Two-speed jet fans installed in a basement car park

Ventilation and Smoke Evacuation Systems for Car Parks

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Introduction

Buildings are growing vertically due to scarce land availability, and almost all high rise buildings have multilevel underground and over ground car parks. In case of fire, these become smoke reservoirs. Let alone basements, even many modern commercial buildings can be called smoke reservoirs, since they rarely have any operable windows. Smoke evacuation system from such constructions is therefore a necessity rather than a matter of choice; moreover, it is mandatory in every building.

Objective - Safety of Public and Property

1) Pollution Mode
   - Healthier environment by removing car fumes
   - Maintenance of pollution level within acceptable limits, not harmful for the public or occupants
2) Fire Mode
   - To provide smoke free access to fire fighters
   - Speedy clearance of post fire smoke

Challenges

- Smoke evacuation and ventilation systems are installed as per National Building Code (NBC) and the local Fire Authority's requirements, which are unfortunately not uniform across India.
- NBC specifies 12 air changes per hour (ACH) rates for normal pollution mode and 30 ACH during fire. The developed world follows 6 and 10 ACH respectively. As a result the installed first cost, electrical demand and electrical infrastructure of the system are very high in India.
- Operating cost is also very high due to excessive ventilation rates; hence operations people tend to switch off the total system, making it a show piece not serving the main purpose. This defeats the objective of installing the system, putting human habitats and building fabric at risk.
- During a fire, the continuously non-operational system often fails and public and property safety is subjected to high risk. Smoke free access is denied to fire fighters, which may lead

About the Author

Dilip Nemani is founder and MD of Airovient Fans & Systems Pvt. Ltd., Kolkata. He has been involved in HVAC business since 1981 as a manufacturers of fans, and has been a supplier to HVAC trade, steel plants, atomic and nuclear plants, coal mines, power plants etc. He introduced demand controlled ventilation systems for car parks in India, based on pollution levels to minimise energy consumption. His goal is to provide cost effective and energy efficient ventilation solution.

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to loss of human life and cause severe damage to the property.

Energy conservation, efficient newer technologies and innovative ideas are the need of the hour. Engineers have to keep in mind the following factors while designing a cost effective, energy efficient innovative green solution:

- Cost effective energy efficient system.
- Maintenance of pollution level within permissible limits.
- Avoidance of excess ventilation when the pollution level drops, so as to help conserve energy. System should be demand controlled, i.e. operate only when there is a need.
- Instantaneous adjustment of ACH rates depending upon the pollution level.
- Sustaining reduced energy levels to ensure high operational cost savings during the life span of the building, thus lowering the total life cycle cost of the system substantially.
- Fail proof life saving system that can be relied upon during an emergency.
- Mechanism (software algorithm) to ensure the system's health through regular checks, using the diagnostic tool that can be provided in the control panel.
- User friendly operation.

Demand Controlled Ventilation

Typically, in a basement, the pollution level is never constant. It keeps changing depending on vehicle movement. A varying pollution level would require some degree of instantaneous, controlled and efficient ventilation.

Constant rate systems consume energy continuously during the working hours of car park. This makes the system operation unviable due to its high cost of operation as well as promotes global warming indirectly.

On the other hand, demand controlled ventilation is an effective and efficient means of ensuring that the ventilation rate matches the varying pollution levels, while keeping a constant balance and ensuring effective energy use.

Operational Logic

The system needs to be installed following the criteria laid down by the local Fire Authority, which is generally as follows:

- 8-12 ACH during normal pollution mode
- 30 ACH during fire mode
- CO level within 26 ppm, with peak levels not to exceed 120 ppm

The developed world follows *BS: 7346* and/or ASHRAE which calls for

- 6 ACH during normal pollution mode
- 10 ACH during fire mode
- CO level within 30 ppm, with peak levels not to exceed 100 ppm
- Time Weighted Average (TWA) for long term exposure is 30 ppm, while short term exposure limit in 15 minutes is 200 ppm

a) *Ventilation rate* is determined after taking into consideration the number of vehicles in operation, length and time of operation, vehicle emission rate, and acceptable level of CO and CO_{max}. Assuming that the number of vehicles in operation during peak use is 40% of the total vehicle capacity, the rate of 6 ACH has been determined. The rate of ventilation would therefore vary for varying level of pollution, i.e., the number of vehicles in operation. Hence the solution is demand controlled ventilation.

b) *Contaminant level criteria ACGIH (1998)* recommends a threshold CO limit of 25 ppm for an 8 hour exposure, and the U.S. *EPA (2000)* determines that exposure, at or near sea level, to a CO concentration of 35 ppm for up to 1 hour is acceptable. In Europe, an average concentration of 35 ppm and a maximum level of 200 ppm are usually maintained in parking garages.

Various agencies and countries differ on the acceptable level of CO in parking garages, but a reasonable solution is a ventilation rate designed to maintain a CO level of 35 ppm for 1 hour exposure, with a maximum of 120 ppm, or 25 ppm for an 8 hour exposure. Because the time associated with driving in and parking, or driving out of a garage, is in the order of minutes, 35 ppm is probably an acceptable level of exposure. Hence when the ventilation rate is dependent on CO level, there must be a control on the ACH rates to conserve energy.

Therefore, a parking garage ventilation system should meet applicable codes and maintain acceptable contaminant levels. The ventilation airflow rate should be varied according to CO levels to conserve energy. For example, the ventilation system could consist of multiple fans, with single or two-speed motors, or variable pitch blades. In multilevel parking garages or single-level structures spread over extensive area, independent fan systems with individual controls are preferred.

Control Strategies

- Constant volume (CV), where the ventilation system is kept *on* during the entire occupancy period.
- *On/off* control, with fans stopped and started based on input from CO sensors.
- Variable air volume (VAV) control, using either two-speed fans or axial fans with variable-pitch blades, based on input from CO sensors.
- Significant fan energy savings can be obtained using a CO-based demand ventilation control strategy to operate the ventilation system, maintaining CO levels below 25/35 ppm.

Hence the system can be designed with the following considerations:

- Install equipment as per local legislation to get NOC.
- Operate the system as per *BS: 7346* at 6 ACH during peak pollution mode.
- TWA for long term exposure at 26 ppm of CO for 8 hour is not harmful and acceptable as per NBC.
- TWA for short term exposure for 15 minutes is limited to 100 ppm CO (120 AS PER NBC).
- Operational logic to keep varying the speed of fresh and exhaust air fans between 2 and 6 ACH, between CO level 26 and 100 PPM.

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Automation and Control

In order to maximize the benefits, adopting microprocessor based digital variable speed control for a CO-based demand ventilation control strategy would yield maximum benefits.

Fan Operation

a) Normal pollution mode smoke spill fans are operated via VFD,
b) Fire/emergency smoke exhaust fans are operated using DOL starters, and
c) Jet fans with two speed motors (low speed operation during normal pollution mode operation and high speed for emergency smoke extract mode).

Control Panel with PLC

Each fan starter panel should be equipped with Programmable Logic Controller (PLC). CO level monitored through the zonal CO sensors sends signal of pollution level to PLC, which triggers the operation of Jet fans at low speed in the affected zone and, in parallel, regulates the frequency of the variable frequency drive to regulate the speed of normal fresh and exhaust fans.

Fire panel (FACP – Fire Alarm Control Panel) feedback is necessary to operate the system at full speed during fire condition. It is further recommended to provide micro-processor based Remote Logic Controller with all logics and built-in HMI (Human Machine Interface) for monitoring the panel individually.

Individual Fan Starter Panel (FSP) having PLC should be linked with Master Logic Controller (MLC) where the status of all other individual panels can be monitored. MLC is typically placed in BMS room for centralized monitoring. MLC should have HMI for easy user friendly operator interface with touch screen. MLC should have provision for future expansion to link with client BMS. The complete microprocessor logic of fans switching on during fire should also be a part of the system.

Advantages

- Maximum energy conservation hence highest possible energy and operational cost savings, thus reducing the total life cycle cost of the system.
- Step-less automatic control of ventilation rates i.e. without doing excessive exchange rates.
- Lower noise levels due to fans operating at low speed during normal pollution mode. Potential to avoid installation of silencers and back draft damper that saves pressure drop and reduces installed load on main fans.
- Wear and tear and maintenance on mechanical and electrical equipment is also reduced.
- Viable for regular operation that keeps fan and system healthy. On an average, power of 5% of the installed capacity is sufficient for a 12/30 ACH design to maintain IAQ during normal day-to-day operation.
- Ensures healthy environment and clearance of smoke in case of fire. ❖