Hybrid ventilation systems enslaved by IAQ sensors

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1 INTRODUCTION

We're spending 90% of our life in enclosed environments, of which 50% in our homes (OMS, 2000). Indoor Air Quality (IAQ) of residential buildings must be control to guarantee health of the inhabitants. Conventional ventilation systems are basing their exhaust airflows rates on the regulations in force which is aging now and doesn't take the new IAQ data we have today into account. In the mid 80's, humidity sensitive ventilation systems appear to modulate the air inlets and outlets sections regarding to the humidity rate in the room thanks to a humidity sensitive material. This was the first step for a smart ventilation system providing an air renewal adapted to the humidity rate.

A lot of researches highlighted that the indoor air is full of pollutants emitted by indoor furniture, floors, paints, human activities. All of these sources can emit volatile organic compounds (VOCs), ozone, benzene, formaldehydes and other air pollutants that are harmful to one's health (CSTB, ANSES, & OQAI, 2014). Conventional ventilation systems can't answer completely to the IAQ matters because they are not equipped with the adapted technology and the ventilation strategy isn't efficient to extract air when it's needed. Regulation is starting to be more precise about these pollutants facts and some directives appear to improve IAQ in public spaces first. In 2011, France Public Access Buildings (PAB) regulation has set limit values for two pollutants: 30 µg/m3 for formaldehyde and 5 µg/m3 for benzene. These values must be downgraded (2011-1727 Decree, 2011) to reach 10 µg/m3 for Formaldehyde in 2023 and 2 µg/m3 for Benzene since 2016. The monitoring of PAB open to the public after these dates is done at the latest December the 31st of the civil year when it opened. This monitoring, conducted by the owner of the building, must be done every seven years or every two years in case of overtaking for at least one of the two pollutants. The measurement of gaseous pollutants must be performed by an accredited organisation that delivers a report to building users.

French residential buildings do not have any regulations for IAQ monitoring and ventilation systems manufacturers can only refer to standards that gives directions to determine performance criteria (CEN/TR 14788:2006, 2006) (EN 15665:2009, 2009). French regulation still bases air renewal on airflow rates that are not adapted to guaranty a good IAQ and constitutes a barrier to the development of new ventilation strategies and technologies. In 2014, a study from CSTB, ANSES and OQAI demonstrated that a bad IAQ was responsible of 20 000 death cases a year, 28 000 new pathologic cases every year and costs €19 billion every year to social security in France (CSTB, ANSES, & OQAI, 2014) (Rapport N°610 - Sénat, 2015).

That's an alarming report which shows ventilation systems' lack of efficiency and, whereas it's important to take IAQ in Public Access Buildings into account, IAQ in Residential Buildings is also a critical topic.

Nowadays, 47% of conventional ventilation units installations are non-compliant (CEREMA, 2012). The absence of a real consideration for the different gaseous pollutants for a good IAQ and the lack of rigor from installers and maintenance staffs are often the cause of these non-conformances. For the installation part, there is nothing to do except monitoring and correcting installers at work. For the maintenance part, the reactivity of maintenance staffs depends on how they're alerted of a ventilation system malfunction. That's why buildings become more and more equipped with connected objects or monitoring and controling systems for buildings equipment. The ventilation sector is now able to appropriate these new technologies to improve its reliability and effectiveness.

Another important stake is to limit heat losses due to the ventilation in buildings and to improve global energy performances of ventilation systems. We already know that hybrid ventilation systems are efficient to avoid heat losses and reduce power consumption in residential buildings by using renewable energies, working in *Natural Mode* (Flourentzou & Pantet, 2015) : thanks to their low-pressure operation and the fact that the operation of the boosted stack effect extraction depends on weather conditions.

In this document, we will present a new concept of ventilation system for residential building, based on a hybrid ventilation system, mainly control by weather conditions and IAQ sensors to optimize exhaust airflows rates, for the purpose of improving global building energy performance and improving the quality of life of the occupiers.

2 THE OPERATING PRINCIPLE OF THE SYSTEM

The system must answer several issues:

- optimize heat losses due to air renewal,
- ensure satisfactory IAQ for population,
- inform the occupiers and building's owner about buildings' health status,
- alert maintenance staffs when a failure appears on the system

To carry out those issues, the system has been separated in three main operating levels.

2.1 From the point of view of a housing

The first step of the regulation will be located inside the housing. Indeed, if we refer to the French regulation in force (Ministerial rulling, 1982), the principle of ventilation in an apartment must follow the general and permanent ventilation law: new air comes from dry rooms (basically living room, dining room and bedroom) window's air inlets, transit through the apartment to reach humid rooms (basically the kitchen, toilet and bathroom) where air outlets are located.

Based on that principle, several types of regulation are available on the market: static system, self-regulating systems, humidity sensitive systems and IAQ sensors-controlled systems. This last one is still unusual as the self-regulated and humidity sensitive systems are used for many decades now. These types of regulation are given by air inlets and outlets accessories, depending on the technology used, that regulate the airflows incoming and outcoming from the apartment.

The way our system will regulate the airflows is based on the IAQ sensors-controlled technology. For each apartment of the building, there will be a sensor box that will be composed of a CO_2 sensor, a Relative Humidity sensor and a VOCs sensor, located in an air confluence area: the hall (Figure 1). These sensors will measure the IAQ in real time, and send their information to a distant server via a telecommunication protocol dedicated to connected objects: LoRaWAN.

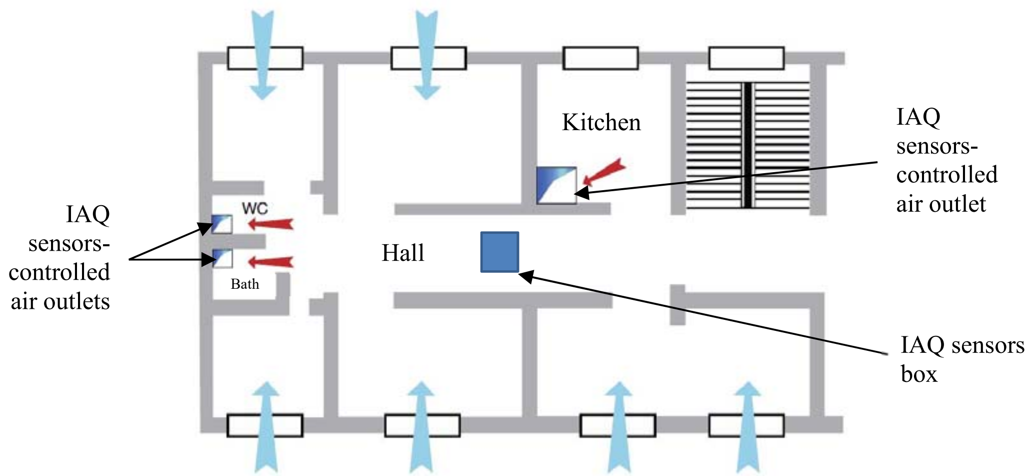

Figure 1: Example of an apartment equipped with the IAQ sensors box and IAQ sensors-controlled air outlets

The distant server will assess the information sent and traduce them. Then, according to the regulation strategy, each pollutant rate values will be above, below or equal to a threshold value corresponding to the pollutant scanned. These thresholds values will be determined thanks to a software specialized in pollutant emissions: Octopus Lab. This software is able to simulate IAQ pollutant emissions in a room or an apartment (room's characteristics can be set on demand) depending on several factors like: the kind of paint used, the kind of furniture in place or the kind of floor (wooden floor, carpet, etc). Then, the software can simulate the air renewal with a given ventilation strategy and establish airflows we need to ventilate the apartment. The main purpose of Octopus Lab for our application is to know how to ventilate at best an apartment to ensure a good IAQ for the occupiers.

Each air outlets in the apartment will have three opening levels: LOW, MEDIUM and HIGH. These sections will be determined thanks to the Octopus software results. Air outlets will also communicate via LoRa protocol and will receive their opening order from the distant server according to the results of data assessments. The same process could be done for air inlets located on the windows, but for a first approach, we'll only use self-regulating air inlets. The action of opening and closing the air outlets will be as simple as possible, using a servomotor mounted on an electronic board and supply with batteries or directly on a power plug (Figure 2).

All the air outlets are independent from each other's, in order to keep the possibility of installing IAQ sensors inside, and control them locally. As an example, when an occupier is taking a shower in the bathroom, if the air outlet is equipped with a relative humidity sensor, the value measured can influence the opening of the air outlet.

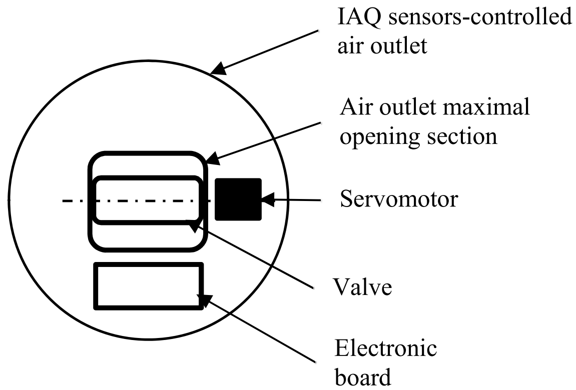

Figure 2: IAQ sensors-controlled air outlet

A last point relating to this first level of the system is that the occupier must be informed about its indoor air quality and can be an actor of it. Indeed, a man-machine interface will be available for occupiers who want to look at their apartment's health status and increase or decrease the air renewal rate according to their activities. That's an answer to the 2015 Energetic Transition for a Green Growth French law which specifies at the article L. 111-10-5. the housing must have a *Digital Notepad* to follow the housing's and its equipment's health status (LTECV 2015-992, 2015). A smartphone application can also be created to allow occupiers to consult housing's data and adapt their needs to their activities.

2.2 From a point of view of a group of housing

In the building, all the air outlets are communicating via the LoRa protocol. The distant server receives all the data from sensors and transmits orders to the air outlets. It also sends IAQ data to the man-machine interface relating to the housing which they belong to. At another scale, custodians could be informed about building part pollutants rates like a group of housing control by the same ventilation unit. That's why a man-machine interface will be available in guardhouses or in technical rooms, to display an average of each pollutant measured (CO_2, Relative Humidity and VOCs) in real time.

2.3 From a point of view of the building

The ventilation unit installed on the building is a Hybrid system which starts its mechanical assistance when weather conditions are insufficient to guarantee a good stack effect. Initially, hybrid ventilation systems do not have any link with IAQ values from housings, their parameters are set from a previous study before it was installed. On a full year, hybrid systems can save about 40 to 60% of power consumption thanks to their climatic sensors that allow ventilation to work in *Natural Mode*. This new ventilation concept must take IAQ data into account to regulate ventilation unit's functional parameters.

When the distant server receives data from IAQ sensors boxes, it assesses them and sends orders to air outlets and sends IAQ information to occupiers' man-machine interface and building pollutant rates averages to the guardhouse man-machine interface. This last interface is linked to the ventilation unit and is able to transfer an order depending on pollutant rates averages calculated by the distant server algorithm. That order is quite the same as those send to air outlets, based on a threshold set for each pollutant rates averages:

- if the threshold is exceeded, the distant server sends an order to the centralizer interface, which forwards the order of increase the ventilation unit's fan speed to the ventilation unit automaton.
- If the threshold is not met, then the order of decrease the ventilation unit's fan speed is send the same way to the ventilation unit automaton.

The purpose of that part is to reduce ventilation unit overconsumption. Indeed, when the building's IAQ status is satisfying, there is no need to keep the same ventilation unit's fan speed. On the same way, if the whole building IAQ assessment is unsatisfying, the need of ventilation is much important.

In order to control pressure generated in ducts, control ducts can be used, adding pressure switches that can send an information to the automaton on the roof. When the depression in control ducts are unsatisfying to guarantee good ventilation conditions, an alert could be send to maintenance staffs through a connected tool: a web platform.

2.4 Maintenance alerts

In France, most of 49% of housings have unsatisfying minimal hygienic airflows, mainly due to the lack of maintenance on ventilation units (OQAI & CSTB, 2009). Maintenance staffs can also have difficulties to know how to diagnose a failure on a hybrid ventilation system because of the automation of their working process that makes ventilation units work or not, depending on the climatic conditions.

To help maintenance staffs to react quickly to a breakdown and to guide them on how to repair the system, a web platform takes information from the same distant server, which recovers the ventilation system data, and display them. In these information, ventilation units' status is also recover so that maintenance staffs can verify the functioning of the system and be alert by e-mail in case of failure.

3 CONCLUSIONS

This ventilation concept is still in reflexion and can be subject to changes to be improve. But in general, this is how the concept should answer to the problematic of measuring the IAQ in housings and controlling the ventilation as occupiers and owners gets information on building's status.

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