Introduction
Over the past 60 years vertical roller mills have become increasingly important within cement production. Today the vertical roller mill is known as the most efficient mechanical comminution method. Recent developments also show that the throughput rate of the VRM has not yet reached its limit, contrary to other mill types. With an increase of the diameter of the mill table and the use of additional rollers, mill manufacturer can increase the capacity of their mills without changing the comminution process fundamentally. Vertical roller mills are extremely flexible and are therefore used in the grinding process of raw meal, clinker, cement, coal and slag. Nevertheless, increasing the throughput rates goes hand in hand with the increase of drive power and places higher requirements on the drive systems.

Despite the long-lasting stagnation of the global economic situation, several large and very large vertical roller mills have been built and put into operation in recent years. This trend is ongoing and
it forced the suppliers of drive systems to further develop their product and in some cases to introduce new and complex solutions.

The conventional drive system

The conventional drive system for vertical roller mills consists of a horizontal electrical motor, mostly a slip ring asynchronous motor and gearbox. Depending on the drive power the gearbox contains two or three gear stages. Besides the reduction of speed and increase of torque the gearbox also has to change the direction of the working axis from horizontal to vertical and transmit the grinding forces from the mill table into the foundation.

Since the 1990s three stage gearboxes for high power demanding vertical roller mills have been used. The first gear stage is, in all cases, a bevel gear allowing a first speed reduction and the redirection of the horizontal input axes into the vertical output axis. The further speed reduction is normally achieved by adding two planetary gear stages in series to the bevel gear stage.

Towards the end of the last decade operational experience has shown an increase in damage to the bevel gear stage with the increase of drive power. By using condition monitoring systems with torque measurement for large gears, cement producers and gear manufacturers could counteract this trend. Nevertheless it shows that the bevel gear stage is the weakest element in the drive train and its limits are strongly related to the operation mode.

In 2007, FLSmidth MAAG Gear began building the above mentioned gearbox in a slightly different way. Instead of using two planetary stages connected in series, FLSmidth MAAG Gear implemented a compound epicyclic gear stage where approximately 20 – 25% of the power is directly transmitted from the planet axes of the first stage into the output flange. With this it is possible to build a compact and efficient reducer gear stage.

The toothing of the bevel gear is always designed as cyclo-palloid gearing with a gear ratio in the range of 2:1. Due to its geometry, this type of gearing allows smooth operation and is characterised by its optimal roll-over behaviour. It is well suited for applications in vertical roller mills. One of the basic design conditions is that the transition of tooth contact from one pair of teeth to the next is uninterrupted, meaning that at least one pair of teeth is always in contact. This characteristic is defined by the overlap ratio. With the correct dimensioning, as applied to all gears of FLSmidth MAAG Gear, it is possible to build bevel gears with an overlap ratio above 2.5. Consequently the torque transmission in such a gear is spread over at least two and for more than 50% of the time. It can even be spread over three pairs of teeth. The result is the possibility of transmitting high torque through a single bevel gear stage.
FLSmidth MAAG Gear designs, calculates and produces the bevel gear for the vertical roller mills individually, meaning the layout and the critical manufacturing steps, like heat treatment and final machining, are kept under permanent control. The sophisticated design, in combination with state of the art production methods, allows the company to build conventional gearboxes for vertical roller mills up to a drive power of 9000 kW with a gear ratio up to the range of 60:1.

Capacity increase at a cement plant in the Middle East
FLSmidth won the contract for a plant expansion in the Middle East. The contract included, among other things, a new cement mill of OK™ 54-6 type. This type of vertical roller mill is designed for a production rate of 328 tph of cement.

The mill is equipped with a conventional three stage gearbox MAAG™ WPV-5000 from FLSmidth MAAG Gear. It is designed for a drive power of 7800 kW and gear ratio of 51:1 reduces the input speed from 995 rpm at the asynchronous motor to the required 19.46 rpm of the mill table. The gearbox has an overall dimension of 5 m in dia. and a height of 3.35 m. With a weight of nearly 200 t it is the largest and most powerful gearbox for vertical roller mills in the world.

After the successful factory acceptance test in the workshop in Elblag, Poland, the gearbox was moved to the cement plant where the installation and commissioning took place in spring 2016. Three months later the concluding load tests under the mill were carried out successfully. With this commissioning FLSmidth reached a new milestone in the field of vertical roller mills and drive systems.

But this new cement mill will not have the largest conventional gearbox for long. A second gearbox, of the same size, for the expansion of an Indonesian cement plant has passed its factory acceptance test in 2015. This gearbox is designed for a type OK™ 56-6 raw mill with a drive power of 8600 kW and a gear ratio of 45:1. The commissioning of this gearbox is expected to be in the nearest future.

Conclusion
The trend towards single mill cement lines is strengthening despite the stagnating global economic situation. The vertical roller mill is the ideal mill type for this application because of its flexibility, low energy consumption and high throughput rates. The vertical roller mill will likely become more important in the future and will gain more market shares.

With increasing throughput rates the power demand of the drive system is also increasing. The recent past shows a cumulation of mills in the power range of 6000 kW to 9000 kW.

The major suppliers for drive systems have developed different new drives for vertical roller mills with high power demand.

With the WPV-gearbox FLSmidth MAAG Gear can provide a unique drive system for the above mentioned mill applications. The high-grade bevel gear in combination with the innovative compound epicyclic gear and an efficient condition monitoring system enables the cement producer to rely on common drive technology for high power application. It makes the implementation of complex control systems for new drive solutions needless.