can greatly increase the efficiency of the building of the substation. Per room only the architectural supplier is working in the sometimes restricted space. The use of Generation IV type internal wall sandwich panels gives the flexibility and speed of a quick installation of the main architectural components, allowing for a decrease in the overall project schedule, compared to welded walls with insulation plus liners. Also, late adjustments can be coped with more easily as the sandwich panels are precoated and installed fully before penetrations are made. These penetrations can easily be made on the right position after the room is handed over as clean room, Figure 5.

Figure 5 After clean room handover Electrical supplier can exactly note the location of the penetration in the already installed Generation IV sandwich panels.

5.1. Production sequence of welding and coating of yard steel.

Some EU based yards outsource the production of the total primary steel structure to a low labor cost region, where expertise on welding of primary steel structures is grouped. These yards benefit from lower cost and shorter building times. The tolerances of primary yard steel typically are appx +/- ¼ inch, whilst secondary steel has a tolerance of +/- 1/8 inch. The secondary steel structure can be installed pre painted after the installation of the primary structure instead of together as usual on oil and gas platforms. The primary steel structure can be produced and painted with higher tolerances, thus more efficiently. Pre-painted secondary steel for the internal walls can now be installed together with the internal walls and doors, by means of certified bolting to the already painted primary steel structure (Figure 13). This saves considerable time on the schedule and reduces the correction work required at site considerably as well. Building tolerances for the internal walls will be 50% lower than the tolerances of the primary steel.

6. Best Practices

In this chapter best practices for design and installation of architectural scopes for OSS substations are shared. These practices are certified according to the DNV-ST 0145 and US Coast Guard standards. With emphasis on easy installation and low maintenance.

6.1. Penetrations

A0, A60 – H120 penetrations, pipe, HVAC and MCTs are relatively easy to install in accordance with supplier manuals [4].

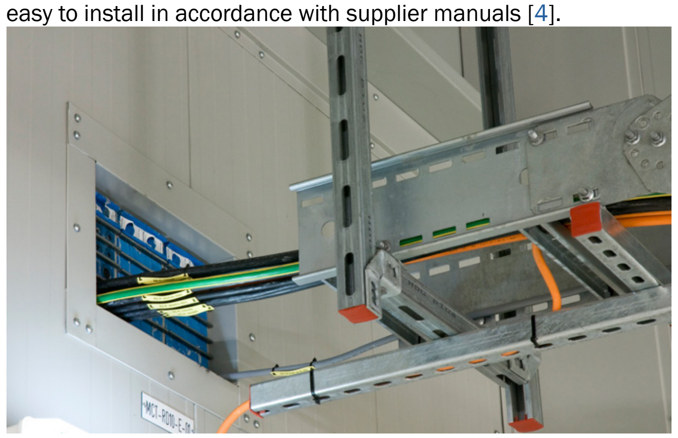


Figure 6 Cable penetration detail of Generation IV sandwich panel wall system. Seen from inside.

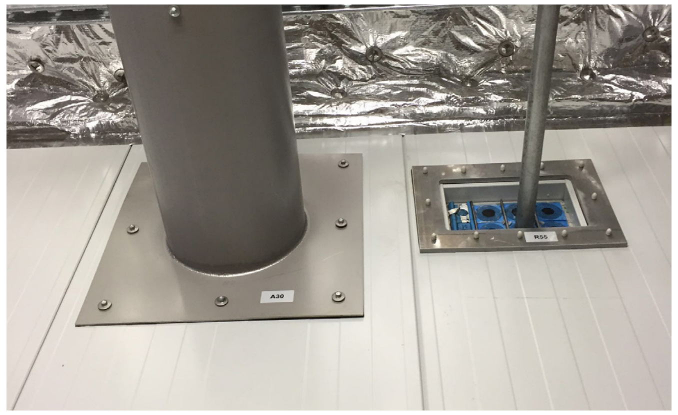


Figure 7 Pipe penetrations in Generation IV sandwich panel wall system. Seen from inside.

Some areas require grouped or "multi" penetrations. For these few areas it is advisable to make use of banking plates as per figure 7. Most penetrations can be cut out of the panels without the use of banking plates, exact calculations according to the sandwich panel supplier databook [4].

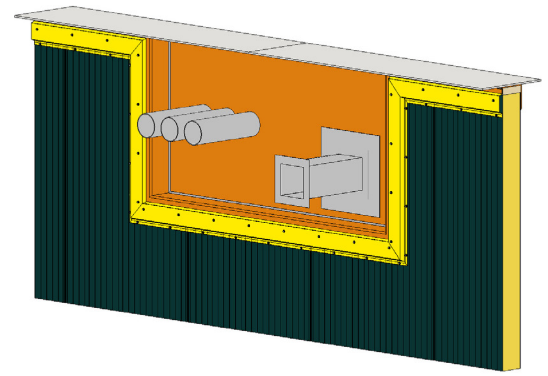


Figure 8 Multi penetration area for Generation IV sandwich wall panels.

Figure 9 Generation V wall overpressure release vents and bolted on cables on sandwich panels, seen from inside.

6.2. C profiles for intermediate support, bolted on starters

When intermediate support is required to absorb the wind load and other loadings on external sandwich walls of the Generation IV type, a low cost and low weight solution that is commonly used on European OSS substations is this cold formed C profile. This profile can be sourced and installed by means of bolting to starters. These starters are welded to the primary structure, prior to painting of the primary structure.

Figure 10 C profile for mid span support of large (over 20 ft long) Generation IV A60 external sandwich panel wall. The C profile penetrates an A60 internal Generation IV sandwich wall and is A60 certified closed with Nofirno.

6.3. Removable panels

Most OSS substations require removable panels, allowing incidental replacement of large equipment. The current standard is to have these built up from Generation IV sandwich panels. This allows for a low weight fully certified removable panel.

Figure 11 A60 removeable panel in Generation IV external sandwich panel wall, seen from outside.

6.4. Temporary protection of doors and walls

Doors are required to be installed prior to hand over of individual rooms. To avoid damage of doors after handover, it is advised to use temporary doors and install the actual doors after the electrical, piping and HVAC disciplines are finished. During this period the rooms can be closed off with the use of the temporary doors. Temporary cables can either be laid out underneath the wooden temporary door or through a later to be finished penetration (Figure 12).

In high traffic areas, the walls could be protected with ¼ inch nonflammable protection board, to avoid damage of panels after handover of the involved room (Figure 13).

Figure 12 Temporary wooden door in Generation IV external wall (combination is not fire rated yet, but can be closed off and handed over as clean room in the construction phase of the substation).

Figure 13 Generation IV internal sandwich panel wall A60 with protection board up to 8 feet and markings (top of wall) for 3 square penetrations.

6.5. Bolted secondary steel, not welded

Stud bolted angle bar bottom and top. Installing secondary steel for the sandwich panels without hot work provides an efficient method for installation of internal walls and significantly reduces the volume of welding for the architectural secondary steel. However, a few points of attention are to be taken into consideration. These points are to be included in the final design of the walls as well as in the execution. The best performance and lowest risk for yards is obtained by outsourcing the supply and installation of this steelwork together with the supply and installation of the walls and doors to one sub-vendor, responsible for all measuring and installation aspects.

6.6. Equipment mounted on walls

On fire rated walls it is only allowed to directly install equipment up to the allowed weight stated on the wall certification [4], Figure 15. Heavier equipment requires the weight to be distributed to the floor or ceiling.

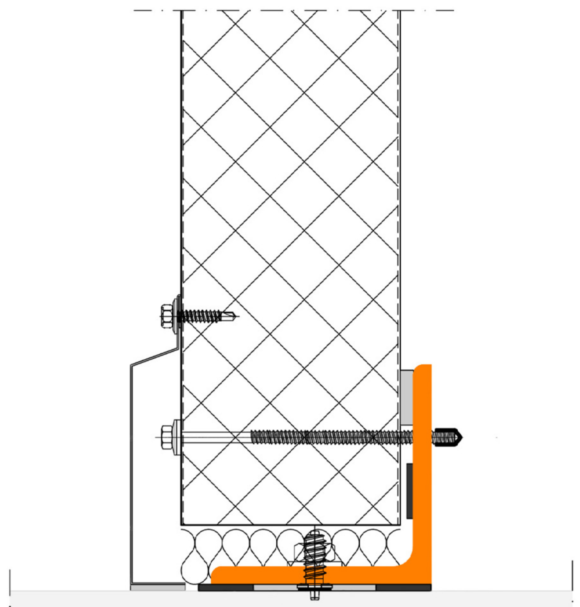


Figure 14 Studbolt detail for non-welded secondary steel A60 certified. For internal Generation IV sandwich wallpanels only.

6.7. Comfort flashings

For certification purposes the edges of the Generation IV wall panel system are not required to be finished by flashings. For cleanness purposes and longevity flashings are added.

Figure 15 Left, equipment installed on Generation IV internal sandwich wall panels, within limits of A60 certification. Right, 5x66 pounds (30kg) equipment mounted on sandwich panels during fire test, 3 on cold side and 2 on hot side.

Figure 16 Bottom detail Generation IV sandwich panel wall system including screwed on flashing. Seen from inside.

Figure 17 Top and side detail of Generation IV sandwich panel wall system including screwed on flashings. Seen from inside.

7. Standardized architectural details for USA build OSS substations

The details that follow in this chapter are adapted for production of OSS substations in the USA, with the use of secondary yard steel with dimensions that are readily available in the USA.

Bending steel to form profiles with a thickness up to 3/8 inch is readily available throughout Europe. In the USA however, this is less common. So, the standard design had to be adjusted to allow for readily available standard profiles that usually are in stock at most of the regular yard suppliers.

The adaptation of these approved and for the USA standardized details will allow engineering companies and construction yards to minimize lead and production times.

The drawings are divided into 3 paragraphs:

1. Internal walls, Generation IV sandwich panels
2. External walls, Generation IV sandwich panels
3. External walls, hurricane proof, Generation V stressed skin+ sandwich panels

(Technical drawings are available upon request)

Architects and structural engineers can adopt these details in the standard design for USA build OSS substations. This will result in an efficient design and production of OSS substations, taking all learnings from the 60 OSS substations as per paragraph 3.3 into effective consideration.

References:

[1] FACT SHEET: Biden Administration Launches New Federal-State Offshore Wind Partnership to Grow American-Made Clean Energy - The White House

[2] Further weight and cost saving on modularized oil and gas installations via a new, 4th type of blast and fire resistant walls and a comprehensive decision making model, Canada LNG, May 2017

[3] DNV Standard DNV-ST-0145 Offshore substations, Edition amended September 2021 DNV-ST-0145 Offshore substations

[4] Databook A- /H- /J-Fire & Blast rated wall systems, V5.22 – December 22

For further information, please contact:

InterDam
Your shield in the field.

Klompenmakerstraat 12
2984 BB Ridderkerk
The Netherlands

T: +31 (0) 180 470 030
E: info@interdam.com
W: www.interdam.com