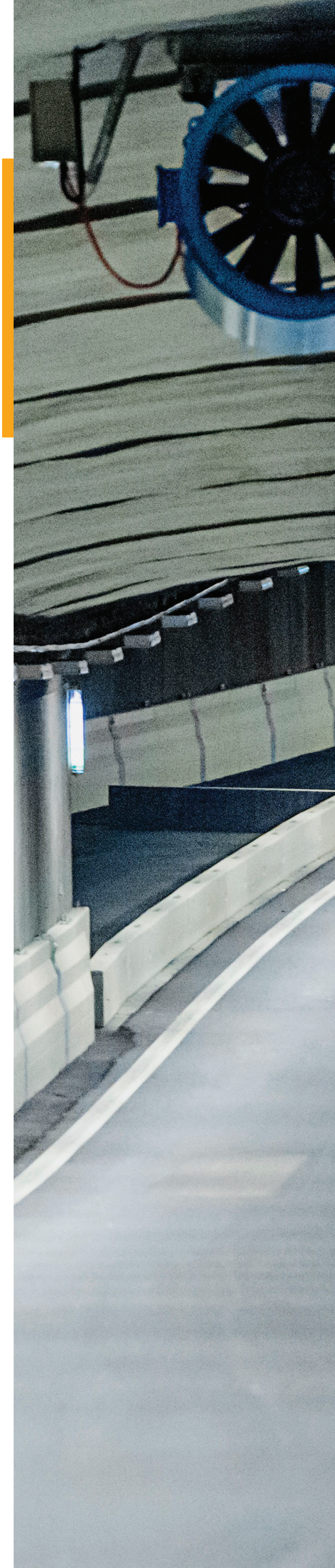
Tunnelling Journal

Controlled ventilation boosts tunnel safety



The use of variable frequency drives (VFDs) and electric motors to control the speed of ventilation fans in road and rail tunnels are increasingly becoming a solution of choice in air ventilation systems. We asked Frank Grundholm, Vice President, Global HVACR Sales, ABB Motion, a few questions to explain why the prominence of VFDs is on the rise.

What is the role that VFDs play in tunnel fire safety management, specifically in terms of containment and evacuation?

Instead of letting ventilation fans operate between shutdown and continuous full-speed operation, the variable speed drives sit between the electrical supply and fan motors, enabling one to control their speed precisely to meet the actual demand for ventilation. So, in the event of a tunnel fire, the fan speed can ramp up fast with the added ability to change the direction of airflow to contain the spread of smoke and poisonous gases. This creates safe zones to allow people to evacuate the tunnel without harm. However, only axial fans and some jet fans offer the capability to reverse airflow direction.

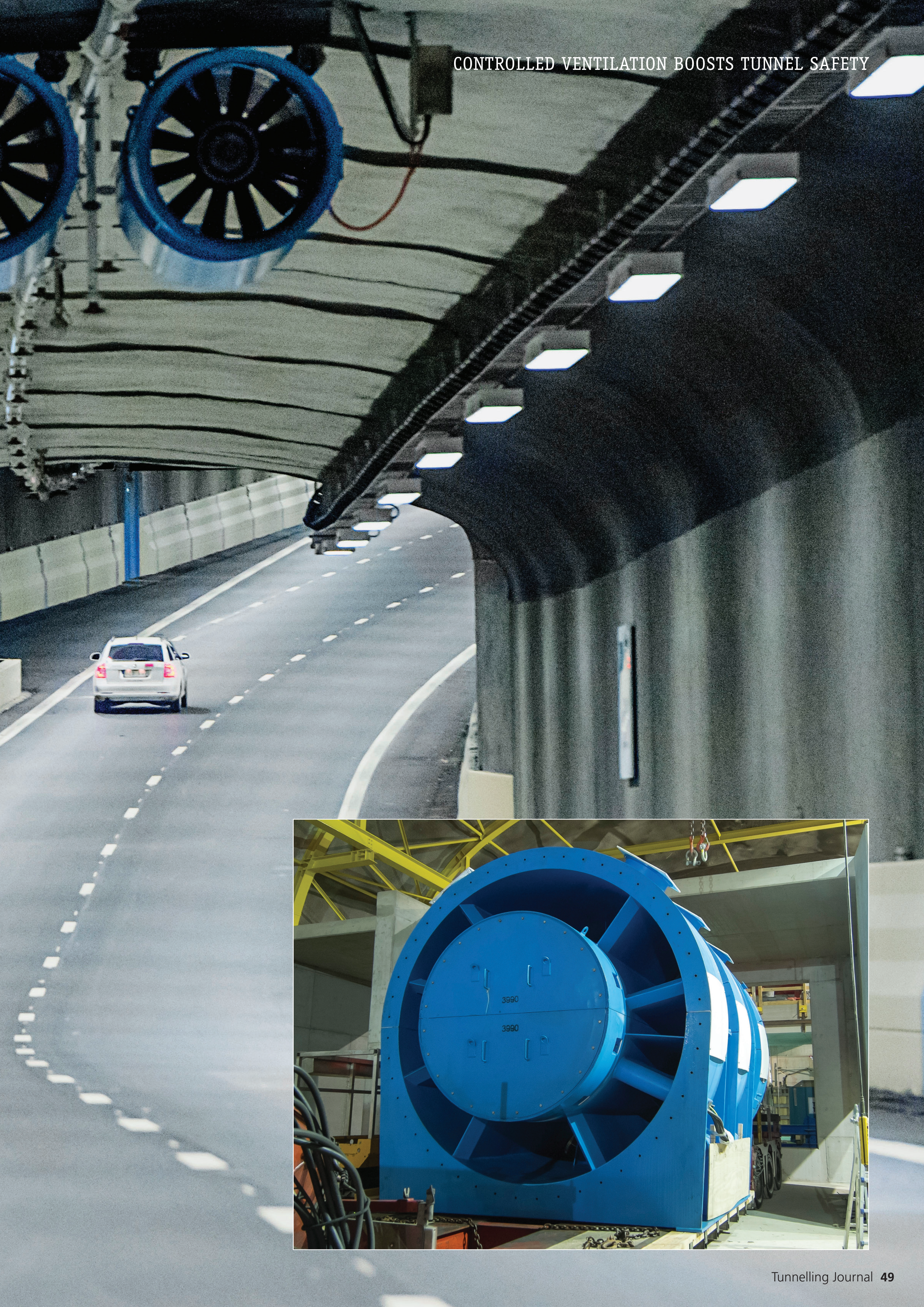
Is it safe to assume that the drives would then also have a positive impact on energy consumption?

Indeed. With drives, the fan speed can be adjusted by the tunnel's overall control system to meet changing airflow needs during the day. This is typically triggered by sensors monitoring the levels of respirable dust, gases and other pollutants within the tunnel. So, there's no need to run the fans at full speed all the time. The energy required to operate a fan varies in proportion to the cube of its speed. That means minimal speed changes can yield substantial energy savings – a speed reduction of 10 percent results in a 27 percent energy saving. Reducing fan speeds can also reduce noise levels. For instance, reducing the speed by only 20 percent can reduce sound pressure by more than 50 percent.

Does this mean regenerative technology also has a role to play?

Correct. When tunnel fans are shut down, they become free to rotate backwards, In this state of free-spinning, also referred to as 'wind milling', it's possible to utilise the airflow through them with regenerative drive technology. The fans effectively become generators that produce energy that can feedback into the local power grid to reduce electricity costs. Moreover, braking resistors are often used when fan speed needs to be ramped down fast, which then dissipates energy as waste heat that adds to the heat burden of the tunnel. Regenerative drives that capture braking energy can eliminate the need for resistors and reduce heat output as a result.

Tunnels are often also in remote locations, where the grid can be unstable or even weak. Any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variation in load can, therefore, harm the sensitive voltage of the grid. With regenerative drive technology, however, full-load operation of the fans can be secured even if there is a drop in voltage. The result is full operation for more extended periods than what would be possible with traditional drives that cannot boost voltage. The active front end of the drive can also reduce the effect of harmonics on the transformer when it is not delivering regenerated power to the grid but operating the ventilation system instead. This helps to avoid overloading.

Do road and rail tunnels require different ventilation schemes?

Yes, they do. A long tunnel for an electrified rail network may have moderate needs for daily ventilation, since the piston effect of trains moving through the tunnel ensures regular exchanges of air. The main focus would, therefore, be on fire safety. A road tunnel, on the other hand, has more complex usage patterns and often consists of multiple lanes in one direction only. The roof is therefore high compared to vehicles, which reduces the piston effect. Some road tunnels reverse the flow of traffic to manage congestion at peak periods, requiring ventilation to work evenly in both directions.

Can you give us some examples of recently completed projects?

Sure. The first example is of a rail tunnel that houses the world's most powerful ventilation system. The Gotthard Base Tunnel, a railway tunnel that stretches for 57km through the Swiss Alps, is also the world's longest railway and deepest traffic tunnel. The flat, low-level route, which is the first of its kind through the Alps, was opened in 2016 to establish a direct route for high-speed rail and heavy freight trains. It's referred to as a base tunnel because it bypasses the old, winding mountain railway line opened in 1882.

The fans used in the ventilation system have an outer diameter of nearly 3.5m, making it the largest and most powerful system in the world. To put it in perspective: the system has an installed capacity of 15.6 megawatts, which is the same as the combined power of 25 Formula 1 racing cars. At the two tunnel portals, there are 24 jet fans, while the two ventilation centres accommodate eight primary supply and exhaust fans.

An ABB ACS1000 medium voltage (MV) drive controls the speed of the motors for the eight primary fans, meaning they only consume as much energy as is necessary for each operating mode. The ventilation centres are responsible for the exchange of air inside the tunnel and form the 'lungs' of the system. The supply air fans provide fresh air from the outside via long vertical shafts, which is regulated by shutters and then distributed in the tunnel. The exhaust air, which has its own shaft, is transported outwards via axial fans with an airspeed of up to 300km/h.

The control of the ventilation system is crucial for the exact adjustment of the fans and the shutters in various scenarios. The master control system regulates nearly 50 scenarios – from normal and maintenance mode to full emergency. The whole system design followed a redundancy approach for safety reasons. In addition to the regular exchange of air, the fans must primarily ensure enough fresh air in the emergency stations in the event of a fire, while simultaneously sucking the smoke through the long exhaust shafts.

The second example refers to the Chenani-Nashri tunnel, the longest highway tunnel in Asia, measuring 10.89km in length. The four-lane road link runs in an all-weather tunnel and was opened in 2017 to improve mobility and safety on India's National Highway 44 between Kashmir and the rest of the country.

It is the first road tunnel in India, and the sixth in the world, to utilise a transverse ventilation system enabled by ABB drives and motors that uses separate air ducts to introduce fresh air inside the tunnel and displace harmful air. The ventilation system uses low harmonic VFDs and motors installed at the North (Nashri) and South (Chenani) portals for air supply and exhaust. To ensure maximum uptime, these VFDs also comprise inbuilt redundancy.

The tunnel design, which boasts unique features such as an integrated traffic control system, fire detection and management, and wireless communication, features a parallel escape tunnel apart from the main tube. The safety software includes an override control feature to mitigate any fire emergencies.

Can you tell us a little more about the override feature?

Many modern VFDs boast an important feature known as the 'fireman's override, an input that allows fire services to take control of VFDs and turn them into smoke extraction units to maintain escape routes. A special key at the fireman's control station usually triggers this mode, which forces the drive to a pre-defined set of running conditions stored in the override menu.

The VFD is programmed to enable a 'run at all costs' mode of operation until destruction, discounting most of its warnings and alarms that would usually stop it if the application was at fault. This ensures maximum availability during the emergency.

Lastly, air quality and fire safety are critical standards in modern tunnel ventilation systems. Variable frequency drives can help to not only ensure maximum uptime and energy efficiency, but also reduce the risk for people in case of fire.