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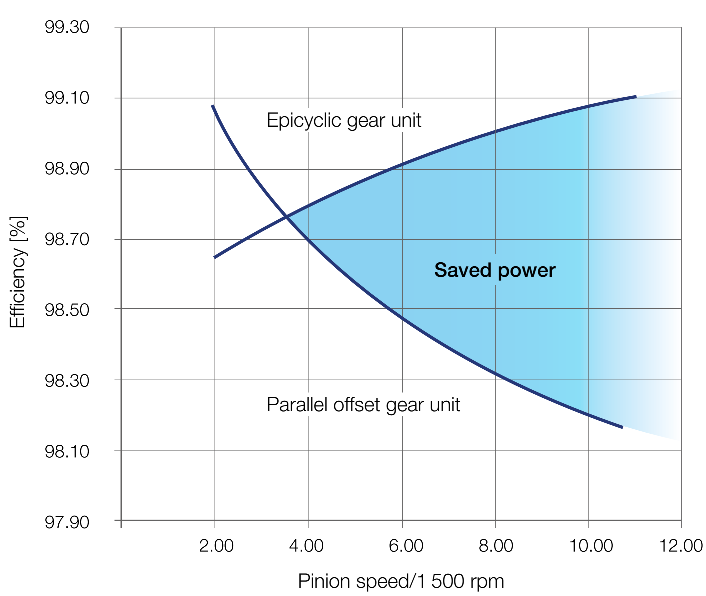
Advantages in power generation
BHS Planetary gear units

Comparison between planetary and parallel shaft gear units in generator trains driven by gas, steam, and expansion turbines

Gearboxes are used to reduce the turbine rotational speed to the generator‘s speed at performances up to approx. 110 MW or turbine rotational speeds of approx. 60 000 rpm. Parallel shaft gear units are usually used in these applications. However, some packagers and generator manufacturers use planetary gear units for gas and steam turbine systems. The majority of planetary gear unit manufacturers are located in Europe, which might explain why planetary gear units are used less commonly in the US power generation market. Many engineers seem to be unaware of the advantages of planetary gear units and feel uncomfortable using them in light of the more complex design and more elaborate inspections. The well-known standard API 613 covers only the design and construction of parallel shaft gear units; therefore the utilization of planetary gear units is nearly impossible in the API world. The objective of API 613 is the creation of a gearbox with a sufficient safety margin.

This can be achieved just as well with planetary gear units by simply selecting an appropriate safety factor. Planetary gear units are furthermore constructed according to proven designs and offer a maximum level of reliability. Some manufacturers have even specialized in this type of gearbox. Design standards according to ISO (formerly DIN) and AGMA are available for this. Nevertheless, most turbine systems today are equipped with parallel shaft gear units, even if planetary gear units might be the better choice. Some key points should therefore be taken into consideration. The input and output shaft of planetary gear units is aligned coaxially, which permits a compact train design.

Efficiency factor comparison between a planetary gear unit and a parallel shaft gear unit by Voith

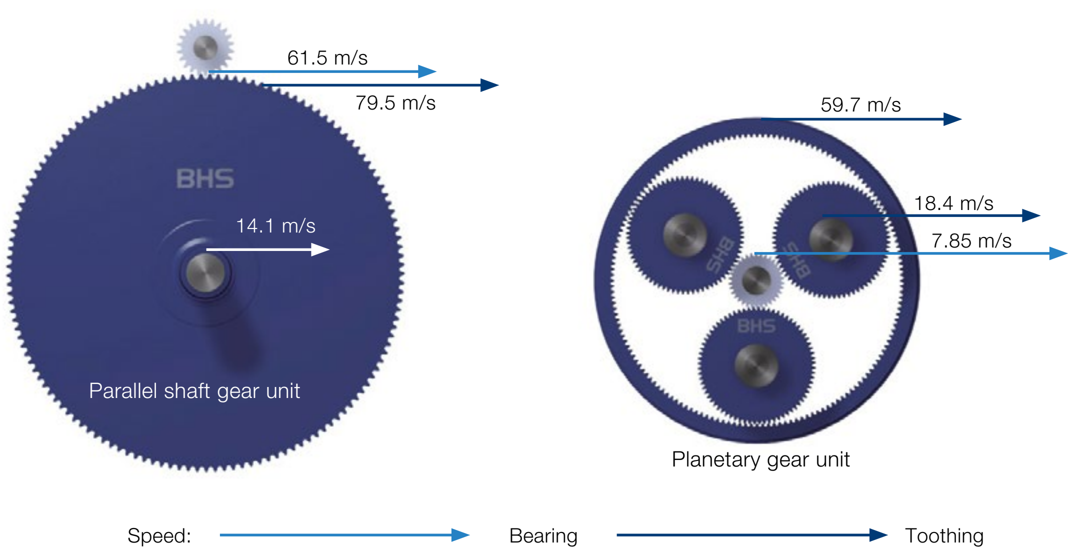


Planetary gear units need less space and weigh less in comparison to parallel shaft gear units due to the transmission of power via three or more planetary wheels.

Various gearbox designs exist among major manufacturers, all of which guarantee a balanced load distribution between the planet gears. The very well-known Stoeckicht principle is characterized by a “floating” sun wheel and annulus gear. Neither of these toothed wheels requires bearings and both of them can freely adjust to the planet gears within the meshing points. The sun wheel is directly connected to the turbine shaft via a coupling. The annulus gear is connected to the slower gearbox shaft via the annulus gear bushing. This design guarantees perfect load distribution. The missing bearings on the faster gearbox side, which usually bear the majority of the high power losses in parallel shaft gear units, explain the high efficiency factor of this type of planetary gear units. The short sun wheel shaft with a small overhang moment shows an excellent rotor-dynamic conduct and permits speeds of more than 60 000 rpm – far below the first critical rotational speed. The efficiency level of planetary gear units according to the Stoeckicht principle increases slightly with larger gear ratios. In contrast to this, parallel shaft gear units have the best efficiency levels with small gear ratios while their efficiency level with higher gear ratios drops significantly. Planetary gear units should therefore be used with higher gear ratios (see image 1) in order to achieve an optimum efficiency level. The planetary gear unit design also causes a lower pitch-line velocity on the toothing and the bearings (see image 2). These factors influence their higher operational reliability.

Comparison of pitchline velocity on bearings and toothing

Example: Steam turbine - generator,
P = 5 900 kW @ 10 680 / 1 500 rpm



Economic evaluation of turbine systems – a comparison

The economic aspect as well as technical aspects e.g. efficiency level, reliability, space requirement, etc., of a decision between two fundamentally different solutions should be taken into consideration. The investment costs as well as operating costs should be taken into consideration. The comparison (see table 1) uses a parallel shaft gear unit solution and a 2 pole generator as a measure. The advantages and disadvan-tages may be weighted differently depending on the application, the country of installation, and customer requirements.

The study clearly shows that a simple comparison of parallel shaft gear units and planetary gear units is not appropriate. Rather, the generator must also be included in the comparison. In the stated example, the lowest total costs (investment + operation) are achieved with a planetary gear unit and a 4 pole generator. The low-loss, low-cost, and compact con struction of turbine systems is possible by specifying the use of planetary gear units. Planetary and parallel shaft gear units, as well as couplings, rotor turning gears and integral gear units are chiefly used in the power generation, petrochemical, chemical, and oil and gas industries.

Comparative study

	2 pole generator (3 000 rpm)		4 pole generator (1 500 rpm)		
	Parallel shaft gear unit	**Planetary gear unit**	**Parallel shaft unit**	**Planetary gear unit**	
Price gearbox + coupling(s)	0 (-)*	-	-(--)*	--	Higher gear ratio leads to a larger and more expensive gearbox
Price generator	0	0	++++	++++	Great price difference between 2 pole and 4 pole generator
Total weight and dimensions	0 (+)*	+	--(-)*	-	Space requirement for mounting base (coaxial: +; 4 pole generator: --)
Total energy loss	0	0	--	++	Cost savings
Total oil consumption	0	-	-	0	Size of lube oil system
Total advantages	0 (0)*	-	--(--)*	++++	

Parallel shaft gear unit with horizontal shaft offset vs. planetary gear unit with integrated coupling on faster and slower side
Example: Turbine on generator – rated load = 17 MW,
Rotational speed turbine = 9 700 rpm
Design pursuant to AGMA min. service factor = 1.3

* in parentheses: Parallel shaft gear unit with quillshaft and vertical shaft alignment
0 = no significant financial advantage/disadvantage
+/- = financial advantage/disadvantage of 10 000 to 25 000 EUR
++/-- = financial advantage/disadvantage of 25 000 to 50 000 EUR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