APPLICATION GUIDE

# Fire safety features in ABB HVACR drives

## Override mode and active braking

**Fire safety is of the utmost importance when it comes to designing HVACR in buildings and other infrastructures. Variable frequency drives can play a crucial role in HVACR management in critical situations, offering unique smoke control and removal techniques and ensuring evacuation routes and areas of refuge.**

# Table of contents

# What is override mode?

Large buildings and other infrastructural facilities often need sophisticated heating, ventilation, air conditioning and refrigeration systems to ensure indoor comfort or special conditions in everyday use, but also play a critical role in extreme situations including fires.

Variable frequency drives (VFDs) can bring enormous benefits to HVACR in buildings, yet many of these benefits are not widely recognized. As a result, end-users can be missing out on considerable cost and time savings, but most importantly, life and property safety.

Initially drives are used to provide energy savings in HVACR systems, since the systems are sized to handle peak loads but almost never operate at peak. Drives adjust the speed of motors running fans, pumps or compressors to meet the actual demand. This results in average energy saving over 25%.

Furthermore, some HVACR drives also offer a fire safety capability, called fireman's override mode or simply override. Override directs the drives to respond in fire and life-threatening situations by giving HVACR systems extra flexibility to manage smoke and fire, as well as maintain evacuation routes for safe passage. But it's important to understand that there is no general safety standard governing override mode implementation in drives. Therefore, the feature can differ depending on the drive manufacturer. When specifying the drive's response in case of fire, consultants must examine the details, rather than just requiring override mode as part of the drive software.

To be safe, override mode should allow drives to run a motor at an adjustable, predefined or PID controlled speed, in either direction.

The override mode is usually triggered by the building's Fire Alarm system relay output contacts or by the firefighter's control station. Upon receiving a signal (a contact closure) from the building's fire alarm system, the drive enters override mode and ignores all other inputs whether they be analog or digital, communication signals, or local commands from the drive's keypad.

The drive may be programmed to ignore or reset faults to ensure a "run at all costs" operation. Override mode cannot be triggered by any other signal: once override mode is activated, the drive cannot exit this mode until the fire condition signal is reset by opening the contact closure or removing power from the drive.

**IMPORTANT:** Local regulations and requirements should be checked before using the system.

# Override for ABB HVACR drives

**Introduction**
Override mode is activated by a single digital input to the drive. When override mode is active, operation of the drive system is defined by a programmed set of parameters and most other control inputs are disabled. It is impossible to edit override-specific parameters during override mode. In addition, specific alarms and faults will be ignored or reset.

While this mode is most commonly used in a fire control or a smoke extraction situation, it can be used in any other application that requires such a function.

Fieldbus communications can be used to edit the VFD system's parameters during normal operation, but can neither control the VFD system nor edit its override-parameters when override is activated.

When ABB's HVACR drive is in override mode:
- The display of the control panel will show a message that the override is active.
- The HAND, OFF and AUTO keys on the control panel will be disabled.
- The impact of faults depends on their priority:
  - Faults are grouped into high priority faults and low priority faults.
  - High priority faults are displayed, and they will stop the drive.
  - Reset of high priority faults can be defined to support limited or infinite reset trials.
  - Low priority faults have no impact on the operation of the system when override mode is activated.
- Configured interlocks, if not satisfied, stop the motor when override is activated.

During override mode, the following low priority faults are typically ignored:
- DC under voltage (although it may force the motor to slow down or stop if it is excessive)
- Analog input signal loss (although it may impact the speed of the controlled motor – programmable)
- Motor over temperature
- Drive over temperature
- Panel loss
- Motor stall
- Underload
- Overload
- Supply phase loss
- Motor phase loss
- Over speed
- Communication failure
- External faults
- All other low priority faults

Some faults will cause the system to trip during override mode since ignoring these faults would lead to the system failure. The system can be programmed to attempt a certain number of restarts with a programmed time delay between each restart. This automatic fault reset is programmable independently from the way that such restart attempts are executed during normal operation. These faults are:
- Overcurrent
- Earth leakage
- Short circuit
- DC link overvoltage
- Braking chopper fault
- Safe Torque Off

During override operation, the ABB HVACR drives will be able to control their relay outputs, digital inputs and outputs, and analog outputs in order to communicate their status to the firefighter's control station and the building management system. For example, during override mode DIs may be programmed for different functions than those used during normal operation.

While override is active, the system will continue to communicate and provide status information to the building control system via a fieldbus connection. But commands from the fieldbus or other connectivity can not impact the operation of the VFD system.

When override is no longer active, the system will return to its prior operating state. This means:

- Any external interlocks which might interrupt the operation of the system during normal operation will again be able to provide the same function.
- When override is deactivated, the drive returns to the original programmed mode of operation. If the drive was in the HAND mode before Override was selected, the drive returns to the OFF mode after override is deactivated.
- If the system was in a faulted condition prior to the activation of override mode, the fault will initially be cleared. However, if the same fault occurs once override mode has been disabled, the fault will behave as programmed for normal operation.


Figure 1. ACH580 control panel view for normal and override mode.

**Override method of operation**
The function of the override is determined by programming appropriate parameters in the drive system. The parameter settings determine:
- How the drive's output frequency will be controlled.
- The digital and analog signals that will control the system during override mode.
- How the system will respond to external interlocks.
- How faults will impact the system's operation in override mode.
- How the system will attempt to automatically reset faults which cause the system to stop during override mode.

Access for editing these parameters in override operation can be password protected after commissioning, to prevent unauthorized or accidental changes.

Listed below are the override mode functions, helping to better understand how the drive operates when in the emergency mode.

**Stop**
This function stops the motor. Unlike a normal interlock, this will show on the control panel that the override function is active and keep the system from running in VFD mode.

**VFD**
This function activates the VFD in override mode. The system will follow the rules which were programmed for this mode of operation. If the VFD stops functioning, the system will stop.

For VFD override mode the drive is programmed to control the speed of the motor. This may be the same method that is used for normal operation or it may be unique for the override mode. Examples of VFD operating modes are mentioned later in the paper. In all cases, it is possible to reverse the direction of the motor by activating an appropriate digital input.

**Preset, fixed speed**
When override is activated, the VFD will run the motor at a single, preprogrammed fixed speed.

**Preset, multiple fixed speeds**
Up to three digital inputs can be programmed to allow the selection of up to 8, preprogrammed fixed speeds. The selected speed can be changed while the system is running in override mode. Alternatively, a single digital input can be tied to a specific fixed speed, to allow the selection of up to 6 fixed speeds with 6 independent inputs.

**Variable speed control**
An analog speed reference signal can be programmed to control the speed of the motor during override operation. While this may be the same speed reference that is used for normal operation, it does not have to be. This speed command cannot be provided through a fieldbus or other connectivity.

**Closed-loop PID control**
The speed of the controlled motor can be controlled by the VFD's PID controller. This may be the same control method that is used during normal operation, although it may also be unique for override mode. The feedback signal will be hard-wired to one of the VFD's analog inputs. The setpoint may be provided by:
- a drive parameter that is programmed for the desired setpoint.
- an analog input to provide the setpoint for the PID controller.
- selecting from up to four unique setpoints.

The control signals for the override mode can be hard-wired analog and digital inputs. System operation during override cannot be controlled by a fieldbus or any other connectivity.

**Floating point control**
Two digital inputs are programmed for "increase speed" and "decrease speed". When either is activated, the output frequency of the VFD will change as dictated by the digital input activated. The rate of change of the output frequency will be determined by an appropriate acceleration and deceleration ramp setting.

# Override application examples

Most of the deaths or injuries that occur in a fire are not caused by heat or flame. Instead they are the result of smoke inhalation and intoxication due to high levels of carbon monoxide and nitrous oxides. Therefore, proper smoke management via airflow control is critically important for minimizing injury and death to people, as well as damage to property. Here we give some examples of factors to be considered in fires regarding smoke and air control, and how the ABB HVACR drive's override mode works in such situations.

**HVACR units in residential and commercial buildings**

Proper integration of HVACR components, including VFDs into a building's smoke control system is critical. Modern smoke control systems can automatically identify the location of the fire, stop fresh air supply to the source of fire, exhaust smoke, prevent its further spread, and change the evacuation route depending where the fire is detected. To accomplish this advanced control, the VFD package must be specified with care.

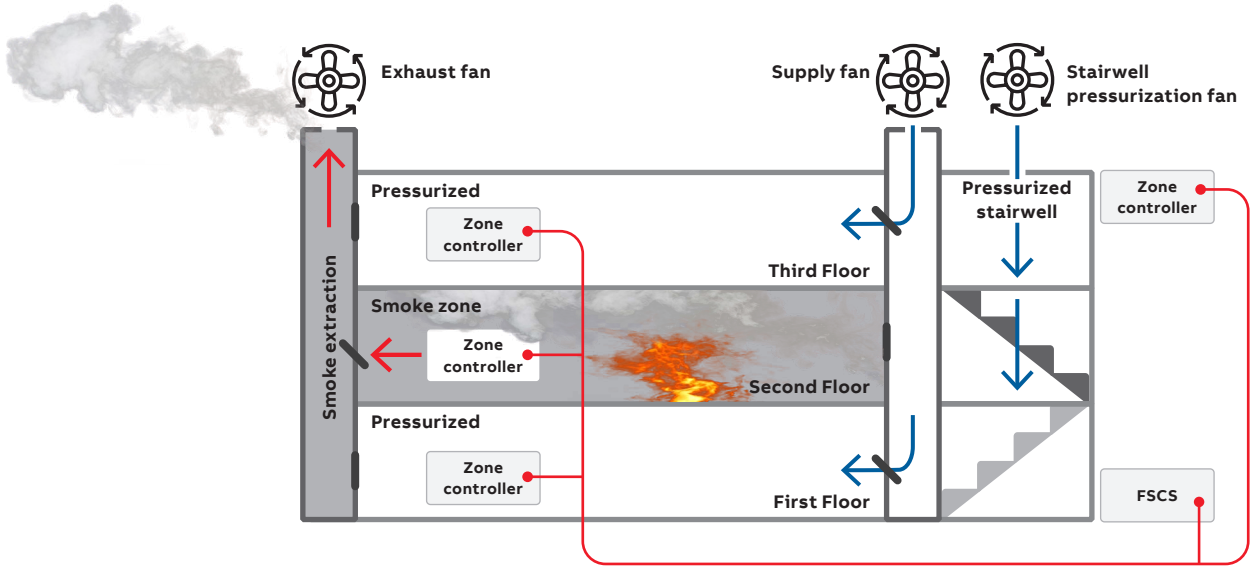
In case of a fire in a large building, basically two functions of fans are required: extraction of smoke, and bringing in and managing fresh air flows. It must ensure that no additional oxygen is being fed to the fire, while at the same time delivering air to escape routes and safety zones.

Smoke control strategy depends on numerous factors such as the number of floors and the construction of the building, and usually requires a pressurization technique in combination with compartmentation. In such case a building is considered as a number of smoke control zones that are separated from each other by walls, doors and floors. Depending on the specific building and HVACR system design, a smoke control zone can include several floors and even an individual floor may include several smoke control zones.

When a fire occurs in a smoke control zone, all the adjacent zones become pressurized. The fireman's smoke control station (FSCS) may also pressurize unaffected zones or leave them in normal operation. Pressure produced by the fans limits smoke movement from one smoke control zone to an adjacent one, and also to unaffected zones (figure 2). Some engineers call this concept a pressure sandwich.

The ABB's drive override feature allows it to run exhaust fans in reverse to provide additional pressurizing capability that may be helpful in certain cases. Similarly, supply fans running in reverse mode can help to remove smoke from the building. Note: Before applying this bidirectional strategy, the fan type and design must be considered.

—
Figure 2. Smoke control zones in buildings.



The result is that the drive override mode can ensure that, in complex smoke and airflow situations in large buildings, the fans are running in the best way for optimum fire and smoke control. So override can be a very useful tool in any smoke control strategy.

**Evacuation routes in buildings**
Smoke management for stairwells applies pressurization techniques to prevent smoke from spreading through stairwells to other floors and also to provide both safe evacuation routes for building occupants and staging area for a firefighting crew. In case of a fire, the stairwell becomes a high-pressure zone and the pressure difference across closed stairwell doors prevents smoke infiltration into the stairwell.

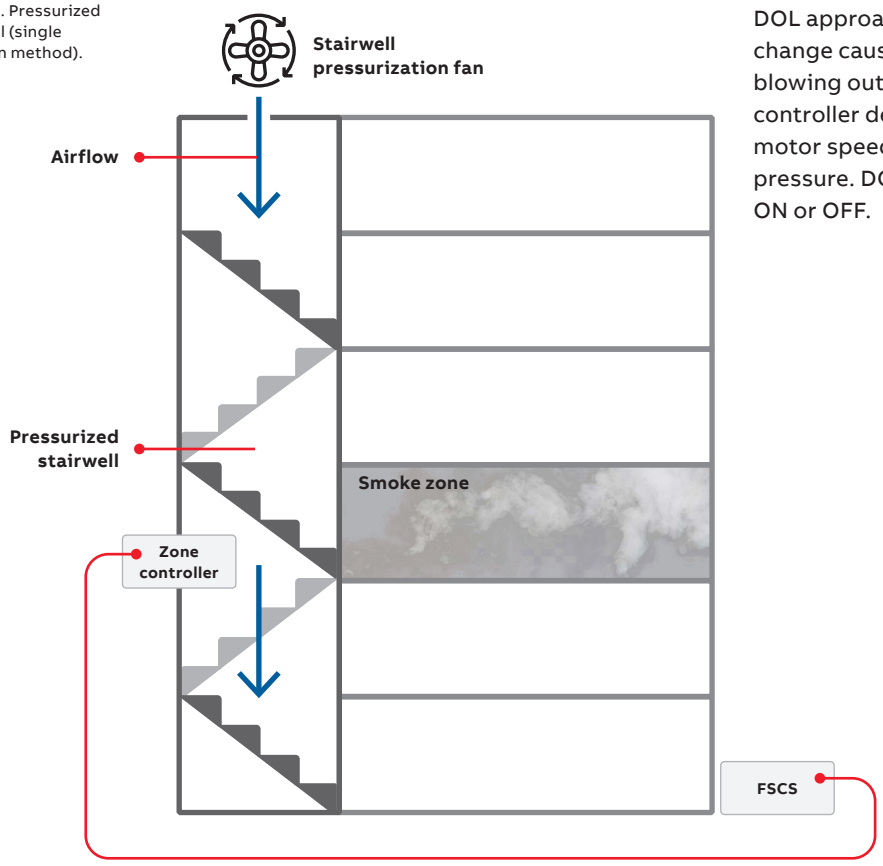
Stairwell smoke control can use different air injection and pressure compensation techniques, but the most reliable and efficient solution to the problems associated with insufficient or excess pressure in stairwells is the application of variable frequency drives. VFDs are able to control the fan's speed and therefore the pressurization rate during override mode.

Multiple fan speed operation during override mode solves a number of significant problems. It avoids excessive stairwell pressures that might block stairwell doors and cut off evacuation routes. And, at the same time, it keeps the pressure high enough to prevent smoke leakage to stairwell spaces.

Using stairwell pressurization to ensure escape routes are accessible is easier with a VFD in PID control than with an uncontrolled direct-on-line (DOL) motor. This is because DOL runs the motors at full speed without any control, whereas PID control maintains the pressure in a stairwell at a constant value, thereby keeping the stairwell positively pressurized to keep smoke out and ensuring the doors can still be opened.

ABB's HVACR drives, with their ability to control fan motor speed, can enable a more elegant and adaptive smoke control strategy than traditional DOL approaches. If there is a sudden pressure change caused by doors opening or windows blowing out or walls burning away, the PID controller detects such changes and alters the motor speed accordingly to keep the correct pressure. DOL cannot do this, as it is only ON or OFF.

—
Figure 3. Pressurized stairwell (single injection method).



**Malls, atriums, arenas and similar large volume spaces**

Similar principles of smoke management apply to long-span, large-volume buildings. Although, it is usually more difficult to control smoke and air flows in these buildings since they are quite often oriented more horizontally than vertically.

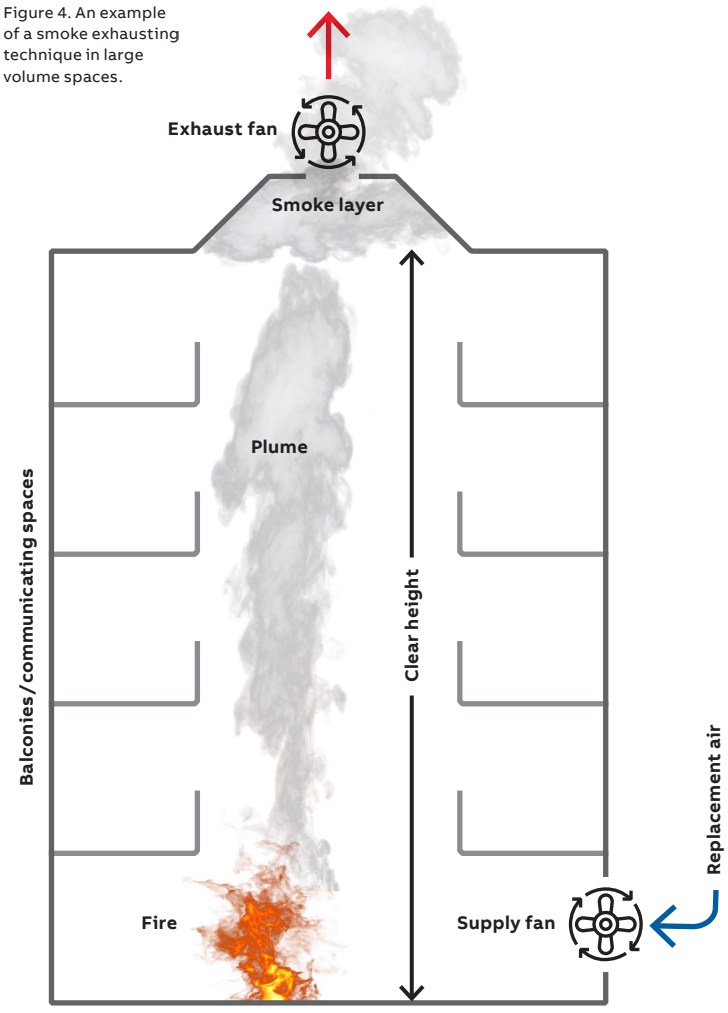
In case of fire in a large volume space, a typical strategy is to exhaust smoke through the top of the structure. Smoke management systems must be able to keep the smoke layer higher than the occupiable zone of the highest floor that is being used for evacuation purposes. Therefore, exhaust fans under the ceiling must remove smoke at a rate that is greater than or equal to the smoke production rate. And maintain this rate to prevent the smoke layer from descending, thus supporting safe evacuation.

At the same time, the smoke cannot be extracted at too fast a rate, to avoid a plugholing effect when the fresh air from the atrium space is being removed through the smoke layer, making the smoke removal inefficient.

In certain cases, smoke extraction is followed up by introducing fresh air to the space. Fresh air replaces the volume of smoke exhausted by fans and keeps inner indoor pressure positive to facilitate the process of smoke extraction.

A well though-out solution for HVACR systems in large volume spaces is required to maintain a comfortable environment during normal operation and to react properly in emergencies. ABB HVACR drives are well equipped to meet crucial airflow-management challenges in malls, atriums, arenas and similar buildings. The possibility for bidirectional variable speed fan control in override, and the flexibility to change from normal mode to override, while ignoring all the low priority fault signals make these drives excellent support for fire control and smoke control strategies.

—
Figure 4. An example of a smoke exhausting technique in large volume spaces.




**Tunnels**

A road tunnel is a sophisticated engineering construction that has very strict requirements for air quality. Special attention has to be paid to the design of tunnel ventilation systems which control the concentration of contaminants emitted by vehicles in normal operation. However, the most important design requirement is to extract smoke and provide evacuation routes in case of a fire.

Smoke control in tunnels is typically achieved by either extracting the smoke through air ducts or by pushing it through the tunnel and out a portal. The choice of smoke control strategy depends on the type of ventilation systems, the mode of traffic operation and the surrounding environment.

Regardless of the ventilation system type, tunnels often require more than one fan speed while in override mode. Override mode in tunnels typically starts at a low speed to maintain stratification and provide escape routes under the smoke layer. The speed increases after finishing the evacuation, to keep the smoke on the downstream side of the fire and provide a staging area for firefighters. In this case, the fireman's smoke control station will provide individual contact closures to the VFD to select the various preset (constant) speeds or use floating point control.

The ABB HVACR drives allow fans to run at any speed in either direction to better manage the airflow and control smoke movement inside the tunnel. Depending on the location of a fire and its stage, the fire control system defines airflow velocity and direction by, for example, placing air supply fans into reverse mode to provide smoke extraction. Note: only valid for bidirectional fan types.

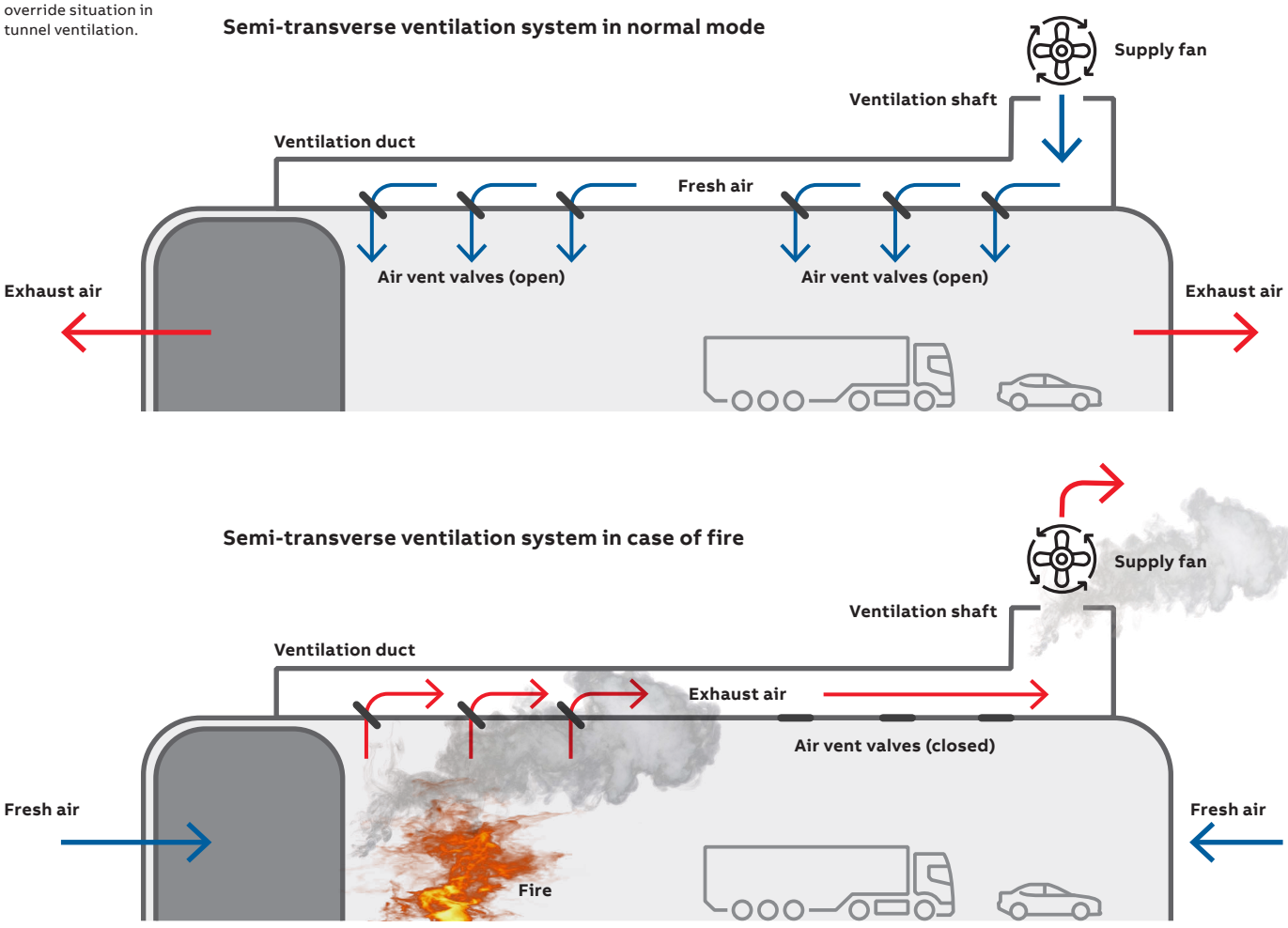
It is also important to consider active braking in these reversing fan-direction applications. Active braking is covered in more detail in the next section.

Another important feature of the ABB drives while in override mode is their ability to handle a flying start. Wind in a tunnel often causes freewheeling of the fans. Thus, the drive that controls the fan motor needs to be able to handle a flying start by catching the rotating fan load – to either continue turning the fan in the same direction, or change it if necessary.

A change of direction can cause a mechanical shock to the system. The advantage of flying start capabilities in the ABB drives is that they recognize what is happening in the particular situation and are able to quickly and smoothly catch the rotating fan load and match the motor frequency, without first having to take the speed down to zero if the fan was windmilling in the right direction before.

Tunnel ventilation systems have sophisticated designs, and high installation and operational costs, since they consume a considerable amount of energy and require expensive, high-technology equipment. The ABB HVACR drives meet tunnel ventilation system design requirements, while also decreasing power consumption, boosting efficiency and helping to control fire and smoke events, to protect both people and infrastructure.

—
Figure 5. Example of override situation in tunnel ventilation.



# Active braking

*) Note: check with your local ABB representative if the feature comes as standard with your ABB ULH drive or needs to be purchased separately.

The active braking functionality is available as an additional feature for ABB ultra-low harmonic HVACR drives *).

Active braking feature allows drives to address specific fire safety needs in tunnel ventilation systems as described below. It is also useful in other facilities that require fast fan stops in case of emergency, like biosafety labs.

**Use cases**
There are several distinct use cases where active braking can be utilized in emergency tunnel ventilation when timing is critical – stopping a running or windmilling fan to 0 speed or changing a running fan direction to the opposite.

**Windmilling**
Windmilling can happen due to pressure differences at different ends of air ducts or tunnels, which can lead to random fan rotation in any direction. Starting the fan in the right direction can cause mechanical damage if it was spinning in the opposite direction before. To avoid this, the drive must catch the spinning fan, stop it first and then start it in the right direction. If there is no braking solution employed, the drive may not be able to stop the fan fast enough, or at all – if the overvoltage limit is reached, the drive will trip. With the active braking feature, this process takes significantly less time, which is critical in case of a fire.

**Stop or direction change is needed**
When tunnel fans are in normal ventilation mode, and a fire is detected, active braking can be helpful for stopping them or changing their direction. In this case, a lot depends on the tunnel ventilation system design and smoke extraction strategy.

If fans are single purpose and supply fresh air in normal mode, they might need to be stopped as quickly as possible to stop adding fresh air to the fire.

If the fans are dual purpose, they can supply fresh air in normal mode and work as smoke exhaust units in case of fire. Depending on in what part of the tunnel the fire occurs, the ventilation system design and the fan type (uni-directional or bi-directional), the fans might need to be stopped as quickly as possible and then reverse in full speed to start extracting the smoke from the tunnel.

Under these conditions, the drive usually works in critical override mode, and active braking is needed for stopping the fan in the shortest possible period of time.

**Feature overview**
Active braking is activated in two scenarios. One scenario is when the drive enters the critical override mode. In this case active braking will deactivate after the drive exits the critical override mode.

The second scenario is when the drive needs to start the fan motor, and the motor is spinning in the opposite direction. Active braking will remain active until the motor is brought to stop, after which the drive starts to follow the given frequency or speed reference.

For systems that have generator power as backup, a digital input can be used to disable active braking once the drive is connected to generator power. This is due to the fact that generators have limited ability to absorb regenerative active breaking power. Unless the regenerative power will be consumed elsewhere in the system, active braking should be disabled when the drive is connected to a generator.

**Active braking when starting the drive**
If there is a drive without active braking, and the motor is already spinning, but the user requests speed reference to the opposite direction, it is not possible to perform fast reversing. As the dive will not allow braking energy regeneration, it will cause DC voltage to rise until it hits the drive overvoltage limit.

As the drive activates the Overvoltage control, it will lower the torque to keep DC voltage at the overvoltage level until the motor speed has reached the zero-speed region. If there is a lot of inertia, this can significantly extend the time it takes to reach the requested reference speed.

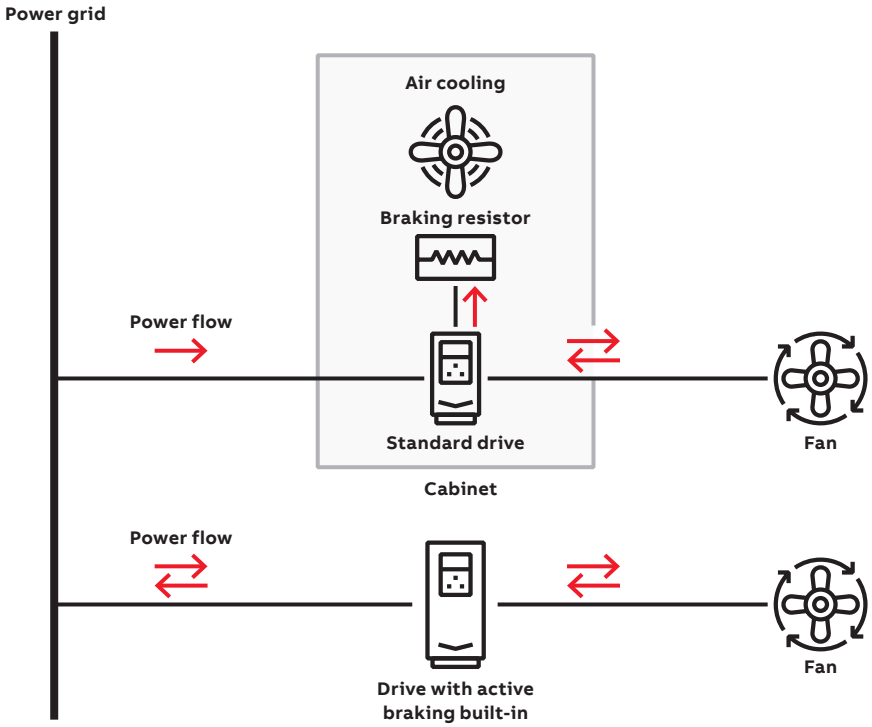
The situation changes if the drive has active braking. In that case braking power regeneration back to grid becomes possible, which can be up to 50% of the drive's nominal power.

The drive will brake the fan much faster, without reaching the overvoltage level if regenerative power does not exceed the active braking power limit.

If needed, the user can disable active braking, for example with a digital input. This will immediately disable active braking and prevent further activations.

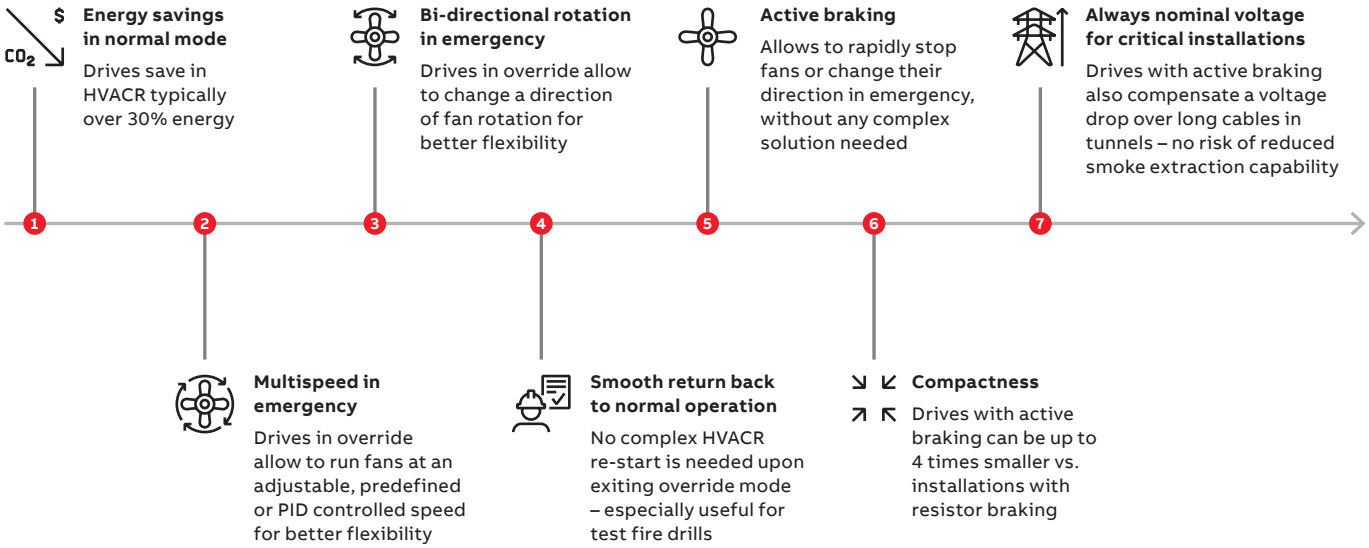
**Active braking when in critical override mode**
If the drive does not have an active braking feature, braking power regeneration back to the grid is not possible. A drive without active braking would be decelerating the fan motor slowly to avoid overvoltage while being activated in critical override mode, when the user requests the fan stop or reversing to the opposite direction with parameter Override direction.

The situation changes if active braking is available for a drive. In that case, when the user activates the critical override mode in the drive, then active braking activates and allows regenerative power up to parameter Active braking power limit. Active braking will stay active until the drive exits critical override mode or until disabling is requested via Active braking disable.




—
Figure 6. The systems with resistor braking vs. active braking as part of the drive.

# Benefits for owners




In addition to saving considerable amounts of energy during the normal mode, the ABB HVACR drives make HVACR and smoke control systems more flexible and more robust during adverse conditions. The integrated override mode is one of the best features that further enhance their robustness.

One of the key differences between ABB HVACR drives and other drives is the ability to shift from normal mode to override mode and then back again seamlessly without interrupting the operation the HVACR system. This means in facilities where override mode is used for evacuation purposes, properly designed and executed regular inspections and test runs (fire drills) will not upset the HVACR even when the facility is operating. The required indoor conditions will continue being maintained upon the fire test run is done.

Another important feature of ABB HVACR drives is the ability to be controlled at multiple speeds without interrupting override mode. This is critical for pressure management in spaces used for evacuation. The multiple speed feature on the drives allows fans to produce enough pressure to keep smoke from entering the evacuation routes while avoiding too high overpressure that might cause blocking the doors to the evacuation routes and trapping people. The drives provide reliable and efficient solutions to the problems with insufficient or excess pressure by regulating air flow and therefore pressurization – even in the override mode.

Furthermore, the drives allow the smoke control system to put bidirectional air supply fans into reverse mode immediately, to rapidly provide smoke extraction capability in case of fire.

The list of benefits goes even further with drive-based active braking features combined with override. As fast braking is often a requirement in tunnel ventilation, the standard solution includes a cabinet consisting of a standard 6-pulse drive, brake chopper, external braking resistor and air conditioning, as the cabinet needs to be cooled down once the resistor starts dissipating braking energy in the form of heat. Usually the footprint of such solutions is considerably larger (4 times or more) compared to drives with active braking built-in, which is critical for tight underground spaces. And the installation cost is usually higher as well.

In addition to braking capabilities built-in, ABB active front end drives can compensate voltage drops occurring over long cables in tunnels and deliver nominal voltage at the application end. This is essential for emergency applications like smoke exhaust fans, where reduced smoke extraction capability can be life threatening.

# Conclusions

ABB drive engineers pride themselves in designing features tailored specifically for different types of HVACR applications. When designing HVACR drives, we concentrate on getting a thorough understanding of the overall market, specific HVACR applications and individual customer requirements. This focus steers the overall ABB HVACR drives design strategy. It results in our drives having many useful features that our customers can trust and rely on for safe and efficient operation of their facilities.

The sales and support departments of ABB Drives as well as ABB channel partners also play a major role in keeping facility owners satisfied, as spare parts are stocked across the world and are often available the same day. This is highly important when the application is an educational building, healthcare unit, tunnel or other critical environment. ABB's global service and support network provides help whenever and wherever needed.

Mission-critical environments all require specific indoor conditions and simply cannot tolerate failure. The fact is that fan packages from some suppliers are often sold based upon simplicity and their ease-of-use – rather than whether they are fit for purpose. ABB HVACR drives are always fit for purpose, extremely energy efficient, highly reliable and offering excellent spare parts availability. All of these differences add up major benefits and added value being delivered via HVACR systems to building and infrastructure owners and operators.

# Frequently asked questions

**What is Firefighter's override mode in drives?**
The override mode aids building services engineers in designing well-functioning escape routes and smoke control strategies within a building in case of fire emergency. It also allows emergency services to easily trigger essential functions to aid in the evacuation of occupants or whilst fighting fires.

Variable fan speed allows more specific escape routes to be designed by employing areas of positive pressure to hold stairwells free from smoke. Also, because the speed can be variable and under PID control, changing building and fire conditions can be accommodated.

Override mode can also ensure the drive continues to run as long as possible, prioritizing this mode and giving maximum availability to the mode once triggered.

**How does it work?**
Override mode is triggered by the emergency services or the Fire Smoke Control Panel and puts the drive into a predefined set of running instructions, including preset speeds and preset control locations.

The function can be protected by passwords.

When in override mode, the VFD is programmed to ignore most of its faults and warnings that would normally stop the drive, ensuring maximum availability during the emergency.

**Why is it important?**
Override mode is designed to allow fire departments and other emergency responders to use drives for assistance with smoke management and to maintain escape routes. The mode is usually triggered with a special key at the firefighter's control station. The drives may then operate the fan motors in the required direction at a required speed to remove smoke from the building, assisting with visibility and safety during firefighting. The override mode in ABB HVACR drives also allows stairwell pressurization to be accomplished, which may require motors to be run at "overspeed" to keep escape routes free of smoke.

**Why is it not a feature of all drives?**
The ABB HVACR drives have this feature as a standard because of the HVACR industry requirements. The feature allows the drives to take smoke management control, thus reducing complicated wiring and central BMS control. It can be activated regardless of the state which the drive is currently in. Other industries do not require this special function, so it is not included with non-HVACR VFDs.

**What happens if there is no such feature?**
Without Firefighter's override mode built into the drive, the function would have to be handled by the building management system (BMS), requiring much more complex programming and installation. Also, since the drive has to locally control the motor so that it ignores most faults, this function could not be performed by the BMS on its own, as the drive needs a special mode to ignore these issues internally. A more complex systems would have to be employed which would be less straightforward to control. As a result, large infrastructures like modern high-rise buildings would be harder to protect.

**Additional information**
We reserve the right to make technical changes or modify the contents of this document without prior notice. With regard to purchase orders, the agreed particulars shall prevail. ABB does not accept any responsibility whatsoever for potential errors or possible lack of information in this document.

For more information, please contact
your local ABB representative or visit

**new.abb.com/drives/segment/hvac**
**new.abb.com/drives/drivespartners**



3AUA0000206522 REV E EN 11.4.2024