Summary Comparison Study
MMW Wind Turbines Gearbox or Direct Drive

Schagen, November 2021

VerVent is working on concept designs of a new powertrain for large-scale horizontal axis wind turbines (HAWTs) in the range of 10-20MW, the VerVent MergedGear and Megatorque 20.

The study *Comparison Multi Megawatt Wind Turbines Gearbox or Direct Drive* is based on professional literature written by scientific and research organizations and on information from suppliers and manufacturers. VerVent states emphatically that the study only concerns the offshore wind energy market.

During the project, good thought was given to other wind turbines and drive systems, gearboxes and direct drive. The questions that arose then have not all been answered

The global offshore wind energy market currently has three major players: GE and Siemens Gamesa (direct drive) and Vestas (gearbox). The nominal capacity of an (offshore) wind turbine is growing rapidly. 12 MW is already becoming a standard and Vestas wants to bring a 15 MW to the market in a few years.

The growing Multi Mega Watt Wind Turbine power can be a game changer for direct drive and gearbox wind turbines. Direct drive turbines, like gearbox turbines, will become heavier. The direct drive ring generator will grow in diameter, require a larger support structure and become heavier. Deformation can be avoided, but there is a price to pay in the weight gain for a rigid structure.

The Vestas turbine has a gearbox and a strong position in the offshore wind energy market, also competitive in the growing capacities (MWs). The gearbox of the Vestas Turbines is a type that has been used for years. The question is whether this gearbox will meet the requirements for scaling up to more than 15 MW. Will it become heavy, expensive and fragile?

Direct drive will need more electro-magnetic materials (copper, neodymium because more poles to transform torque into electricity). Some of these materials must be imported from China and are subject of increasing prices.

Both technologies have been analysed. The analysis and comparisons were made with the knowledge and experience of VerVent and public literature. VerVent explicitly states that the analysis is not exhaustive and that there will also be other arguments when choosing gearbox or direct drive technology.

Conclusions of the technical and financial analysis

The weight of direct drive wind turbines is likely to grow proportionally faster than the weight of gearbox turbine. The consequence of the growth of the nominal power and thus the need for a larger generator (larger diameter) is that the supporting structure will also become heavier to prevent deformation during the rotations of the generator.

Although the reliability of gearboxes has increased through experience and maintenance and repair has become less, the question is to what extent the current gearboxes for medium and high(er) speed generators can be scaled up to a significantly increased torque.

The proportion of active material (copper, neodymium, etc.) in direct drive turbines remains high and will also grow rapidly as the nominal power increases. This and the cost of a heavier load-bearing structure will have a major impact on the cost of the direct drive nacelle.

Direct drive turbines will undoubtedly keep the advantage of lower regular maintenance costs over a gearbox turbine. But the difference can get smaller. If a direct drive generator fails, repair and/or replacement costs can be high and higher than a gearbox repair.

The question is whether such a repair or replacement will take place and how often during the lifetime.

With the conclusions drawn about the development of both technologies, direct drive and gearbox, sensitivity calculations have been made.

Two perspectives were used for these calculations. One of these is based on the results of the literature study, the VerVent Calculations; for the second, the basis is the Pathway study, made by TNO and BLIX. This perspective is called VerVent Pathway Calculations.

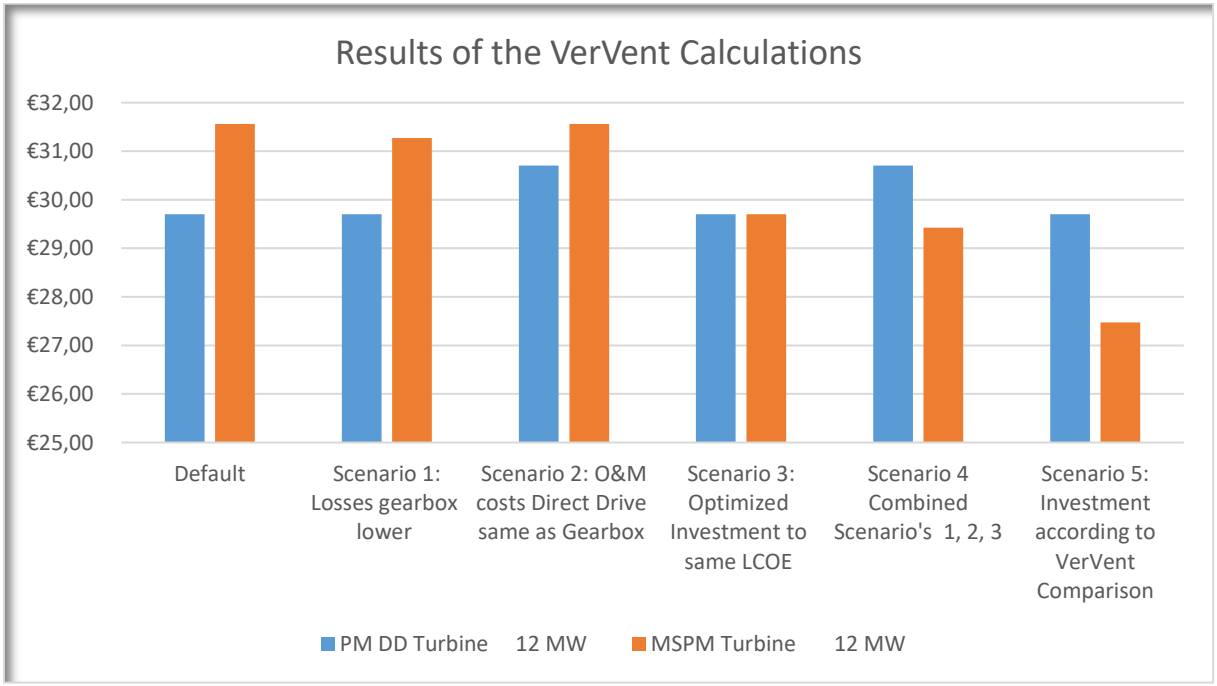
Because most investment studies calculate with a turbine that is not further defined as a gearbox or direct drive, VerVent uses the same investment costs as Default for both types.

The scenarios relate to variations in system losses, O&M and investment costs. By using the same investment amount for direct drive and gearbox turbines, the effect of a different % for system loss or O&M or a lower investment amount for gearboxes becomes clear.

The results of the *VerVent Calculations* are, as expected, that the direct drive turbine in Default has a lower LCOE, as both system losses and O&M costs are lower for this type of turbine. The simple conclusion is that the investment in an MMW gearbox turbine should be lower than that in a direct drive turbine.

		PM DD Turbine 12 MW	*MSPM Turbine 12 MW*
Default	*LCOE/MWh*	€ 29,70	€ 31,56
Scenario 1: Losses gearbox lower	*LCOE/MWh*	€ 29,70	€ 31,27
Scenario 2: O&M costs Direct Drive same as Gearbox	*LCOE/MWh*	€ 30,70	€ 31,56
Scenario 3: Optimized Investment to same LCOE	*LCOE/MWh*	€ 29,70	€ 29,70
Scenario 4 Combined Scenario's 1, 2, 3	*LCOE/MWh*	€ 30,70	€ 29,43
Scenario 5: Investment according to VerVent Comparison	*LCOE/MWh*	€ 29,70	€ 27,47

The sensitivity analysis further shows that with an equal investment for direct drive turbines and gearbox, a reduction in the system losses of the gearbox turbine has no significant impact on the LCOE.



An increase in the O&M costs of the direct drive turbine, due to a larger ring generator and heavy load on the MBU) certainly increases the LCOE of this turbine. The increase used in the analysis is not yet sufficient for an LCOE comparable to that of the gearbox turbine; the latter continues to hold a higher LCOE.

If the investment amounts that have emerged from the studies (and have been processed by VerVent to make a total overview) are used, then the gearbox turbine has the lowest LCOE.

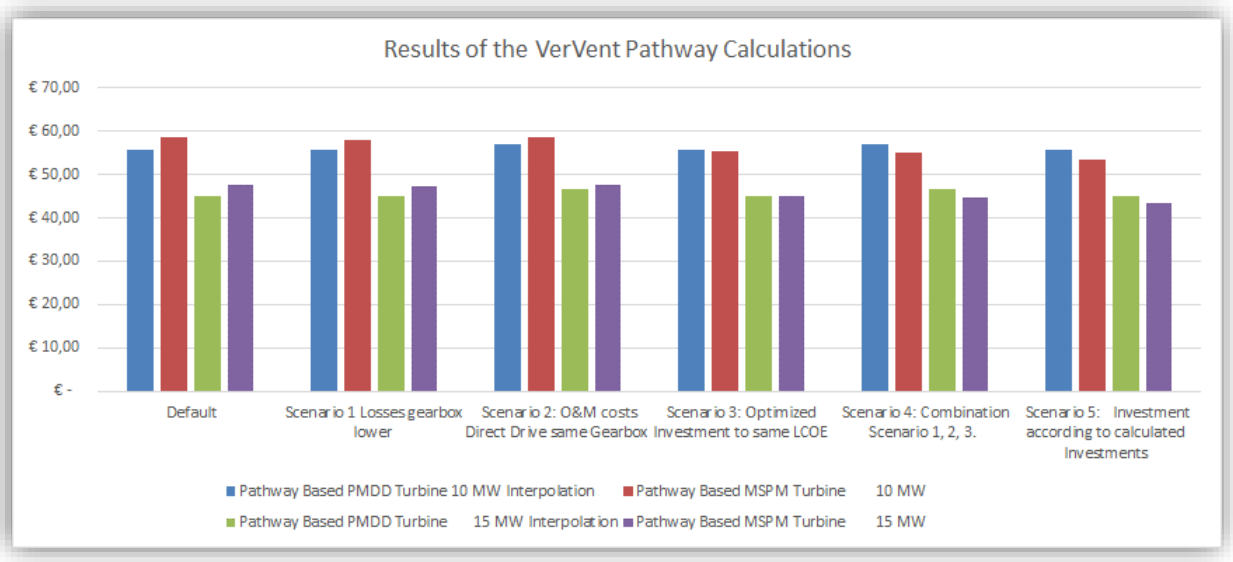
The Results of VerVent Pathway Calculations do not differ much. As In the VerVent Calculations, in the Default situation where only the system losses and O&M differ, direct drive has the lowest LCOE. Scenarios 1 and 2 pictures for system losses the same as in the VerVent Calculations and lower system losses do not change the picture much.

With a 7% lower investment in gearbox turbines (scenario 3) the LCOE of direct drive and gearbox turbine are the same. Following the investment costs of Pathway this is a difference in the investment of approx. M€ 150 for 10 MW turbine and M€ 203 for the 15 MW turbine (both gearbox investment lower).

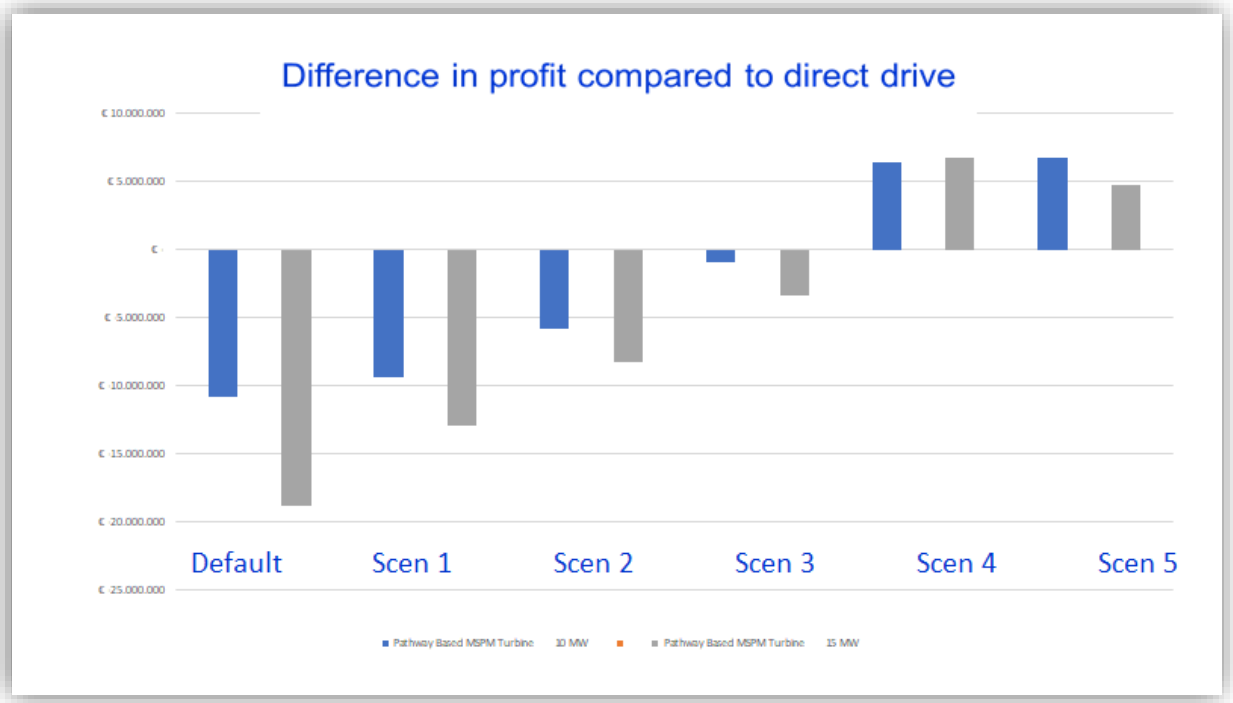
	Pathway Based PMDD Turbine 10 MW Interpolation	Pathway Based MSPM Turbine 10 MW	Pathway Based PMDD Turbine 15 MW Interpolation	Pathway Based MSPM Turbine 15 MW
Default	€ 55,59	€ 58,45	€ 45,07	€ 47,67
Scenario 1 Losses gearbox lower	€ 55,59	€ 57,99	€ 45,07	€ 47,30
Scenario 2: O&M costs Direct Drive same Gearbox	€ 57,09	€ 58,45	€ 46,57	€ 47,67
Scenario 3: Optimized Investment to same LCOE	€ 55,59	€ 55,52	€ 45,07	€ 45,09
Scenario 4: Combination Scenario 1, 2, 3.	€ 57,09	€ 55,09	€ 46,57	€ 44,74
Scenario 5: Investment according to calculated Investments	€ 55,59	€ 53,41	€ 45,07	€ 43,50

It is obvious that if the investment of the gearbox turbine is lower (scenario 4,)the system losses according to scenario 2, the O&M costs according to scenario 3, the LCOE for turbine with gearboxes is much lower than that of direct drive.

Scenario 5 uses the Pathway study investments for the 10 and 15 MW gearbox turbine. The difference between direct drive and gearbox turbines is 12% (10 MW) and 9% (15 MW) respectively.



In scenarios 4 and 5 of the Pathway Calculations the LCOEs of the gearbox turbine are lower than those of direct drive. But that does not necessarily mean that the gearbox turbines makes more profit. Because the system losses of the direct drive turbine are lower than those of the gearbox turbine, the efficiency is higher and thus the turnover.



The difference in LCOE between the two must be large enough in favour of the gearbox turbine to make up for this increased output/profit.

Overall

Investment costs for higher powers (>10 MW) can go faster for direct drive than for gearbox turbines. If the system losses and O&M remain at the same level as assumed, the LCOE for gearbox turbines will be lower than that of direct drive, because direct drive must be able to

accommodate an unequal wind load of the increasingly larger ring generator. This demands a lot from the generator, MBU and supporting structure.

While many gearbox improvements have been made and there is also a growing confidence, the question is whether the increasing torque can be managed by the gearbox and whether this increased torque also leads to higher O&M costs for gearbox turbines.

The weight and investment cost of direct drive will grow proportionally faster with increasing rated power than that of a gearbox turbine. This works in favour of the gearbox turbine. Although the analysis of the 12 MW turbines shows a lower LCOE for direct drive, the difference between direct drive and gearbox technology is small.

The three main producers of offshore wind turbines, Siemens Gamesa, Vestas and GE, show that there is at least a market equilibrium. If the conclusions about growth in rated power, weight and cost of direct drive and gearbox turbines are correct, this could lead to a competitive, lower LCOE of gearbox turbines compared to direct drive.

Which type of turbine is currently best prepared for growing abilities? The question is whether (incremental) improvements are sufficient to cope with these abilities for both direct drive and gearbox turbines or are technical game changers needed for both types.

The current gearbox will also have to be thoroughly examined to see if it is suitable for the increasing MMW capacities, despite all the improvements in recent years that have made it much more reliable.

It is more about the confidence that an owner will have to have in gearbox technology and the guarantees that the supply chain partners are able to provide. It is up to the shareholders to make a choice that they believe will meet the expectations of the asset during the operating period.

The shareholders of the OEM are also confronted with continued product innovation and incremental improvements. The lifetime of individual turbines need to be ensured from a project perspective, while at the same time the turbine platform should enable upscaling and margin improvements as well. Increasing the nominal power of currently available turbines are or will be confronted with limits to increase the rated power on the same platform.

Contact

VerVent is a subsidiary of Sustainable Business Investment BV and part of the not-for-profit company Stichting ATO.

www.vervent.nl
www.megatorque.eu
www.ato.nl (in Dutch)

VerVent BV
P.O. Box 16
1740 AA Schagen
The Netherlands
info@vervent.nl

Associate Partner in USA
Lockwood Hill Associates
Jan Willem van der Werff
+1 513 312 3638
jw@lockwoodhillassociates.com