Study of Energy and Cost Savings of Demand Controlled Fresh Air Systems

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Abstract

This paper presents findings from a study on the energy and cost savings of Demand Controlled Fresh (outdoor) air systems for existing office buildings. The study was based on technical analysis of data from an existing 11 storey office building located in London. The study proposed a retro-fit mechanical system and control solution to convert the existing constant volume fresh air system to a demand based system. The four key parts of the proposed system were the occupancy detection device, local ventilation zone branch control, central ventilation plant control and overall controls logic.

The building and proposed control solutions were simulated. The results revealed up to 39% annual energy savings for the fresh air plant. This equates to 4% reduction of the overall building annual energy and an overall building annual energy cost saving of around 3%.

Keywords: Demand, control, energy, cost, ventilation, fresh (outdoor), building.

1.0 Introduction

The design of partially centralised air conditioning systems generally consists of a fresh air unit sized to provide the anticipated peak fresh air volumes. For constant volume systems, this is provided at a constant flow rate with energy expended to deliver the peak design volume flow rate throughout the whole occupied period.

However, work patterns are becoming more flexible, with more companies offering staff the option to plan office hours and external engagements within their workdays. Plus the streamlining of office space through mechanisms such as 'hot desking' due to some staff having the added option of working from home. All of these factors make office occupancy profiles increasingly complex to correctly predict at the design stage and optimise the system design accordingly. Coupling this with greater emphasis being put on fresh air provision, with developers aiming to future-proof their offices above statutory requirements, makes constant volume fresh air systems a logical place to target energy savings. This progressive step will lead to energy efficient demand based systems becoming normality in any new design, with the possibility to retro-fit to existing systems.

2.0 Literature Review

Review of available literature suggests that traditional occupancy diversity guidelines (benchmarks) do not account for the stochastic nature of true occupancy patterns in offices. This is backed up by findings and results presented by Carlos Duarte where maximum diversity factors as low as 60% were reported[1]. This is compared to ASHRAE recommendations of maximum diversity factors of 95% during the day[2]. With flexible working patterns becoming more common, and fresh air flow rate recommendations increasing, a move away from constant volume fresh air systems to demand controlled, is a logically progressive step for energy efficient design.

The main regulations and guidance for fresh air provision based on bodies that influence UK design are shown in figure 1:

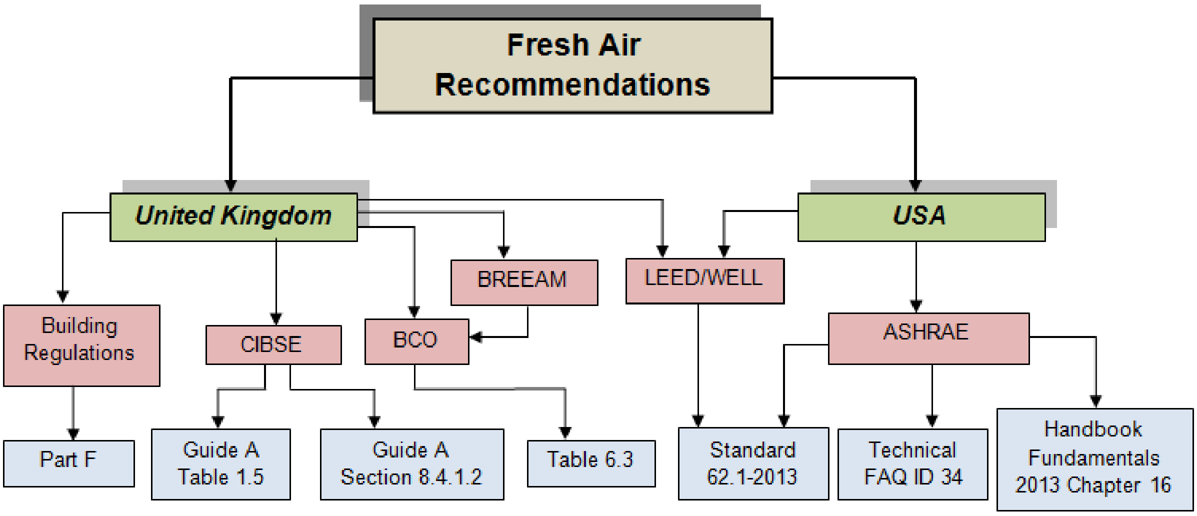

Figure 1 - Fresh air recommendations relevant to UK design

3.0 Methodology

The main aim of this study is to evaluate the energy and cost savings of retrofitting a constant volume fresh air system in an existing office to a demand controlled fresh air system.

To achieve this, the existing design and information for an existing 11 storey office building with a constant volume system were used for the case study and a retro-fit solution was proposed with the following objectives:

- Develop methods to measure occupancy in real time and match this to fresh air delivery rates.
- Develop a full engineering solution to convert existing constant volume fresh air systems to demand based.
- Simulate and ascertain annual energy and cost savings from the conversion of constant volume to a demand based system.
- Conduct a financial analysis on this conversion through calculation of a payback period of investment.

The building was completed in approximately 1998 and is currently owned by a single tenant who occupy all the floors with approximately 4179m^2 usable office area.

The building has an existing four pipe fan coil system with a constant volume fresh air supply Air Handling Unit (AHU) and extract fan located on the roof. It is understood that the base build fresh air system was designed at a rate of around 1.2l/s per m^2. The base build design is such that there are two main risers for services distribution, which are proportioned at around two-thirds and one-third. There is a mix of private and open plan offices on each floor. An indicative general arrangement is indicated in figure 2:

Figure 2 - Case study building indicative existing typical floor plate

To fulfil the requirements of the study, it was necessary to tackle four key components:

1. Occupancy detection devices
2. Local ventilation zone branch control
3. Central ventilation plant control
4. Controls logic and Building Management System (BMS) Architecture

Building dynamic simulation software was used for the simulation of both existing and proposed systems. To complete this analysis a number of key points and assumptions were made:

- The supply and extract fans for the proposed case were simulated based on open plan occupancy diversity factors from the graph presented by Duarte et al[3].
- The measured open plan office diversity figures derived from Duarte et al. were imported into this proposed case simulation (not the private office data).
- Since this simulation is based on open plan offices across the whole building, the resultant energy savings are conservative, meaning that more detailed studies, that include a breakdown for the private offices that are also present in the case study building (which have lower occupancy profiles), could prove further savings can be achieved.
- A 15-minute system response time (to signal) of the fresh air system was assumed in the simulation and from discussions with BMS Engineers, this was deemed achievable.
- The case study building's total energy consumption, total energy cost, and electricity and gas cost for the period of 2014, was taken from its Energy Savings Opportunity Scheme (ESOS) report (issued in September 2015).

4.0 Key Component Solutions

4.1 Occupancy detection device

The case study building has three lifts that typically open out to lift lobbies on each floor of the building. Each lift lobby has two doors, see figure 3. There are also two other doors per floor accessed via the stairs (within the core) that could be used by occupants, see figure 2. The device deemed most suitable for these doors was the dual beam directional indoor people counter. The design includes for these on all four doors per floor to provide a total dynamic occupancy count to each floor (the ninth floor differs slightly as this is fully meeting rooms). Figure 4 shows a typical dual beam counter[4] .

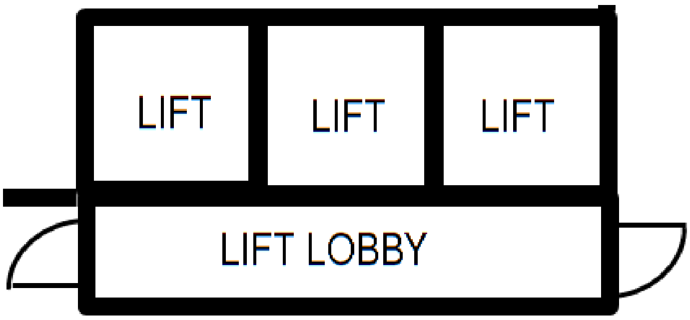

Figure 3 - Typical entrance to each office floor plate

Figure 4 - Dual beam directional indoor people counter

4.1.1 Differentiation between open plan and cellular spaces

Since the case study building consists of both private meeting/ conference rooms and open plan offices the total count to the floor must be further refined to understand where occupants are located. The solution includes a presence detector within each cellular space. When presence is detected in a room, the total fresh air design volume to that space will be provided. The cellular rooms will take priority and once all of the occupied cellular rooms are totalled for the floor, the open plan fresh air flow rate will be calculated (by the difference between dynamic count to floor and total occupied space design volumes) and provided. Further refinements can be made for riser apportionment to the floor.

Details of the formulae developed for the controls logic of this process can be found in the work presented by Ricchetti[5].

4.1.2 Fail Safe Device

The final devices incorporated into the design are over-riding CO_2 sensors (two per floor located in the Open Plan). These are not for the primary control and are only intended to record readings and over-ride the mechanical system in the event of a mechanical or controls failure using the door counters and Passive Infrared Sensors (PIR).

In summary this strategy of occupancy detection leads to a fully non-terminal, non-individualized and explicit detection solution.

4.2 Local ventilation zone branch control

The current fresh (primary) air ductwork distribution is a conventional layout designed to be cost effective and coordinated with other services. There is no distribution separation between cellular spaces and open plan spaces. Proportional balancing took place during commissioning to achieve design air volumes for each duct, and the system runs at constant volume. If the air volume was varied centrally it would vary in relation to how it's been balanced. Modifications are required to achieve demand control using the theory of separating open plan and cellular spaces set out in section 4.1.1. The key principles of this novel alteration to the mechanical design are:

- Individual duct branch supplying the cellular spaces (meeting rooms) Fan Coil units (FCUs).
- Individual duct branch supplying the open plan space FCUs.
- Air volume control achieved by Variable Air Volume (VAV) dampers.
- Individual VAV dampers serving each cellular space.
- Common VAV damper serving all of the open plan FCUs.
- Individual VAV damper serving the extract belmouth.

Figure 5 outlines the indicative existing and proposed fresh air system design both in layout and schematic form:

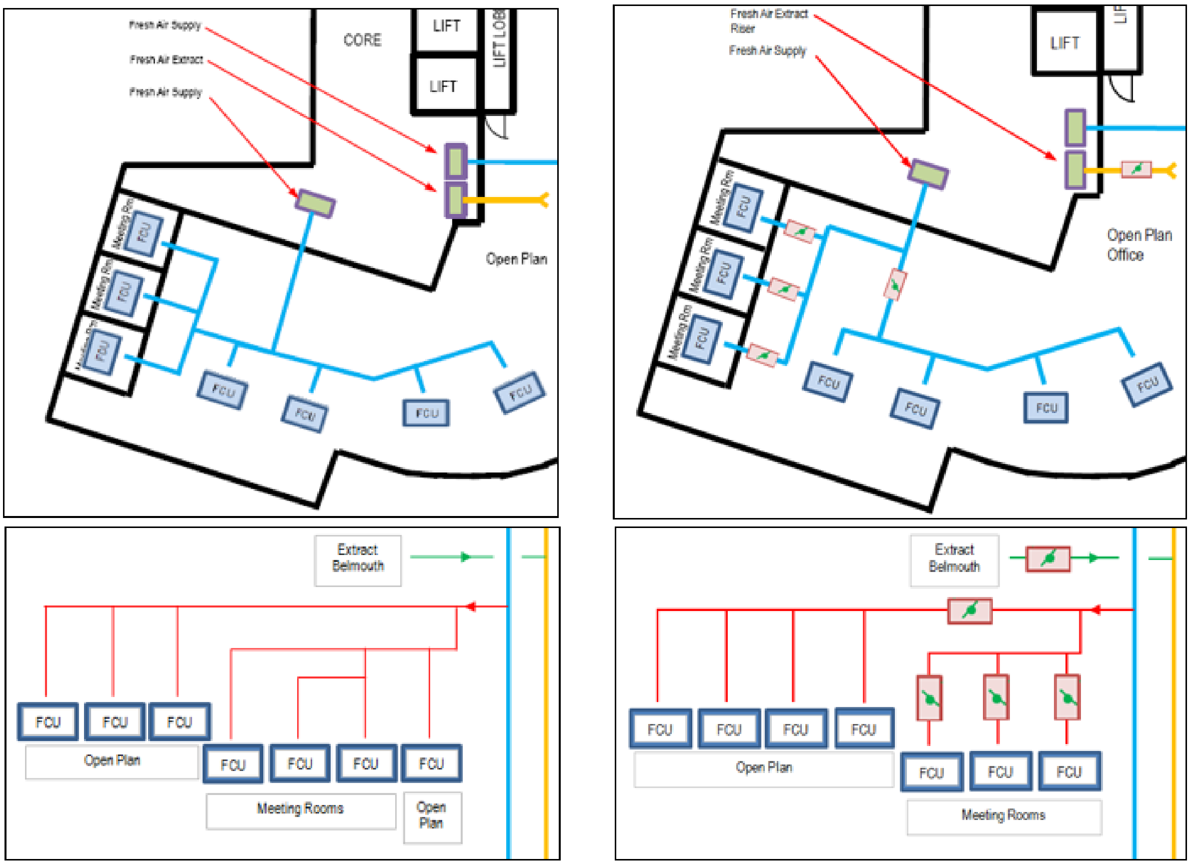

Figure 5 - Existing and proposed primary fresh air ductwork indicative layout & schematic

Careful consideration is required during selection of VAV dampers to ensure their maximum flows and minimum turn downs are within the ranges required for the spaces. Further reference can be made in the work presented by Ricchetti[6] for the formulae developed for this selection for the case study building. The key pieces of input information for these formulae are:

- Design l/s per person
- Design peak occupancy allocation per floor and per cellular space
- Minimum system turndown
- Design ratio of extract air to supply air
- Apportionment of fresh air per riser

An important point to note is that the minimum system turndown relates to the central fan's capabilities, its minimum turndown. This must be considered for each project. A figure of 50% was used for the case study to sit within this range. Also, research suggests that overall open plan and private office occupancy rarely drops below 50% during a typical working day meaning turndown control lower than 50% is not necessary. For floors that have open plan VAV boxes, the minimum system turndown would be achieved via this branch by virtue of the count per floor being normalised to within a range to match the system design turndown. A check of duct sizes would have to be done to ensure the open plan branches are large enough to achieve both minimum turndown and maximum flow to the floor. For floors with meeting rooms only, the minimum turndowns on the VAV boxes would have to be checked and increased as necessary to ensure they conform to the minimum system turndown.

The key selection criteria for each VAV unit based on these formulae are:

- Open plan theoretical maximum flow rate
- Open plan theoretical minimum flow rate
- Open plan flow rate at peak occupancy and all cellular spaces occupied
- Open plan flow rate in dynamic operation
- Cellular space flow rate in dynamic operation

An algorithm is written for each of the above and are written such that they can be applied to other buildings with different design data. VAV units can then be selected.

By carrying out the modifications described above, local ventilation zone branch control can be achieved for each floor.

4.3 Central ventilation plant control

The case study building has an existing four pipe fan coil system with a constant volume fresh air supply AHU and extract fan located on the roof. This is shown indicatively in figure 6:

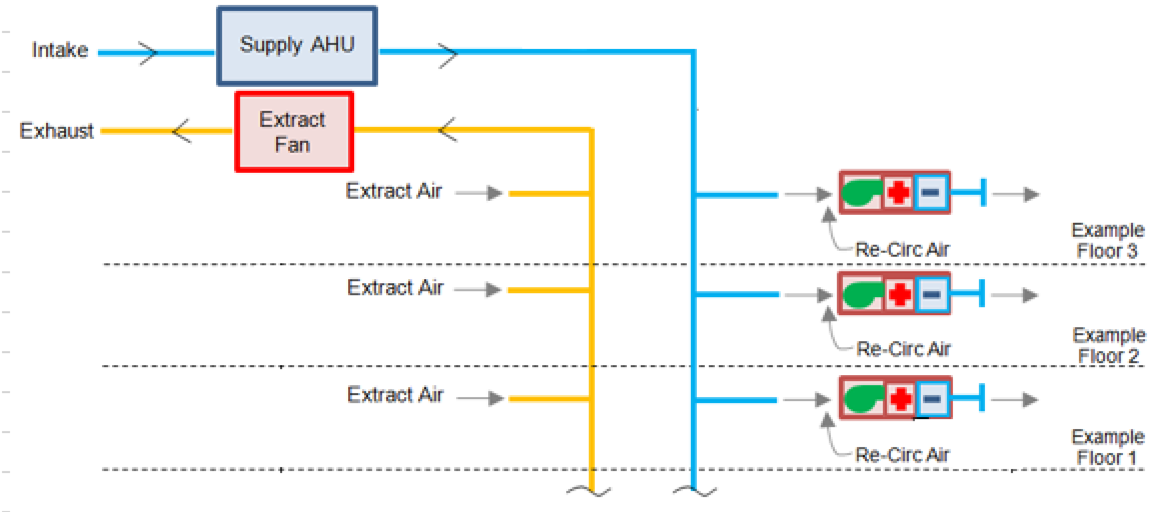

Figure 6 - Case study building HVAC strategy

The control of this fresh air supply and extract plant is based on a time clock, it operates between 5AM – 7PM Monday to Friday and on an ad-hoc basis on Saturdays.

The components that make up the supply AHU are common for UK design and consist of a motorised damper, heating and cooling coil, various filters, fan, and various sensors related to temperature and humidity. Note that there is no form of heat recovery or pressure control in this particular system. The supply air temperature set point is 14°C. Whilst this offers some primary cooling credit to the FCUs, any reduction in supply air during low occupancy periods (from the introduction of a demand based system) is considered to have a negligible effect on the FCU duties. Peak cooling conditions are likely to be expected during peak occupancy conditions, at which full design fresh air would be provided.

The requirement of a demand based system is that the fans vary their speed to match demand. It is necessary to introduce pressure control in the form of an outlet static pressure sensor for each fan to achieve this. This pressure set point would be based on a static pressure controller which will be described in the next section. Figure 7 shows the existing and proposed plant configurations for supply and extract:

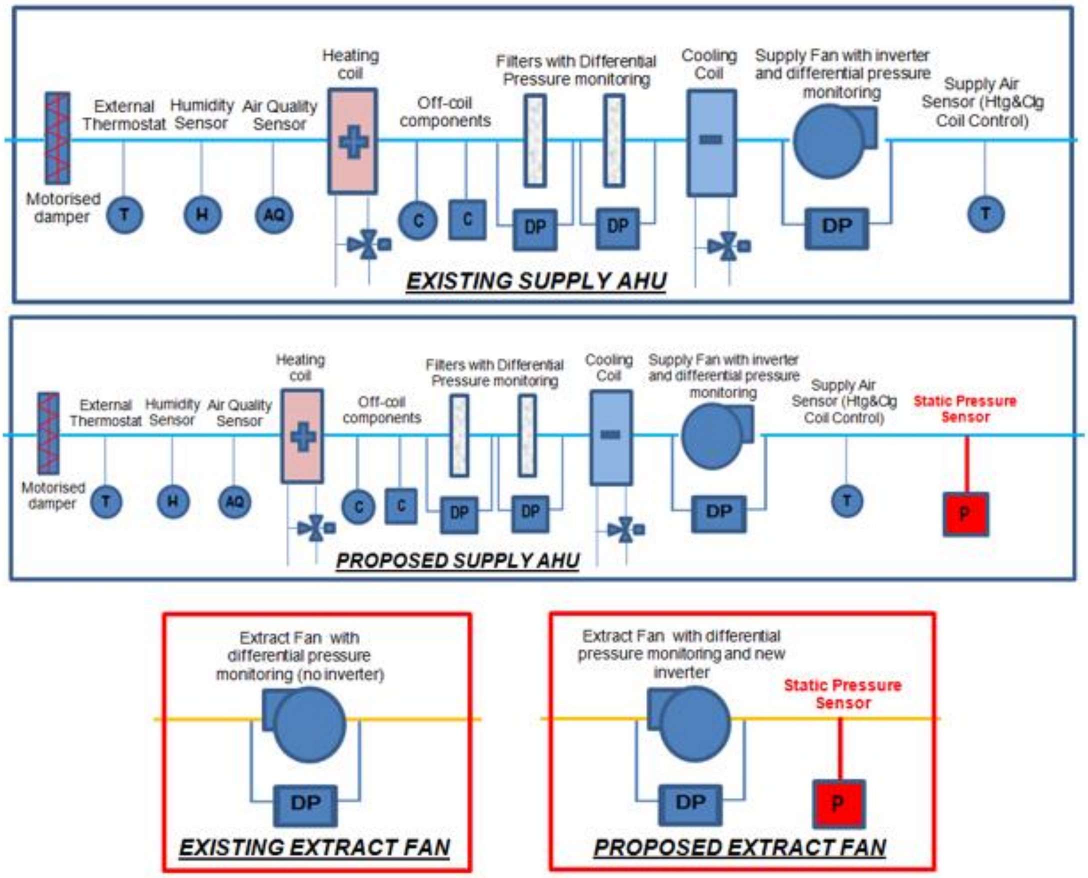

Figure 7 - Existing and proposed supply AHU and extract fan configuration

The over-arching controls strategy chosen for the pressure control of the system is Fan Pressure Optimization. When the VAV dampers close or open to regulate air volumes, the pressure in the system changes. Static duct pressure sensors are mounted at the supply/extract fan outlet/inlet and the static pressure set point is adjusted by a static pressure controller. This pressure set point is based on the position of the VAV terminal dampers. The controls system would continually look for the 'most open VAV damper' (polling). The BMS control system would then adjust the duct static pressure set point to ensure that at least one VAV terminal is nearly wide open (the one requiring the highest inlet pressure)[7]. The fans would then control via their inverters to maintain this outlet pressure set point and thus operate based on demand. The existing heating and cooling coils will continue to operate under their current controls regime and will match output based on demand.

There are options to have the static pressure sensor located elsewhere in the system (e.g. 2/3 down the supply duct). This is known as 'Supply Duct Static Control' and the polling of the VAV dampers wouldn't take place, as the location of the sensor gives a broader overview of system pressure. But this option requires much more intrusive works to find the optimum location (especially in existing buildings), whereas the fan inlet/ outlet locations are likely to be easily accessible. Therefore, the chosen strategy of Fan Pressure Optimization with static pressure sensors on the fans inlet/ outlet is deemed most suitable for this application.

4.4 Controls Logic & BMS Architecture

To complete this engineering solution, it is necessary to develop a controls logic to take the occupancy detection device readings and provide an output for each VAV unit. This was done by development of various formulae and algorithms sequenced together. These are summarised in the overall controls flow chart in figure 8.

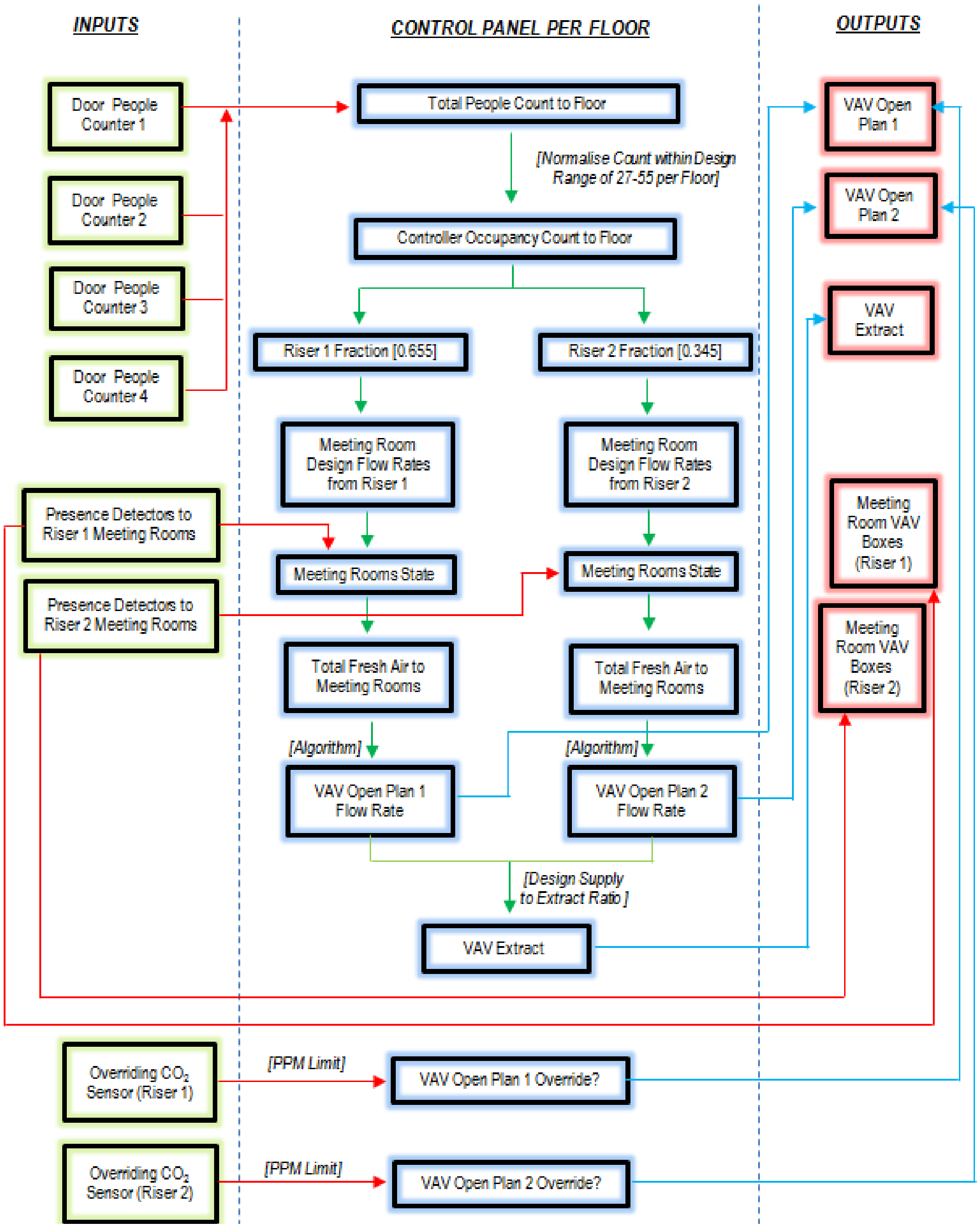

Figure 8 - Controls flow chart

Reference can be made in the work presented by Ricchetti[8] for the development of this as well as a detailed breakdown of the algorithm and formulae. The key algorithms developed are firstly that of normalising the total people count to the floor to within a range of the peak design occupancy to minimum turndown. This was written in such a way to allow for input data from other buildings with different design data to be substituted directly in. The design inputs required for this are design peak occupancy and system minimum turndown. The second key algorithm is that of providing a flow rate for the open plan VAV boxes during dynamic operation. This is calculated by the difference between the dynamic count to the floor and the total occupied cellular space design volumes, whilst accounting for its respective riser fraction. The cellular room calculation is simpler, with it being just the design volume to the space and whether it's in an occupied or un-occupied state.

The overriding CO_2 sensors would set into action if the Parts Per Million (PPM) readings in the space exceeded a pre-set high limit. These would then take control of the open plan VAV units until its pre -set lower limit is achieved. This PPM limit would be based on the indoor air quality classification for the space. CIBSE Guide A 2015 table 4.5 outlines these values for each IDA classification:

Table 4.5 Approximate sedentary CO_2 concentrations associated with air quality classification (BS EN 13779 (BSI, 2007)) (all values in ppm)

Classification	Typical rise in indoor CO_2 above outdoor value	Default rise in CO_2 above outdoor value	Typical range in outdoor CO_2 value	Typical total indoor CO_2 value
IDA1	<400	350	350–400	700–750
IDA2	400–600	500	350–400	850–900
IDA3	600–1000	800	350–400	1150–1200
IDA4	>1000	1200	350–400	1550–1600

Figure 9 - CIBSE Guide A 2015 Table 4.5 Approximate sedentary CO_2 concentrations associated with air quality classification (BS EN 13779) (BSI, 2007) (all values in ppm)

A dead-band could be allowed for if desired. This is only for the open plan areas.

4.4.1 BMS Architecture

The BMS 'Architecture' sets out how all of these new control interfaces and logic devices are integrated together within the existing BMS network, see figure 10:

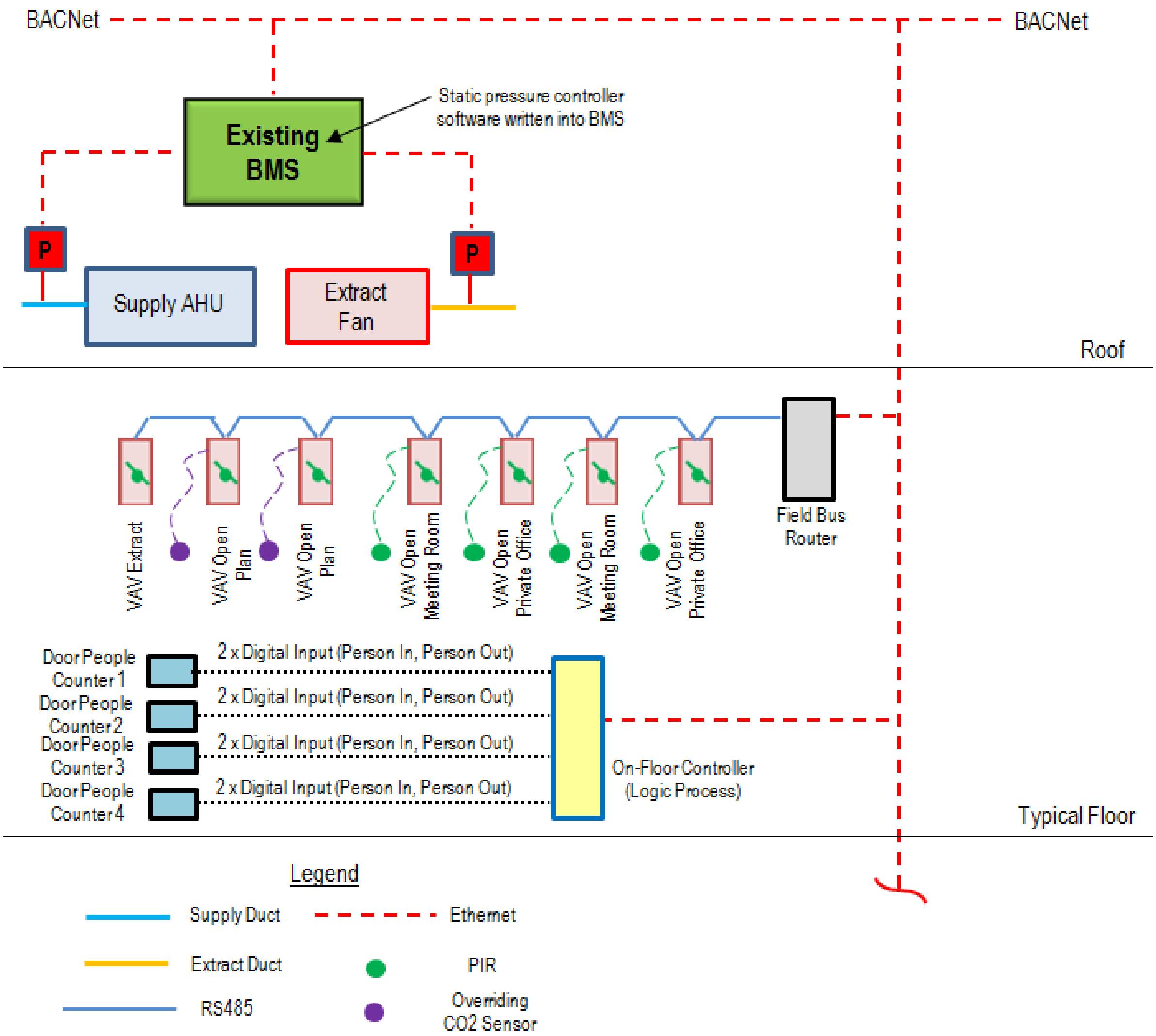

Figure 10 - BMS Architecture

The static pressure controller software is proposed to be written into the existing BMS, and the new static pressure sensors for the supply and extract fans are linked to it. The 'polling' of the VAV box positions takes place over the Ethernet network as does the adjustment of the static pressure set point.

The VAV boxes are proposed to be connected via a new RS485 network and information on their state is fed onto the Ethernet network via a 'Field Bus Router'. This information, along with the PIR sensor states, can be read via the Ethernet network by the on-floor control panel, which in turn can send a signal back out to the VAV boxes. The door people counters are locally interfaced with the on-floor controllers. A logic process takes place locally within these controllers, as described in Figure 8.

4.5 Summary of Solutions

Figure 11 outlines a layout summary of the engineering solution described.

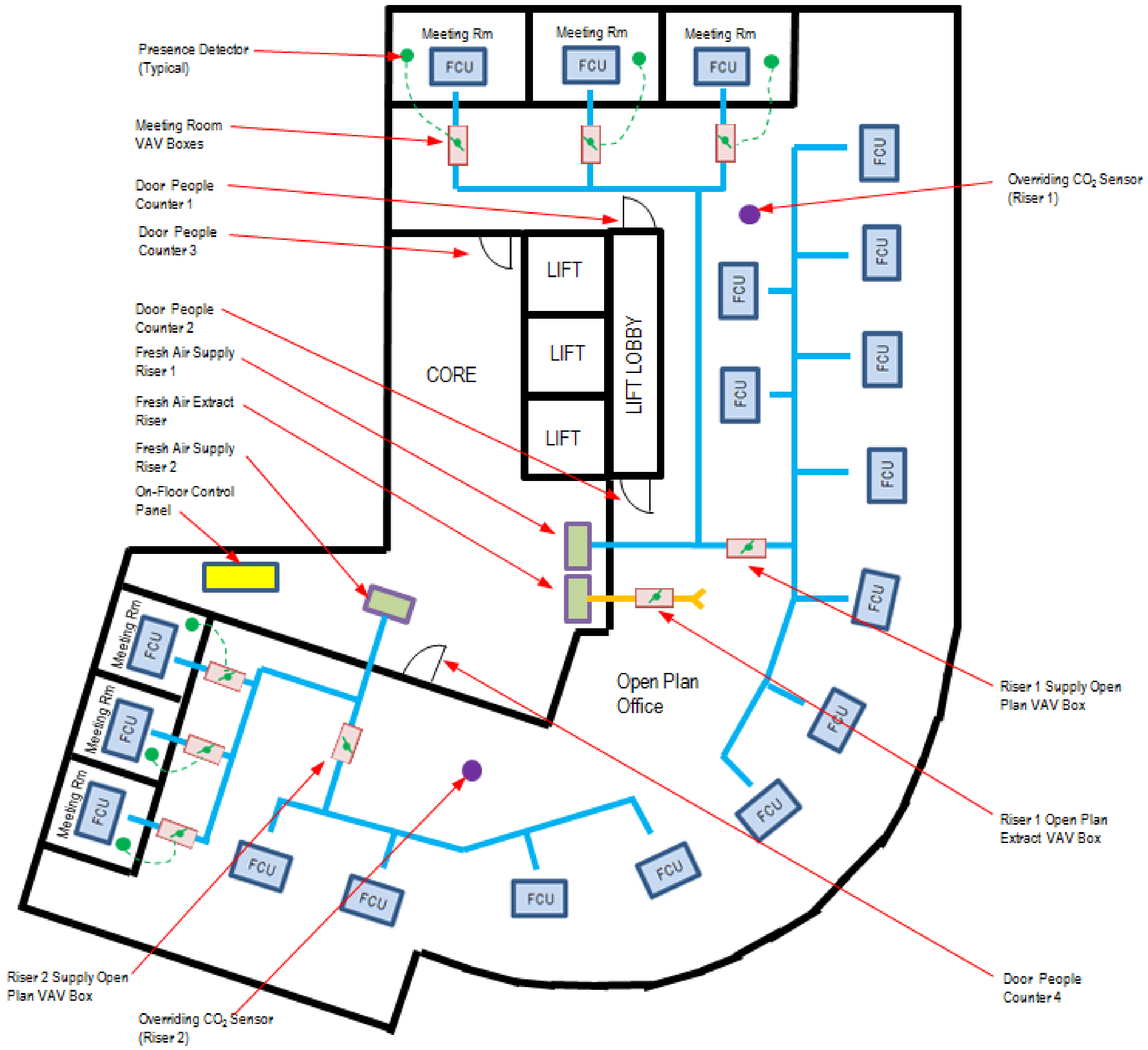

Figure 11 - Summary layout of engineering solution

The principles of this solution established and outlined in this report are transferrable to designs of new fresh air systems as well as other existing buildings with similar systems.

5.0 Results and Discussion

As mentioned in the methodology, simulation software was used for the simulation of both the existing and proposed systems. The key outcomes of this analysis were:

- Annual energy consumption of existing constant volume fresh air system
- Annual cost of existing constant volume fresh air system
- Annual energy savings of the demand based fresh air system

- Annual energy savings of the building incorporating the proposed demand based system
- Annual cost savings from the demand based fresh air system
- Annual cost savings of the building incorporating the proposed demand based system
- Payback period analysis
- Normalised results for energy and cost savings

5.1 Base Case Results

Simulation software was used to simulate the fresh air system for the case study building to ascertain the annual energy consumption from this plant. This includes the energy consumed by all of the components within the supply AHU and extract fan that are dedicated solely to providing fresh air to the building.

The results of this simulation are shown in figure 12:

System Component	Energy Consumption (kWh/yr)	Percentage of Total (%)	Fuel
Boiler Energy	141028	65.4	Gas
Misc. Gas Load	2337	1.1	
Chiller Energy	9804	4.5	Electricity
Fan Energy	49484	22.9	
Pump Energy	11781	5.5	
Heat Rejection fan/ pump energy	1362	0.6	
Total	**215797**	**100**	

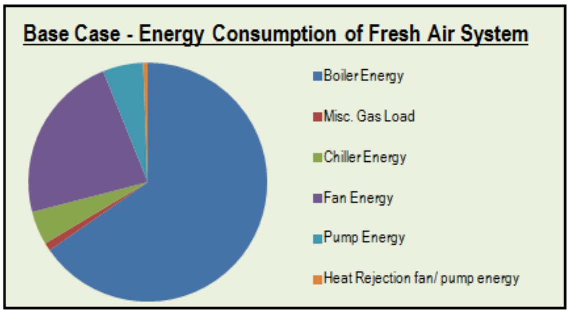

Figure 12 - Base case results – energy consumption of fresh air system

The importance of this analysis is that it gives a clear breakdown of each components energy consumption for the fresh air system in isolation to the rest of the building.

The results show that a total of 215,797 kWh/ year is calculated to be consumed by this system. The majority of this is heating (boiler) energy (65.4%) required to heat the air to the required set point. This is followed by the fan energy (22.9%) which consumes almost a quarter of the total annual energy. Interestingly, the chiller energy consumption (4.5%) (and associated heat rejection energy 0.6%) is comparatively small. It should be noted again that this system does not have any form of heat recovery.

To put these results into perspective the case study buildings total annual energy consumption for 2014 was 1,928,147 kWh. As a percentage of this the fresh air system (constant volume control) is calculated to consume 11.2%.

The equivalent financial analysis was done based on the 2014 gas and electricity energy prices. For the fresh air system only, and based on the above simulation, the annual cost of gas was calculated to be £5,878 and the annual cost of electricity was calculated to be £8,764. As a percentage of the total buildings energy costs for 2014 this works out to be 7.6%.

The majority of the systems energy consumption is gas, but since this is cheaper than electricity the largest cost is from electricity consumed.

The base case results have shown that the fresh air system consumes a noticeable amount of the buildings overall energy consumption and cost. The heating and fan energies are the largest consumers meaning these are the key areas to target the energy savings. The next section describes the proposed case simulation in which the demand based system is simulated to ascertain energy and cost savings.

5.2 Proposed Case Results

There were four changes made from the base case simulation to complete the proposed case simulation. These were done to model the system as a demand controlled system and essentially simulate the system varying fan speed to match dynamic occupancy. They are as follows:

1. Supply fan characteristic changed from constant volume profile to variable volume.
2. Extract fan characteristic changed from constant volume profile to variable volume.
3. Supply and extract fan time clock profiles were replaced with occupancy diversity factors found by research conducted by Duarte et al within the research paper 'Revealing occupancy patterns in an office building through the use of occupancy sensor data'.
4. The controller time switch profiles for supply and extract fans were consequently swapped out for the demand based weekly timer as described in point 3. This was done to simulate the demand based control characteristic.

Duarte et al. produced measured private and open plan office diversity factors to compare against the ASHRAE 90.1 2004 diversity factors. For the purposes of this study, the measured open plan office diversity figures derived from Duarte et al. were imported into this proposed case simulation. This is to represent 'real world' occupancy patterns that, in theory, would be detected by the proposed occupancy detection system.

With reference to open plan offices, Duarte et al. did make clear from their research that *'it is not possible to describe occupancy with confidence due to the limitations of the occupancy sensors in large spaces that are likely to have multiple occupants such as conference rooms, and open plan offices. Future research is planned to incorporate additional measurement techniques to better describe occupancy profiles in such spaces'*[9].The confidence of the work by Duarte et al. was deemed appropriate for this research and simulation. These diversity figures along with the incorporation into the simulation are shown in figure 13[10]. These open plan diversity figures were imported into the simulation by manually transferring the graphical data at 15-minute intervals into the time clock profile. Note that in conjunction with the controls design, the 50% minimum turndown is incorporated into this profile, and the profile starts at 7AM and ends at 7PM. The Saturday profile for the supply and extract fans is from 7AM to 12 noon and is the same profile as shown in figure 13, but at 12 noon it simply switches off. Sundays are off.

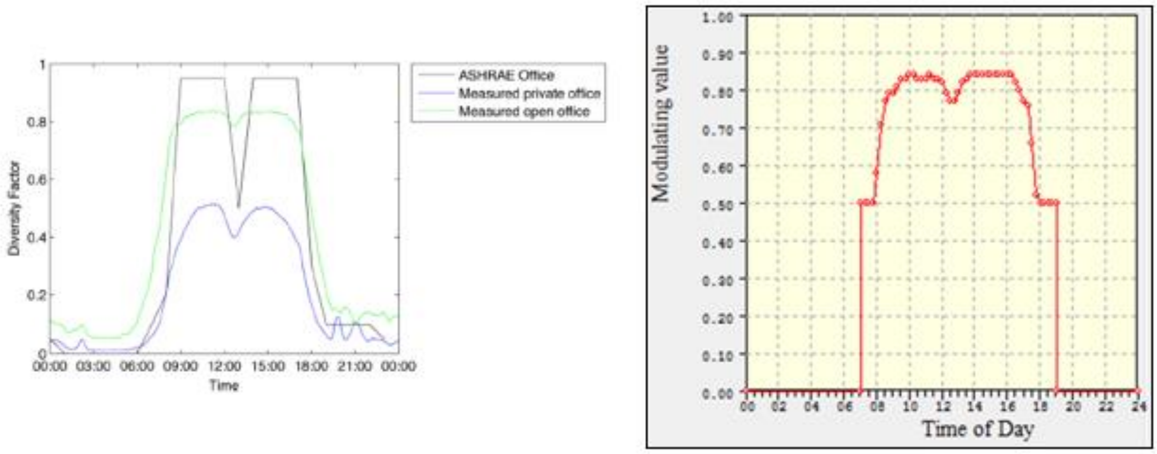

Figure 13 - Duarte et al diversity figures compared to ASHRAE 90.1 2004 and this transferred into the simulation

The case study building has a mixture of private offices and open plan offices. For the proposed case simulation, only the open plan office profile was used for all cases. As seen in figure 13, based on Duarte et al. there is more diversity on the private offices than open plan, meaning that the resultant energy savings would be greater. Since this simulation is based on open plan offices across the whole building, the resultant energy savings would be conservative, meaning that more detailed studies could prove further savings.

The results of the proposed case simulation for the case study building are shown in figure 14:

System Component	Base Case Energy Consumption (kWh/yr)	Proposed Case Energy Consumption (kWh/yr)	Saving (kWh/yr)	% System Component Saving	% of Overall Saving
Boiler Energy	141028	82625	58403	41.4	69.1
Misc. Gas Load	2337	2338	0	0.0	0.0
Chiller Energy	9804	8479	1325	13.5	1.6
Fan Energy	49484	25875	23608	47.7	27.9
Pump Energy	11781	10773	1009	8.6	1.2
Heat Rejection fan/pump energy	1362	1178	184	13.5	0.2
Total	**215797**	**131268**	**84529**	**39.2**	**100**

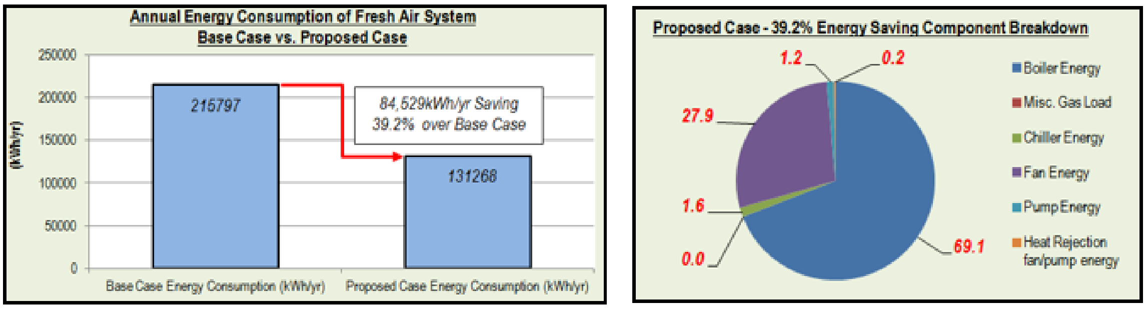

Figure 14 - Proposed case simulation results

The results show a 39.2% reduction in the annual energy consumption of the fresh air system. The majority of the savings were made from the heating energy (69.1% of the 39.2%) and fan energy (27.9% of the 39.2%). The overall 84,529kWh/year saving relates to a 4.4% reduction in the overall buildings annual energy consumption (1,928,147kWh/year). Refer to section 3.0 for the key points and assumptions made for this analysis.

The cost savings from this analysis are shown in figure 15:

	Fresh Air System Annual Energy Cost Savings						
Fuel	Base Case Energy Consumption (kWh/yr)	Proposed Case Energy Consumption (kWh/yr)	Saving (kWh/yr)	Base Case Cost (£/yr)	Proposed Case Cost (£/yr)	Annual Saving (£/yr)	% of Total Saving
Gas	143366	84963	58403	5,878	3,483	2,395	43.1
Electricity	72431	46305	26127	8,764	5,603	3,161	56.9
Total	**215797**	**131268**	**84529**	**14,642**	**9,086**	**5,556**	**37.9**

Figure 15 - Cost savings

The annual saving was calculated to be £5,556 which is a 37.9% reduction in the cost of running the fresh air system at constant volume. The majority of energy savings were from gas, but the cost savings have electricity to be slightly more (56.9%) due to this being more expensive per unit. Compared to the buildings 2014 overall annual energy cost (£193,010) this £5,556 relates to a 2.9% cost reduction.

5.3 Summary of results

- The existing constant volume fresh air system accounted for approximately 11.2% of its total annual energy consumption for 2014.
- The existing constant volume fresh air system accounted for approximately 7.6% of its total annual energy cost for 2014.

By incorporating the theoretical retro-fit solution to make the fresh air system demand controlled, the following annual savings have been calculated:

- **39.2%** saving from the fresh air plants annual energy consumption.
- **4.4%** saving from the buildings overall annual energy consumption.
- **37.9%** saving from the fresh air plants annual energy costs.
- **2.9%** saving from the building's overall annual energy costs.

From the usable office floor area for the case study building (4179m^2), this relates to:

- **20.2kWh/m^2** per year energy saving.
- **£1.33 / m^2** per year energy cost saving.

5.4 Cost Analysis and Payback period

An economic evaluation was conducted for the case study building to estimate the capital cost of converting its constant volume fresh air system to a demand based system. The design of this demand based system would be as outlined in this report. This analysis was done using available UK cost data and rates, manufacturer quotations and industry used £/m^2 figures. Reference can be made to work presented by Ricchetti[11] for the full costing analysis.

The findings revealed an installation cost of £144,553.77. When compared to the annual cost savings calculated (£5,556) this gives a simple payback period of 26 years.

The cost and savings would vary with each building. Fresh air provision is a statutory requirement for all buildings in the UK, meaning energy savings could be achieved to all existing systems that are constant volume. The application range is much wider than a lot of other technologies.

The solutions developed could also be applied to other building types, e.g. schools or university buildings, and to new buildings. For new buildings the cost of implementation in relation to overall cost would be much less as it can be incorporated at an early stage of design.

5.5 Summary of findings and normalised results

The key results have been normalised for floor area and are indicated in figure 16. This depicts the energy savings super-imposed on the comparison of real-life researched occupancy profiles, compared to a typical constant volume fresh air system profile.

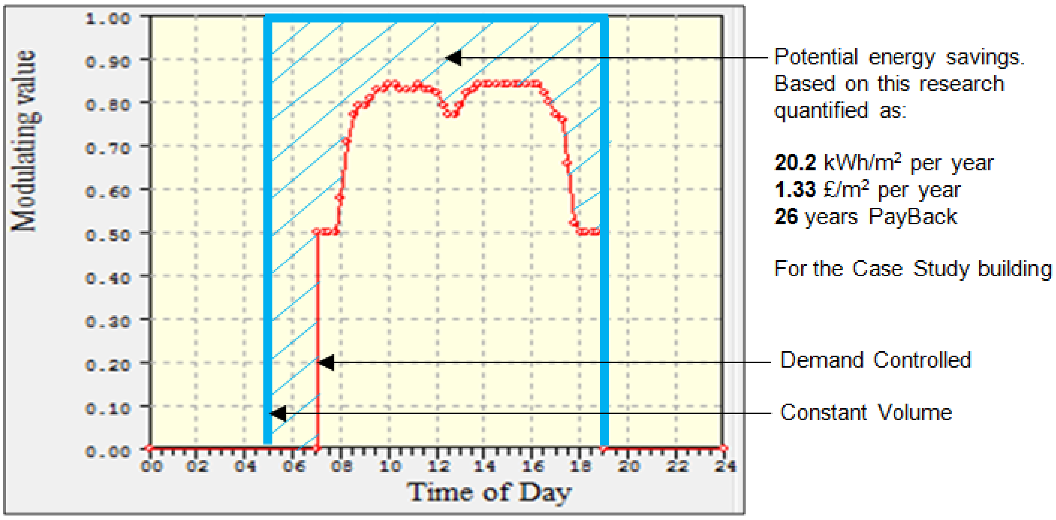

Figure 16 - Normalised results summary

6.0 Conclusion & Recommendations

A study was carried out to establish the energy and cost savings potential of introducing demand controlled ventilation on an existing 11 storey office building located in London. As part of this study a full engineering solution to convert this system was put forward. The study was based on simulation of the installed fresh air system and the results were used to compare against the buildings actual annual energy consumption.

The engineering solution developed to convert the existing constant volume fresh air system to demand control consisted of four main parts. These were; occupancy detection device, local ventilation zone branch control, central ventilation plant control and the overall controls logic. Dual beam directional indoor people counters, assisted by PIR sensors and overriding (fail safe) CO_2 sensors, were deemed most suitable for this application. The concept of dedicated open plan and cellular space ductwork branches accompanied by VAV dampers was developed to achieve local ventilation zone branch control. Central ventilation plant control and controls logic was proposed to be achieved by the introduction of fan outlet static pressure sensors in conjunction with fan pressure optimization. Unique algorithms were developed to integrate these components and strategies together as part of the overall BMS architecture.

The final results and findings revealed that the existing constant volume fresh air system attributed to 11.2% of the overall buildings annual energy consumption and 7.6% of its annual cost for 2014. The largest demand was found to be from the heating and fan energy. Once demand controlled ventilation was introduced it was calculated that approximately 39% reduction in the fresh air plants annual energy consumption (equating to a 4.4% saving in the buildings overall annual energy consumption) could be achieved. These energy savings equated to approximately 38% annual cost saving of the fresh air plant which meant an overall annual energy cost saving to the building of approximately 3%. The results were normalised to 20.2kWh/m^2 per year energy saving and £1.33/m^2 per year cost saving. After an installation cost was ascertained, the payback period was calculated to be 26 years.

This report represents a clear design solution that could be applied to many other similar buildings, both existing and new, in the UK and across the world. It is backed up by calculated energy and cost saving results compared directly against actual energy consumptions.

Further research is warranted for studies outside of the UK which incorporate different climates and design practices.

References

[1] Carlos Duarte, Kevin Van Den Wymelenberg, Craig Rieger. Revealing occupancy patterns in an office building through the use of occupancy sensor data. Energy and Buildings, 2013, 67, page 588.
[2] Carlos Duarte, Kevin Van Den Wymelenberg, Craig Rieger. Revealing occupancy patterns in an office building through the use of occupancy sensor data. Energy and Buildings, 2013, 67, page 593.
[3] Carlos Duarte, Kevin Van Den Wymelenberg, Craig Rieger. Revealing occupancy patterns in an office building through the use of occupancy sensor data. Energy and Buildings, 2013, 67.
[4] Chambers Electronics, Dual Beam Directional Indoor People Counters (DBPC) technical datasheet (2014).
[5] Antonio Ricchetti, Study of Energy and Cost Savings of Demand Controlled Fresh Air Systems for Existing Offices, MSc Sustainable Energy Systems dissertation, London South Bank University, 2016. Pages 38, 39, 45 & 46.
[6] Antonio Ricchetti, Study of Energy and Cost Savings of Demand Controlled Fresh Air Systems for Existing Offices, MSc Sustainable Energy Systems dissertation, London South Bank University, 2016. Pages 38 & 39.
[7] TRANE, Ventilation and Fan Pressure Optimization for VAV Systems, page 9. Available from

https://www.trane.com/commercial/uploads/pdf/866/VentilationFanPressureOptimization.pdf [Accessed 19.02.16]

[8] Antonio Ricchetti, Study of Energy and Cost Savings of Demand Controlled Fresh Air Systems for Existing Offices, MSc Sustainable Energy Systems dissertation, London South Bank University, 2016. Pages 44 – 48.

[9] Carlos Duarte, Kevin Van Den Wymelenberg, Craig Rieger. Revealing occupancy patterns in an office building through the use of occupancy sensor data. Energy and Buildings, 2013, 67, page 593.

[10] Carlos Duarte, Kevin Van Den Wymelenberg, Craig Rieger. Revealing occupancy patterns in an office building through the use of occupancy sensor data. Energy and Buildings, 2013, 67, page 593.

[11] Antonio Ricchetti, Study of Energy and Cost Savings of Demand Controlled Fresh Air Systems for Existing Offices, MSc Sustainable Energy Systems dissertation, London South Bank University, 2016. Pages 64 - 70.

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