Considerations when moving to TP-less

Pros and cons of TP-less monopiles – M. Kurstjens / S. Erents - August 2022

Abstract

The choice between an MP-TP configuration or a TP-less configuration depends on many factors. In this paper, we have tried to list the pros and cons of these two concepts from all possible angles. The paper is the result of our experience in this field combined with many interviews with developers, design houses, T&I contractors, and manufacturers.

There will always be supporters and opponents of the TP-less concept, especially when taking into account project-specific circumstances. However, having merged all the input, we concluded that the TP-less concept is here to stay – the pros appear to outweigh the cons in many cases.

The Skybox main access platform tries to mitigate some of the remaining cons of the TP-less concept and will be further developed with that aim.

This paper was written as an underlying document for Sif's 2022 IQPC presentation in Bremen, Germany. We have endeavoured to be unbiased, and we look forward to any further discussion on this topic.

It is structured by listing the considerations when choosing between a classical MP/TP configuration and current TP-less designs for each process step or viewpoint. It finishes with a short presentation of Skybox solving some key remaining challenges of current TP-less designs whilst further enhancing the savings of going TP-less.

The design process

When moving to TP-less, a consideration is that the design processes of the primary steel and secondary steel are interconnected. However, if the interface between the two are predefined cleverly, they can be disconnected for some time by using, among others, predefined stress concentration factors (SCF) of the brackets to be welded to the monopile (MP).

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This gives the advantage that the primary steel design process can be finalized faster, and therefore earlier. The secondary steel design process can then be completed in the required longer timeframe, since it has much more influence from stakeholders compared to the primary steel design process. A final overall countercheck must be done; however, if the load assumptions of the brackets on the monopile are initially chosen well, this final check will produce no surprises that might require last-minute primary steel design changes.

MP/TP bolted connection

The monopile/transition piece (MP/TP) connection has become a point of discussion with growing turbine sizes and as a result of that, higher flange and bolt loads. The bolted connection is nearing its maximum scalability, initially at the MP/TP interface level.

The MP/TP connection – most of the time – follows roughly the same diameter as the diameter of the flanged connection between the tower and the TP, which in turn is determined by the original equipment manufacturers (OEM) of the turbine. To avoid larger wave loading than strictly necessary, the diameter of the tower flange is usually carried downwards to the MP/TP flange, which results in this connection becoming critical in recent project designs.

By going TP-less, this is lifted approximately 20 metres upwards to the MP/tower connection where the overturning moment is less due to a shorter arm.

As a consequence, the L-flange connection can still be used at that interface level whereas it may have reached its limits 20 metres lower in the MP/TP connection. On the other hand, the upper flange now needs to be designed with the additional boundary condition of hammering and lifting, on top of the requirements from the wind turbine generator (WTG) OEM.

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Turbine

If the turbine OEM allows for the e-package to be accommodated in the bottom section of the tower, this would contribute considerably to the decision to go TP-less.

If the e-package cannot be accommodated in the bottom section of the tower, then the added complexity to place the e-package in the TP-less monopile, for instance using a cage with platforms at different levels, balances out the majority of the advantages of TP-less. As a result the classical MP/TP solution is most likely more suitable.

It seems that all three turbine OEMs are open to facilitate the move towards TP-less monopiles. Switchgear that normally is housed in a TP can be integrated into the bottom section of the tower or the nacelle, including impressed current cathodic protection (ICCP) switchgear for instance.

Fabrication

Fabrication of a TP-less MP requires the MP supplier to weld brackets on to the MP, which is no problem from a technical point of view. However, in practical terms and to ensure the fit of the separately produced secondary steel items during offshore installation, the tolerances need to be tight (approximately a maximum +/- 5 mm positional and dimensional, in all directions). This might be a challenge when using separate supply chain partners for welding the brackets on the MP and the secondary steel that needs to be hooked on offshore. Pairing of specific MPs with specific sets of secondary steel should be avoided to avoid significant impact on fabrication and logistics efforts.

The welds of the attachments on to the MP should be able to withstand the installation (piling) process as well as the in-place loads, and must be designed, executed, and inspected accordingly.

From a cost point of view, these welds can be costly since they need to be applied to the finished MP before coating, and can lead to bottlenecking in the primary steel production process.

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Since the secondary steel assemblies (such as boat landing, ladder, and access platform) are no longer connected to a TP, the supply chain of these items can be wider and is therefore more competitive from a procurement point of view.

Vessel availability

When going TP-less, approximately 20 metres of tubular steel is added on to the MP, making the MP 250–300 tonnes heavier. Most fabricators have no issue with this; however, installing these higher MP weights and lengths might require the latest generation of installation vessels to be available. The graph below plots the vessel availability versus the maximum installable MP weight. In this graph the installable (TP-less) MP weight is assumed at 75% of the specified vessel crane capacity, and the associated (TP-less) MP is set at 100m length with a 10m diameter.

It is important to state that at the time of conceptually making the choice to go for an MP/TP-solution or to go for a TP-less concept, one typically is not ready yet to confirm and book the required installation vessel. Consequently, the perception of a possible shortage of vessels or the fear of missing out on the required installation vessel plays a role at the specific moment in time when conceptually choosing to go for TP-less. The safe choice without the certainty of a vessel booking is to go MP/TP, which lowers the length and weight of the MP.

From a macro view it seems that the fleet of installation vessels capable of installing TP-less monopiles is growing rapidly and is keeping up with the growing demand over time.

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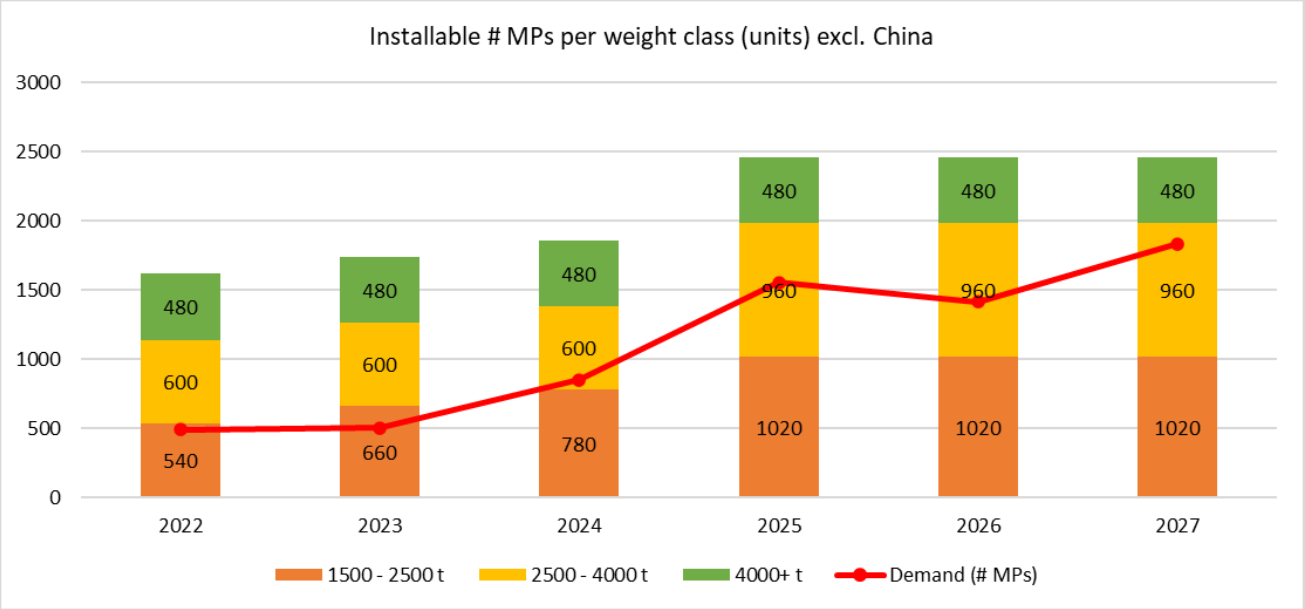

Figure 1 – installable nr. of TP-less monopiles per weight class

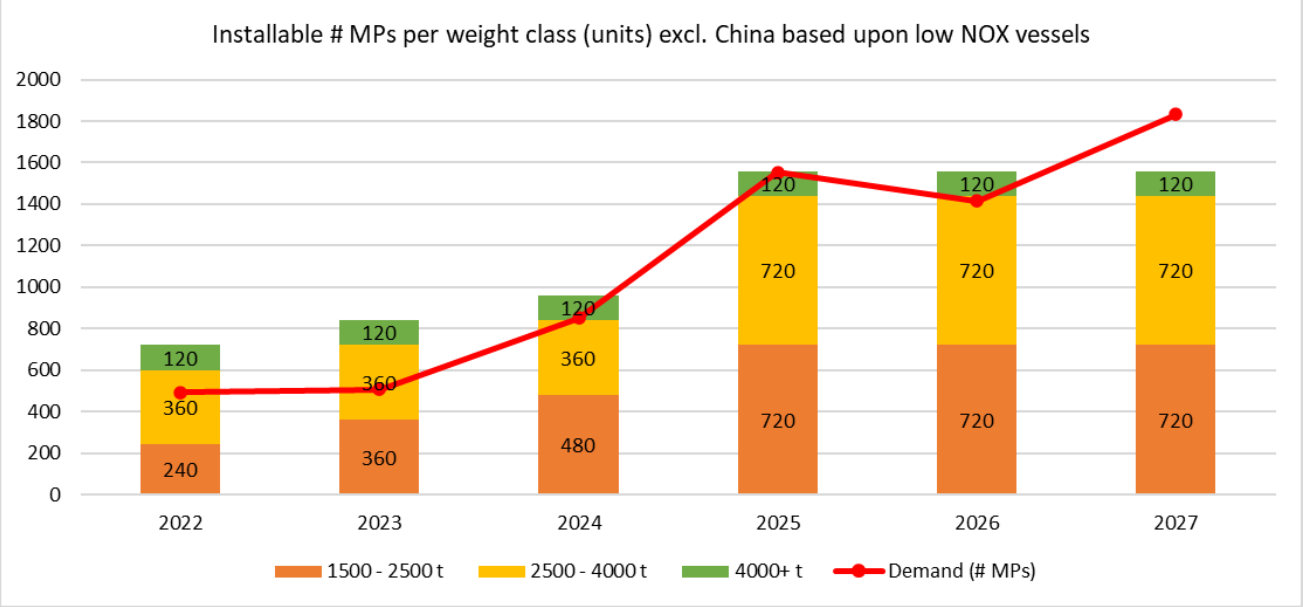

Figure 2 – installable nr. of TP-less monopiles per weight class with low NOx vessels

Assumptions

* *Installable TP-Less MP (length 100m and diameter 10 m), weight is equal to 75% of the specified crane capacity*

** *Average number of monopiles installed = 120 per year per heavy lift vessel (HLV) and 60 per year for jack-up vessels (since jack-ups that are able to handle these TP-less MPs will also be used to install turbines, hence 50% assumed market availability to install MPs).*

*** *Geographical market: the world excluding China*

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Foundation installation

A TP-less design does not require time and effort to make the critical bolted connection between an MP and a TP. However, all secondary steel needs to be attached to the MP separately instead of being attached to a TP that is typically lifted on to the MP in a single lift.

For these separate items, specific one-off installation tools are required to lower these relatively light items into the MP brackets in a controlled operation aligned with the required sea state in which the installation vessel operates. These are often designed as an integrated lifting and installation tool for the airtight platform and boat landing in one.

With a TP-less design, the driven MP-flange interfaces with the WTG tower bottom flange. This interface may lead to discussions similar to those we have seen when converting from grouted to bolted, introducing a ‘hammered’ MP-flange at the MP/TP level.

Cable pull-in and connection to the WTG tower

To maximize economics, a single platform TP-less monopile is the way forward. Lowering a multiple platform cage into the TP-less monopile wipes out a large part of the economics of going TP-less.

The considerations below, based on the assumption of a single platform TP-less monopile, are relevant for the topic of cable pull-in and the cable connection to the WTG tower:

- An over-length of cable has to be pulled in and temporarily stored in the TP-less monopile until the tower housing the switchgear is mounted. Stripping and storage of the over-length can be a challenge. In a standard TP there is more space to perform the stripping and store the over-length; stripping can be performed under the temporary cover or on the main access platform.
- Bending radii of cables in TP-less MPs can be a challenge for both pull-in operations, stripping, and storage, since space is less than in a TP. It is not impossible, but needs attention.

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- Depending on the type of cable, there is a choice between going for an extra junction box or a Pfisterer connector inside the TP-less MP, for the pull-in length and the stripping length to be shortened. In this case, a separate cable will be installed later between the junction box and the switch gear in the tower (so-called dropper cables). This is also often used in MP/TP configurations.
- Greater pull-in length of the cables for TP-less means checks for pull-in loads and the pull-in arrangement. TP-less, as a consequence of this, requires a little more inter-array subsea power cable, compared to the MP/TP configuration where the cable hang-offs are typically positioned at a lower elevation. In an MP/TP configuration the connecting cable up to the WTG tower can be a different and less expensive cable compared to the stripped subsea inter-array power cable.

Distance to shore

This is more a discussion on the use of boat landings other than a discussion on MP/TP versus TP-less. Points to consider:

- Close to shore: gives the opportunity to make use of a possible existing fleet of existing crew transfer vessels (CTVs) in ports nearby. A standard boat landing is required (or a new fleet of CTVs with a ‘GUS™ bow’).
- Further out at sea (>30 km, >1 hr with CTV):
    - boat landing maximum 1.5–1.75 m wave height: very small working window if no accommodation vessel is nearby;
    - GUS™ maximum 2.0–2.5 m wave height;
    - walk-to-work vessel maximum 3.0 m wave height.

Operations and Maintenance (O&M)

TP-less is one bolted connection less to monitor and maintain (the MP/TP flanged connection) with all the associated benefits.

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Health and Safety

Installation aspects

With TP-less, there is no need for anyone to go down into a non-bolted TP to put in the first bolts.

O&M aspects

The bottom of a TP is a confined space with inherent safety risks. Minimizing the need to access this area is the best preventive measure. This is achieved by going TP-less and as a consequence avoiding the need to go to a connection at the bottom end of a TP. Any heavy bolting operation is also inherently risky, so avoiding this is an improvement. Generally, with less hardware to inspect, the number of required offshore operations goes down, further reducing risk.

The economics of going TP-less

Over several projects, an average CapEx saving of €250k – €300k per foundation can be reported (TP-less compared to MP/TP, before installation) due to the omission of MP/TP flanges, bolts and nuts, skirt, flange seal, flange induced SCF-effect on the adjacent can, etc. This is approximately 10% less tonnage on average between MP/TP and TP-less when comparing like with like.

In operating expenses (OpEx), a saving of approximately €15k per asset per 2–5 years on bolt inspections and maintenance will be achieved due to there being one less bolted connection to inspect and maintain. This figure can increase to a multi-million level in case there is an issue with the bolts and they need to be replaced as has occurred before at several projects.

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Summary: TP-less

Overall, the trend in the market seems to suggest that the benefits of TP-less prevail, provided the right installation vessel can be obtained. A further development to highlight separately is Skybox.

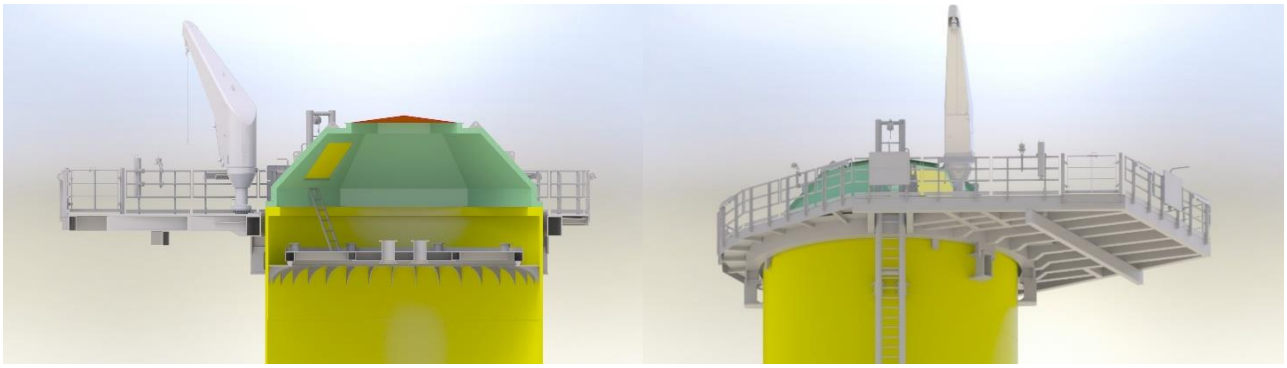

Figure 3 – a current TP-less configuration using brackets and a boat landing in cross-section and 3D view

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Skybox

The next step in going TP-less

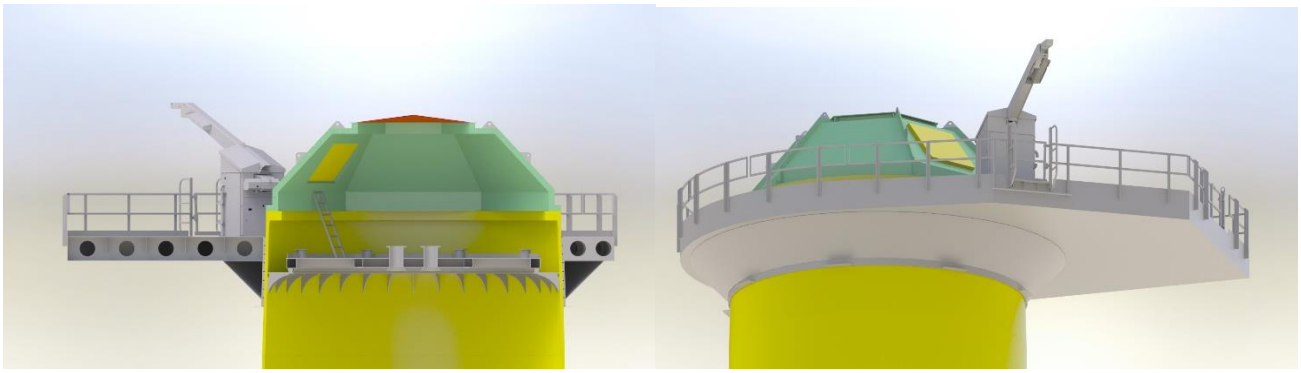

Figure 4 – The Skybox main access platform in cross-section and 3D view

With Skybox we use slip joint technology to install the main access platform over the conical top can of the MP, hence eliminating the need to use brackets that are welded on to the MP.

By integrating the next generation GUS/davit crane, a boat landing is not required. Skybox therefore does not require any brackets to be welded to the monopile for offshore installation of secondary steel.

This installation of the secondary steel offshore is seen as a disadvantage or challenge when going TP-less. With Skybox this is no longer a point to worry about since Skybox is installed with one lift that can be made in sea states beyond the limits for the MP installation.

Skybox can be used in combination with any monopile (with the required conical top can). Both the geometrical properties of the top can of the monopile and the inside of the Skybox conical geometry are scanned, and these data are used to individually tailor each Skybox to the monopile.

Tailoring is achieved by applying tiles, on site, before the Skybox is placed at the installation vessel to go offshore. The tiles are placed between the slip

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joint surfaces of the monopile and the Skybox. These tiles ensure a perfect fit and a predictable settlement height of the Skybox whilst ensuring visual access between both slip joint surfaces for coating inspection of the slip joint during the O&M phase.

As a result, the Skybox is paired to the scanned surface properties and dimensions of each individual monopile to assure the best slip joint fit. This ensures the correct vertical settlement height while using standard fabrication tolerances for both conical slip joint geometries.

Design process

Since the Skybox's only interface with the monopile is the slip joint on the conical top can, the design process of the primary steel can be split from the design process of the secondary steel (the Skybox). The interface loads are clearly predefined and low compared to the loads of brackets that need to be welded to the MP in the case of a standard TP-less design. This enables the developer to secure production slots for the monopile at an earlier phase and allows for more time to finalize the secondary steel design.

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Economics: MP/TP, TP-less, and Skybox compared

Please see below comparison based on a SG14-222 DD WTG in a 40 m water depth reference site.

100 MP OWF	MP/TP	TP-LESS	Skybox
ENGINEERING and MANAGEMENT prim steel	€ 2.279.848	€ 2.279.848	€ 2.279.848
ENGINEERING and MANAGEMENT sec steel	€ 7.136.405	€ 7.136.405	€ 7.136.405
Primary Structure	€ 185.079.179	€ 173.153.309	€ 176.560.701
Primary Structure Others (Prim steel scope - holes in MP)	€ 5.865.852	€ 5.865.852	€ 5.865.852
Primary Structure Others (Sec steel scope - attachments on MP)	€ 9.689.250	€ 12.639.327	€ 0
Boat Landing	€ 9.950.260	€ 9.950.260	€ 10.700.000
Rest Platform	€ 455.461	€ 455.461	€ 0
Main Access Platform (MAP)			
- Platform Structure (steel or concrete)	€ 13.680.447	€ 15.200.496	€ 31.278.075
- MAP sec steel (handrails etc)	€ 4.243.476	€ 4.243.476	€ 1.420.595
External Ladder	€ 1.174.819	€ 1.174.819	€ 0
Flange Access Platform (FAP)	€ 5.149.958	€ 5.149.958	€ 5.149.958
Cable Termination Platform (CTP)	€ 2.984.079	€ 2.984.079	€ 2.984.079
Airtight Platform (ATP)	€ 9.207.470	€ 9.207.470	€ 9.207.470
Final assembly of internal cage	€ 2.468.988	€ 2.468.988	€ 2.468.988
Miscellaneous	€ 2.433.957	€ 2.433.957	€ 2.433.957
Flanges and bolts	€ 23.260.000	€ 8.897.807	€ 6.360.000
Primary Steelwork Coating	€ 22.022.986	€ 17.408.535	€ 17.408.535
Secondary Steelwork Coating	€ 6.760.952	€ 6.760.952	€ 4.039.976
Technical Appurtenances - sec steel	€ 26.052.843	€ 26.052.843	€ 26.052.843
Condition Monitoring System	€ 784.370	€ 784.370	€ 784.370
Structural Health Monitoring System	€ 252.882	€ 252.882	€ 252.882
Transport and storage	€ 3.053.196	€ 3.053.196	€ 1.773.196
Mock-up - prim steel	€ 45.000	€ 45.000	€ 45.000
Mock-up - sec steel	€ 11.500	€ 11.500	€ 11.500
Temporary Items sec steel	€ 251.356	€ 251.356	€ 251.356
Total Capex foundation	€ 344.294.535	€ 317.862.147	€ 314.465.585
	MP/TP	**TP-LESS**	**Skybox**
total	€ 344.294.535	€ 317.862.147	€ 314.465.585
	100,00%	92,32%	91,34%
delta		-7,68%	-8,66%
		-€ 26.432.387	-€ 29.828.949
delta		-7,68%	-8,66%

Installation costs	**MP/TP**	**TP-LESS**	**Skybox**
One-off costs: grillage / seafastening / installation tooling	€ 1.150.000,00	€ 3.000.000,00	€ 1.500.000,00
	* MP cradles 250keu * TP seafastening grillage 250keu * MP upending & lifting tools & rigging 500keu * TP lifting padeyes&spreader&rigging 150keu	* MP cradles 250keu * Sec steel seafastening grillage 250keu * MP upending & lifting tools & rigging 500keu * Sec steel installation tools 2000keu	* MP cradles 250keu * Skybox seafastening grillage 250keu * MP upending & lifting tools & rigging 500keu * Skybox installation tool 500keu
Transport to site: lifting onboard vessel and transport to site	equal	equal	equal
Dayrate of next gen large instalation vessels as from 2025 campaigns	€ 300.000,00	€ 300.000,00	€ 300.000,00
Hourly rate	€ 12.500,00	€ 12.500,00	€ 12.500,00
Lift 1 (hrs) - Lift and install MP	9	9	9
Lift 2 (hrs) - Lift and install TP (connect TP to MP, bolting)	4,5	0	0
Lift 3 (hrs) - Lift and install airtight platform	0	1,5	0
Lift 4 (hrs) - Lift and install boatlanding	0	2	0
Lift 5 (hrs) - Lift and install access platform	0	2	0
Lift 6 (hrs) - Lift and install skybox	0	0	2,5
Total lifting time	13,5	14,5	11,5
Costs for lifting TP/Sec Steel/Skybox per foundation	€ 168.750,00	€ 181.250,00	€ 143.750,00
Installation of MP/TP bolts (per foundation)	€ 20.000,00	€ 0,00	€ 0,00
100 Fou, in field and in position, excl to-and-fro voyage, jacking, anchoring etc)	**€ 20.025.000**	**€ 21.125.000**	**€ 15.875.000**
	MP/TP	**TP-LESS**	**Skybox**
Total installation cost TP/TP-less/Skybox	€ 20.025.000	€ 21.125.000	€ 15.875.000
Delta compared to MP/TP set-up		€ 1.100.000	-€ 4.150.000
delta		5,49%	-20,72%

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Fabrication

With Skybox, the MP does not need to have tolerance-critical attachments welded to it.

Skybox can be installed using any MP, so a Sif-produced MP is not necessarily required. Sif scans the conical outer surface of the top can of the MP and as an outcome of this dimensional MP survey, dedicated tiles are installed instantly. These are mounted to the inside of the Skybox to shim any dimensional deviations of the MP or Skybox.

In this way the vertical point of settlement of the Skybox is ensured within a narrow tolerance bandwidth. This technology (patent pending) also ensures that both the MP fabricator and the Skybox fabricator do not need to use any special or extremely tight production tolerances to make the slip joint work properly.

The spacing between the tiles also allows for visual coating inspection between the surfaces of the slip joint during the lifetime / O&M phase, since the tiles keep both slip joint surfaces apart at a predetermined spacing.

Offshore installation

With Skybox the installation is very simple – no specific tooling is required other than a dedicated installation tool which Sif will design and supply. This includes the grillage and sea fastening for both the Skybox itself and the installation tool.

Wave run-up is countered by the Skybox self-weight through its structural strength properties combined with the working mechanism of the slip joint, and therefore does not require any specific additional countermeasures.

Supply chain

The production of the Skybox itself is open to a much larger supply chain than the TP supply chain, as it does not require similar heavy lift assets compared to the supply chain of TPs. It can be built by smaller companies globally; Sif is therefore developing a global network of licensed Skybox partners.

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Conclusion

In the current market we, as a total and integrated supply chain, need to ramp-up both volume (gross weight) and size (larger turbines, hence larger monopiles). This will have an effect on the challenges ahead.

Only if everyone does the job they are best at we can rise to this challenge of supplying large volumes in good quality, safely, and consistently.

For Sif this means making monopiles without secondary steel attached to it. A monopile without brackets is considerably easier to produce in large numbers compared to a monopile that requires brackets.

The same goes for the TP and the bottom section of the tower: when integrated, there is only one complex part in the total supporting structure that requires a lot of manual welding – the bottom section of the tower.

Only by innovating the total support structure in a logical way, can we produce the volumes required. Going TP-less is an easy decision to begin with, and Skybox is the next step into going TP-less.

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