AirLit-PV – The Development of a Façade Unit to provide Daylight and Ventilation with Integrated Photovoltaic Power.

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A major concern of those wishing to limit the energy use in buildings is the growing trend towards installing air-conditioning in new and refurbished buildings. The Airlit - PV project has taken this challenge and has designed a novel façade unit incorporating the latest thinking in solar control, natural ventilation, daylighting and photovoltaic power. By careful design and intelligent control the goal is to reduce the impact of solar and internal gains to such an extent that mechanical cooling is not required to maintain comfort conditions. The project is co-funded by the EU as part of the Joule programme and in the UK by the DETR as part of the Partners in Innovation initiative.

The façade unit has three main sections:

- lower section (to approximately cill height) is a vent for providing fresh air for comfort cooling in peak daytime conditions and night cooling
- central section a conventional view window openable by the occupants in extreme conditions
- upper section of the unit is a high level window which also acts as a ventilation pathway.

Together with these three sections of the unit there are also the following features to aid its performance:

- A PV panel which is placed above the main view window and acts as a solar protecting light shelf
- A trickle ventilator which also incorporates a fan (driven by the PV power) for providing fresh air for comfort cooling and local air movement
- Internal blinds to both the central and upper windows to provide occupant control of glare.

The design integrates all of these by the means of a local intelligent controller which operates either in a stand-alone mode or by communication with the building BEMS as part of the building environmental control system.

The first prototype units are currently undergoing tests in four locations throughout Europe: in offices at BRE in Watford and in Gotenberg and at test cells in Freiberg and Athens. The tests are under way to characterise the performance of the unit in terms of solar control, natural ventilation provision and PV power output. Further prototypes will also be developed with increasingly complex controls using fuzzy logic.

This paper reports on the design approach and the development of the first prototype unit.

Introduction

As demand for thermal comfort increases, pressure is being placed on the need for mechanical (refrigerative) cooling. Poor building design, high thermal loads and a lack of good control systems contributes to an ever-growing demand for full air-conditioning. In addition, as such systems become more readily available and desirable, continuing growth in the use for comfort cooling may be expected, this trend is unlikely to be reversed. Therefore, to counter the impact on building energy use, it is essential that building design and operation is developed to minimise the use of air conditioning systems.

Within this context, AirLit-PV is part of an integrated approach to provide an energy efficient strategy for buildings. To achieve this end the AirLit- PV unit is a modular façade unit that will reduce, or possibly eliminate, the need for air conditioning by integrating the key energy influences below:

- Optimising daylighting
- Controlling solar gain
- Providing controllable natural ventilation
- Allow optimised night cooling

Therefore the main objective of this project is:

- To develop, design, build and test a prototype of a pre-packaged building façade unit integrating natural ventilation, daylighting and solar protection under intelligent local control and with photovoltaic power,

The principal technical issue that needs to be addressed is the integration of natural ventilation, solar protection and daylighting into one package. Not only will this require a detailed investigation of the interaction of these design aspects but since the unit is being developed as part of a European project it must also be applicable across the wide range of climatic conditions that exist from the south to north of the European countries. As previous work has shown, it is anticipated that it will also will require the development of new intelligent control algorithms to ensure optimum performance. The units, when the design and development is complete, are intended for use in both new buildings and major retrofitting.

It is important that AirLit-PV is a product that can match the varying needs of different buildings. It must also be designed to conform to the guidelines and recommendations of the various studies considered in the review. In particular the amount of glazed area, daylighting performance, overall insulation properties of the element and the provision of ventilation for both summer cooling and winter occupant needs. Integration aspects include incorporating the daylighting and energy saving potential of the façade within the overall structural design of the building.

It is recognised that there are a wealth of related issues which are raised by the development of this research prototype. The integration with other aspects of the building services is important. Not only must it be capable of being physically adapted to the various concerns of facade and heating systems but it must also be capable of operating within the wider context of the overall building environmental control system and, most importantly, the occupants need for control. However, the modular concept adopted for the unit is seen as a means of solving some of these challenges. Derivatives of this first prototype can be developed which may incorporate a subset of the features of this first prototype. For example, for a unit on the northern facade it would probably be more appropriate to remove the PV shading and provide only occupant controlled vents and windows. Naturally, supplying a unit with mains power and retaining full functionality with respect to night cooling and automatic control would be an option.

It is appreciated that the future for the concept may differ from the actual unit now being researched. This prototype unit is providing the test-bed which will enable the research team to address these issues, both in the field and in test cells, and from the findings establish the potential for the concept in the testing commercial environment of the building industry. The commercial viability will depend on the cost of the unit, both capital and operating costs, being acceptable to the industry.

It is estimated that even a modest 2% take-up of these façade units could save directly 1 million tonnes of oil equivalent in five years and contribute to the potential annual saving of 7 million tonnes of oil equivalent within the EU by using natural ventilation and daylighting.

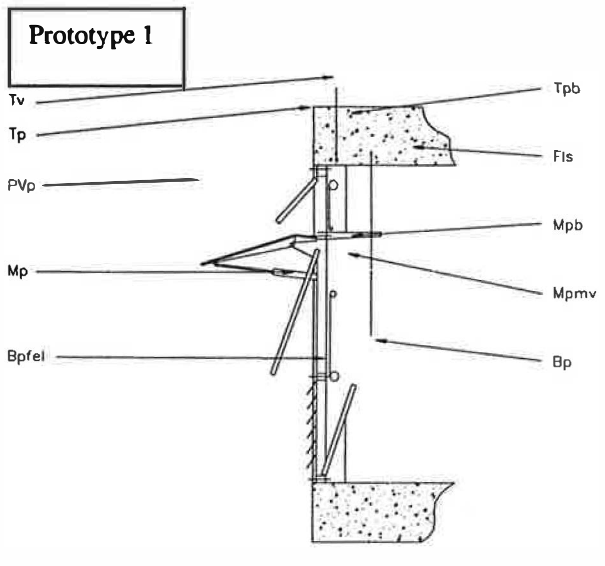
To address these issues two parallel research exercises are being carried out. Firstly, is the immediate production of a prototype system for monitoring in test cells and real buildings, and secondly modelling to optimise the design.

Design of façade

The design of the first prototype was reached by adopting conventional components and adapting them as required. The main intention was to produce a working unit from which development could proceed. Figures 1 and 2 show the design of the first prototype.

The design has been developed to provide adequate glazing areas for daylighting - whilst protecting from excessive solar gain by external shading from the PV panel and an internal blind under occupant control – and sufficient openable areas for ventilation. The PV panel is used not only to provide power for both the control system and associated actuators but also to provide power to a ventilation fan installed within the unit.. In this instance the unit is a stand-alone installation with 24 volt operation. The power is only used locally but given a suitable situation it could be inter-connected to the grid supply to augment the building load.

Figure 1. A section through the façade unit- for key see table below.



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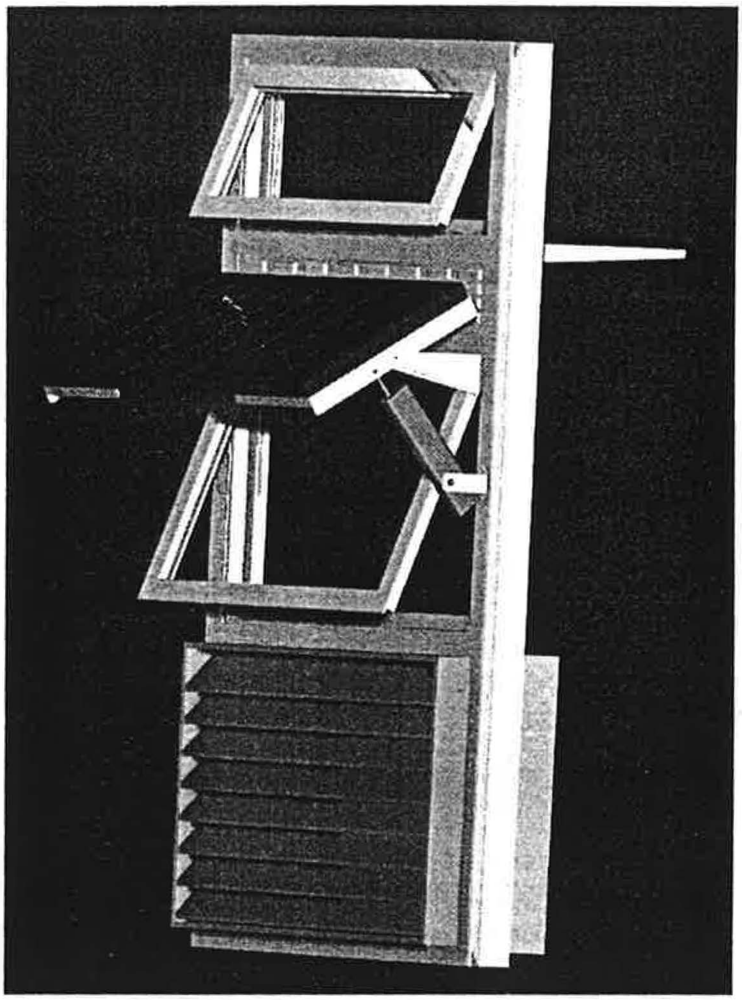

Figure 2. Design of first prototype façade unit.

Prototype details:
Approx. overall size; 1200mm mullion centres x 2700mm high (between head and sill)

Trickle ventilation (Tv)
- Top transom, open area approx. 3000mm^2, automatic electric control (open/closed).
- Insect screen.

Top pane (Tp)
- Approx. size; 1200mm mullion centres x 600mm transom centres. Top hung outward projecting friction hinge, electric actuator (chain drive) automatic control with manual (user) override, double-glazed (6mm-12mm-6mm) with Solar E glass. To provide 160 l/s night purge rate.
- Insect screen.

Top pane blind (Tpb) *(Not applicable to Southern EU façade)*
- White screen, top down automatic electric control with manual (user) override.

Fixed light shelf (Fls)
- Depth 600 mm, full width in brushed stainless steel (0.9 min. reflectance).

Mid pane (Mp)
- Approx. overall size; 1200mm mullion centres x 1200mm transom centres. Top hung outward projecting friction hinge, manual (user) operation, double-glazed (6mm-12mm-6mm) with Solar E glass.

Mid pane blind (Mpb)
- White screen, bottom up manual (user) operation.

Mid pane mechanical ventilation (Mpmv)
- 60 – 150 l/s via automatically and manually (user) controlled electric fans, manually (user) controlled directional flow vanes, automatic actuator controlled duct (external to internal sealing system).
- Insect screen.

Bottom pane (Bp)
- Approx. overall size; 1200mm mullion centres x 900mm transom centres. Bottom pivot inward hinge, electric actuator (chain drive) automatic control operation, opaque insulated (with noise attenuation), opening to provide 160 l/s night purge rate.
- Insect screen.

Bottom pane fixed external louvre (Bpfel)
- Full width aluminium louvres to prevent human and animal ingress.

PV panel (PVp)
- Located on top/mid pane transom, automatic angular rotation to suit shading requirements of site location, output to suit power requirements of façade element relevant to site.
- Infill shading between PV panel and façade, brushed stainless steel.
- Approx. PV panel size 1017mm x 881mm (commercially available size).

Additional shading (Southern EU)
Top transom mounted brushed stainless steel to match above, angle to suit site conditions (to shade top pane).

The facade unit was envisaged as being installed primarily on south facing facades with the photovoltaic panel horizontally mounted and acting as the external solar shielding and tracking the sun by moving vertically. For east or west facing facades the PV panel was to be mounted vertically on an appropriate mullion. The BRE building into which the unit has been fitted has a west facing façade and therefore the unit has a vertically mounted PV panel. See Figure 3 which is of the unit as installed and now operational at BRE.

Control logic

It was recognised early on in the design and specification of the unit that the control of the various elements would be a vital component of the design. The following strategies and requirements have been identified for the control logic of the AirLit-PV unit. These control regimes have been devised to provide the required aims of reducing solar gains, providing ventilation and night cooling whilst maintaining daylight but also – and most importantly - retaining flexibility in operation for the occupant.

All the specified times and set points are those estimated as being suitable for a UK situation. However, as the unit will be required to operate under a wide range of climatic conditions and building types, they should all be capable of being readily adjusted to other values without either hardware or major software changes.

The inputs to the controller - in this first prototype are as follows:

- internal and external temperature sensors (PRT 100)
- Three push button switches - normally open - for occupant control of trickle vent, upper blind and fan.

Two further two input channels are provided for future inputs which could include:

- CO2 for internal air quality
- daylight illuminance (or other) to detect overcast conditions when the PV panel can be moved to the horizontal position to provide increased daylight.

Currently, conventional control techniques are provided. The implementation of 'fuzzy' or intelligent controls will follow the proving of the initial design concept. The results of testing this prototype will contribute to the development of the appropriate control methods.

Similarly, the integration of this unit either with other units, or a BMS, has not yet been addressed. It is recognised that this issue must be dealt with, as in a building with many units incorporated into a facade some level of overall control may be required. For example, adjacent units must not be able to operate in contradictory modes, or a local weather station may provide information about the wind speed and rain to limit the use of vents. This issue requires a more considered view and will also relate to the means by which the unit is to be exploited in terms of new build or refurbishment. Figure 4 shows a table of the control parameters.

Installation and commissioning

A complete façade unit was delivered to BRE in the middle of January 1999. Installation started in the 1st week of February 1999. The unit was installed in an office on the top floor of a four-storey office block, see Figure 3. At the time of writing the unit is operating under a basic control regime and full commissioning and monitoring are underway.

Three further prototype façade units are to be installed in the following European countries, UK, Sweden, Germany and Greece. Two units will be installed in test cells (Greece and Germany) and two in office type buildings (Sweden, UK). The units will be operated under a wide variety of climatic conditions and the conditions of these prototype units will be specific to the locations and monitoring periods.

It is essential therefore that careful evaluation of the prototype units is made and that they are characterised in such a manner that the likely performance in other situations can be predicted. It is a key role of the monitoring to produce this information. To this end a monitoring and testing methodology has been developed. The methodology details a number of performance characteristics of the unit which will need to be measured, in both test cells and real buildings, to enable the unit to be optimised for its given location and conditions, and for other geographical locations. It also details the monitoring experiments that need to be conducted in order to determine these characteristics. For example, measurement of daylight provision and solar shading performance and airtightness and natural ventilation air-flows.

Component	Control	Actuator	Comments
Trickle ventilator	Normally open - occupant control to close by push button during daytime occupancy period. Lighted button to give feedback of signal to operate motor. Reset to open at 12:00 noon and end of occupied day 20:00	Motor - 0.26 amps - 10 second run time	The trickle ventilator is the main source of ventilation in the winter months. The occupant needs feedback at least on the command issued if not the state of the vent.
Upper vent – daytime	Normally closed - opens if not raining and internal blind retracted and Tint >23°C for more than 5 minutes and Text > 10°C Manually open by push button but if Text<10°C reset to close after 30 minutes.	Motor - 1 amp for 10-15 secs.	The upper vent will provide the majority of the fresh air in spring and autumn. However, the occupant can over-ride for short periods even in winter. This vent operation may be linked to CO_2 concentration in future versions.
Lower vent – daytime	Normally closed - opens if: Tint>25°C for more than 5 minutes and Tint>Text.	Motor - 1 amp 10-15 secs 1/8th amp 60 secs.	The lower vent is used in the summer to greatly increase fresh air supply and air movement when the office is significantly overheated.
Night cooling strategy	After 20:00hrs both upper and lower vents open if: Tint>23°C and daily average Tint>22°C and Tint>Text and Tint >heating set point. Continue until 07:00hrs close both vents reset to daytime control regime.	Both upper and lower vent motors.	The cooling strategy is taken from the BSRIA study and relates to UK conditions.
Blind control – daytime	Normally retracted - close under occupant control during occupied period 08:00 to 20:00 reset to open at 20:00. Blind control takes precedence over upper vent control, i.e. if upper vent open and blind is requested upper vent shuts.	Motor - 0.35 amps for 60 secs.	The control of the glare for the occupant is most important although closing the upper vent will reduce the ventilation the blind may reduce some of the heat gains.
PV panel – tracking	Position controlled by solar position obtained from latitude, longitude, date and time of day.	Motor - 0.7 amps ~ 2secs at 15 minute intervals	The PV panel will move at intervals to provide the maximum shading of the mid-pane window. Future versions may allow for the panel to be moved under cloudy sky conditions.
Battery condition	Battery capacity controls fan operation if battery charge < 1/2 fan not available. A battery charging and condition monitoring circuit is required.		A battery charging and conditioning circuit needs to be included so that optimum use of the battery is achieved and it is not 'flattened' by excessive use. An additional battery to back up the controller should be provided.
Fan: night cooling mode - > daytime mode - >	Operates if: Tint>23°C and daily average Tint>22°C and Tint>Text and Tint >heating set point. and time between 00:00 and 06:00. and battery charge > 1/2. occupant control by push button but only at 1/2 voltage and reset after 1 hr.	Motor - 0.72 amps	The fan has two main aims: 1. to provide ventilation and air movement during the day without introducing noise from outside 2. to provide additional night cooling capacity

Figure 4. Control parameters for the AirLit-PV Façade Unit