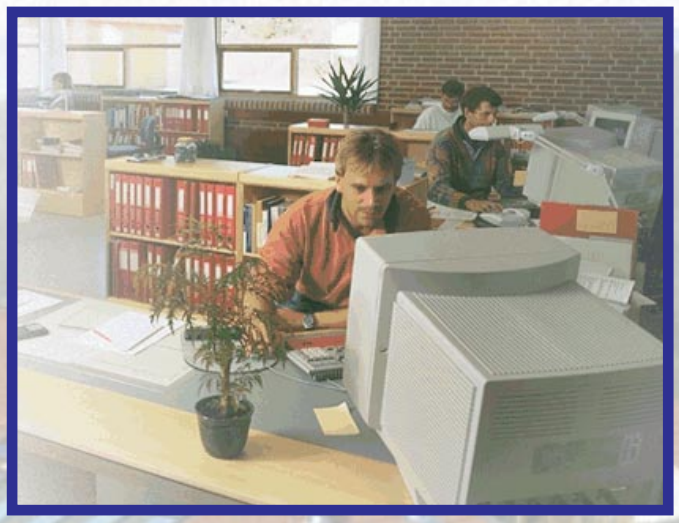
The „Intelligent“ Building at PROCES-DATA A/S



PROCES-DATA A/S has constructed a new building for administration and development activities. The fact that PROCES-DATA originally developed the P-NET Fieldbus, which has now become part of the new European fieldbus standard - EN 50170 Vol. 1, it was a natural consequence to automate the new facility using P-NET. By using the P--NET Fieldbus, with it's inherent support for distributed systems, the new building has become “intelligent”.

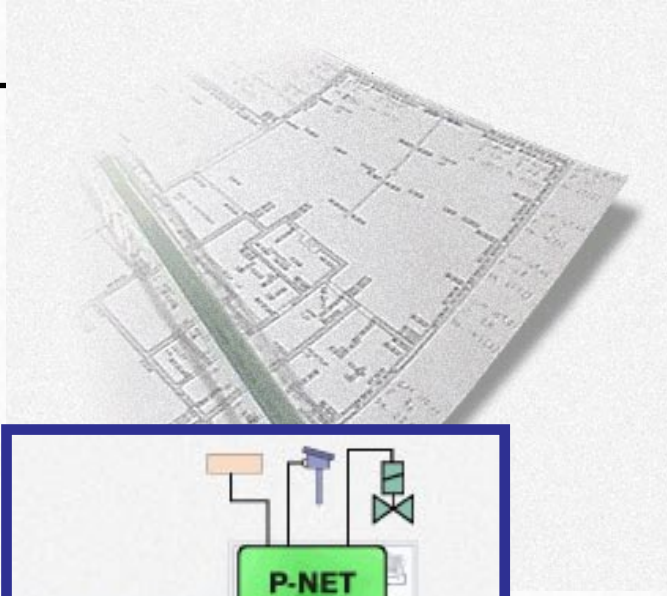
P-NET has been applied in the areas of control, regulation and supervision of all the installed electrical, mechanical and climatic control equipment. Furthermore, P-NET is an integrated part of the Company's PC network, such that telephone, fax, and other electrical equipment, combined with fire and security alarm processes, to become a consolidated automated building solution. In addition, a number of PC software utilities provide the ability for any building control to be accessible from any of the work stations on the network.

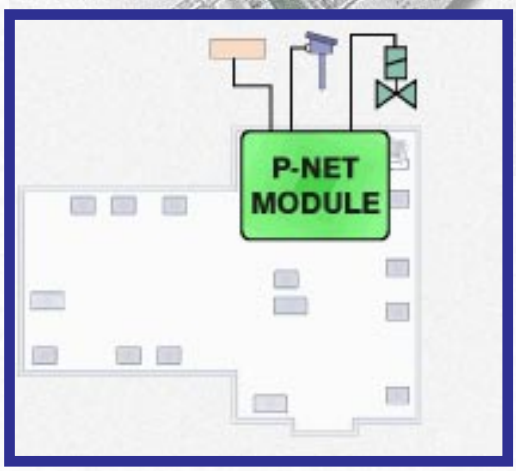
- **EN 50170**
- **Intelligent Building**
- **Control**
- **Regulation**
- **Supervision**
- **Integration with PC network**

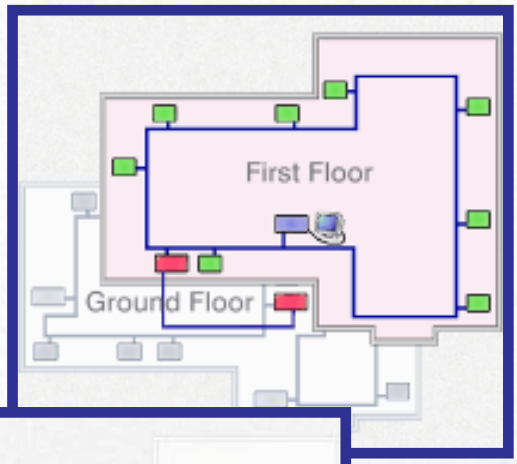
Main Functions

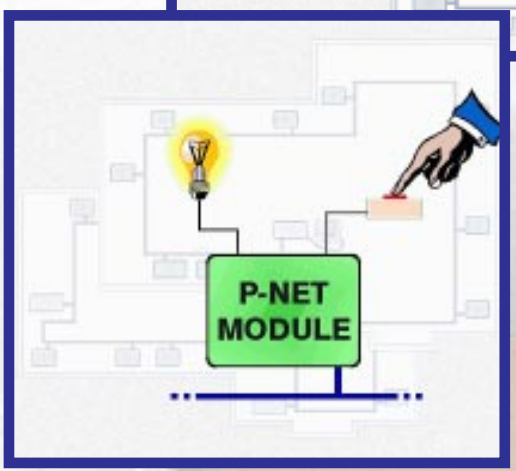
In general terms, the principle of the automation of the building, is that the “intelligence” is distributed throughout the whole structure. Individual sensors, actuators, relays and other elements, are connected to P-NET interface modules, which are placed around the building, and housed in boxes on the walls. This leads to a minimum use of cabling. The majority the P-NET modules are of the PD 3221 Universal Process Interface (UPI) or PD 3120 Digital I/O type.

All P-NET modules are connected together via the P-NET fieldbus, and all are also connected to a common Power Supply Unit having battery backup.









The P-NET structure is divided into two separate sections, one for each floor. Communication between the two P-NET sections is achieved through a routing (dual port) master. The division of the system contributes to the well known high level of integrity of the P-NET fieldbus. This ensures that a fatal error on the one P-NET section doesn’t affect the other.

To control and supervise local functions, a calculator program can be downloaded to the various modules.

PD3120/PD3221 are slave modules. All related inputs and outputs are therefore, as far as possible, connected to the same module, thereby enabling the module to carry out autonomous functions. This means that a central computer need not constantly scan the inputs and outputs, and therefore no unnecessary load is put on P-NET communications.

- **Distributed intelligence**
- **Low cabling costs**
- **Modules connected via P-NET**
- **Battery backup**
- **Multi-net**
- **Downloadable program**
- **Local functions**

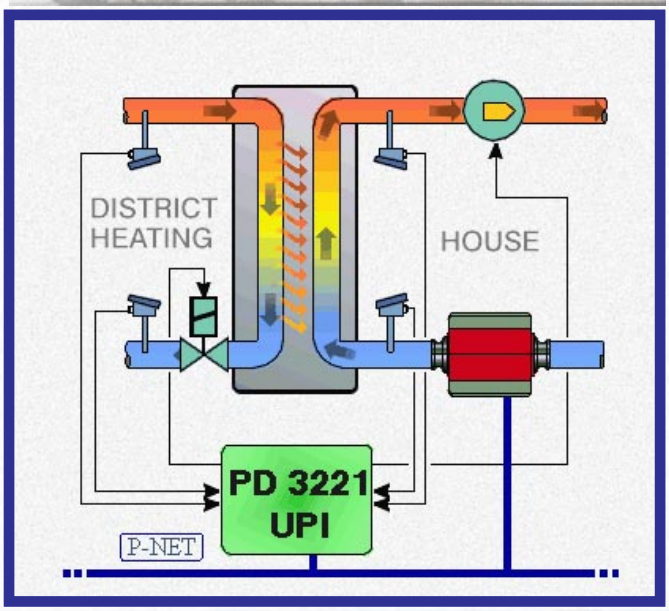
Heat Exchange Control

The building is heated by the district hot water supply. As a safety precaution, the central heating installation is isolated with a heat exchanger, in order to reduce any damage caused by possible leaks occuring in the pipe systems.

The temperature of the piped water is measured in four positions. Two of the measurements (district heating return and secondary forward) are used to regulate the flow, in order to maintain set point temperatures. The remaining temperature measurements are purely for monitoring purposes.

Flow is controlled by a motorised valve on the primary side of the heat exchanger. On the secondary side, a PD 340 flowmeter is used in conjunction with an intelligent pump, to measure and regulate the flow and pressure of the water.

Everything is connected to a PD 3221 UPI, which in turn is connected to P-NET cabling within the building.



- District heating
- Heat Exchanger
- Temperature sensors
- Motor valve
- PD 340 Flowmeter
- Intelligent pump
- PD 3221 UPI

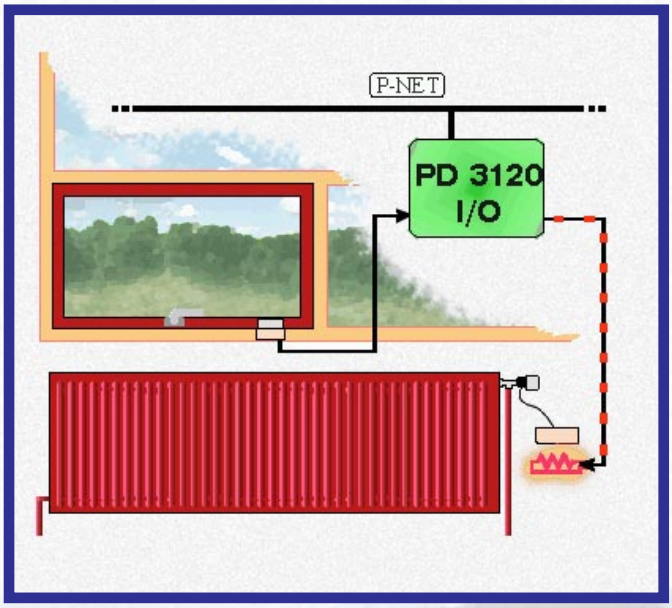
Zone Thermostat

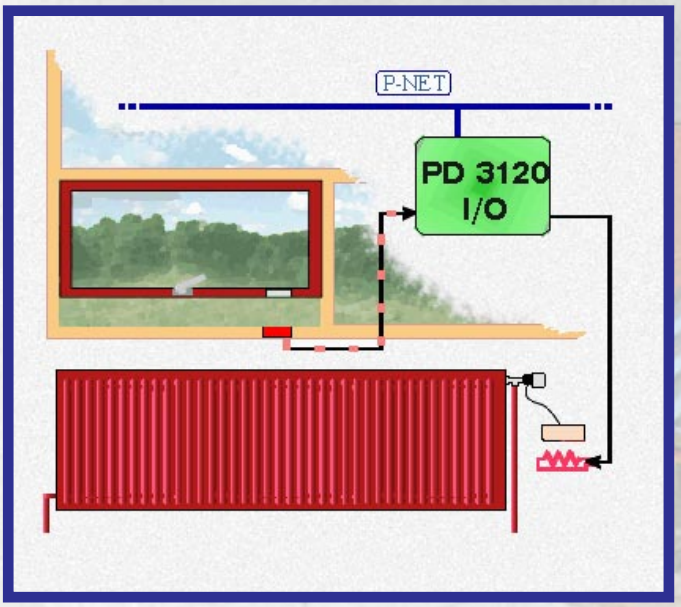
Every radiator is supplied with a thermostat incorporating a remote sensor. This sensor has a small built in heating element, which is able to warm up the sensor by up to 10 degrees celcius. It is therefore possible to fool the sensor into measuring a higher room temperature than actually exists, and by this means, the radiator can be regulated.

The heating element is connected to a digital output configured for duty-cycle control from 0 to 100 %. This provides a temperature variation control of 0 to 10 degrees celsius. This function is used at night and during air conditioning.

Each window is provided with a small switch, which is used to indicate whether the window is open. If this the case, the surrounding radiators are automatically turned down.

Regulation is performed locally by a PD 3120 Digital I/O. However, it is still possible to upload setpoint temperatures and read the status of the window switch, for perhaps alarm purposes, from any P-NET master on the network.





- **Thermostat with remote sensor**
- **24 Volt heating element**
- **Temperature sinking**
- **Duty-cycle control**
- **Window switch**

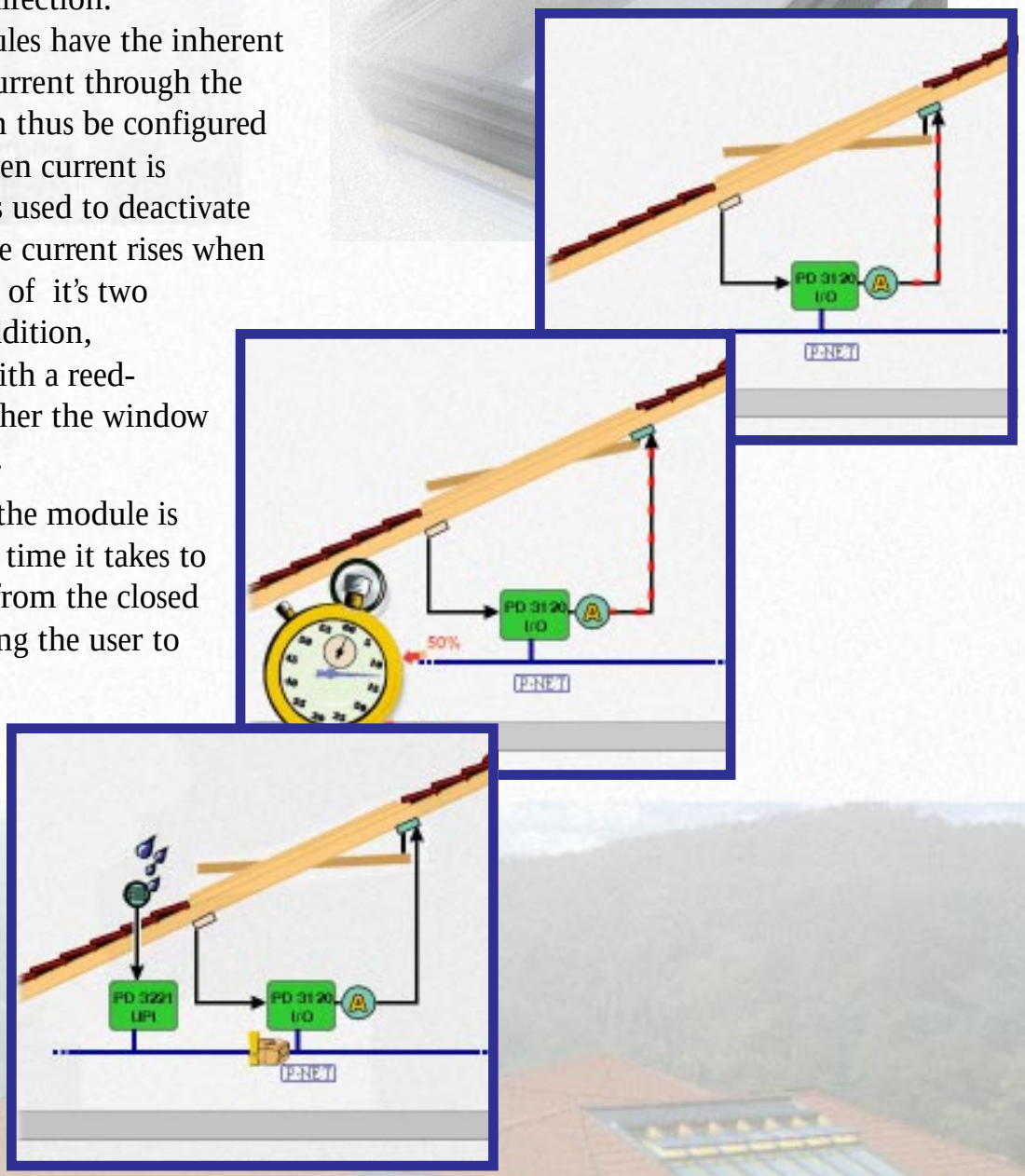
Velux-windows

All Velux-windows in the building are electrically controlled. Each window is supplied with a 24 Volts DC motor. Two outputs from a module are used, one for activation and one for direction. PROCES-DATA's modules have the inherent ability to measure the current through the outputs. The output can thus be configured to switch off when a given current is exceeded. This facility is used to deactivate the motor, as soon as the current rises when the window reaches one of it's two extreme positions. In addition, windows are supplied with a reed-switch, to indicate whether the window is actually closed or not.

As a special function, the module is also able to measure the time it takes to fully open the window from the closed position, thereby enabling the user to open the window to a preferred percentage.

A rain detector is connected to a P-NET module. So should the windows happen to be open when it starts to rain, they are closed immediately.

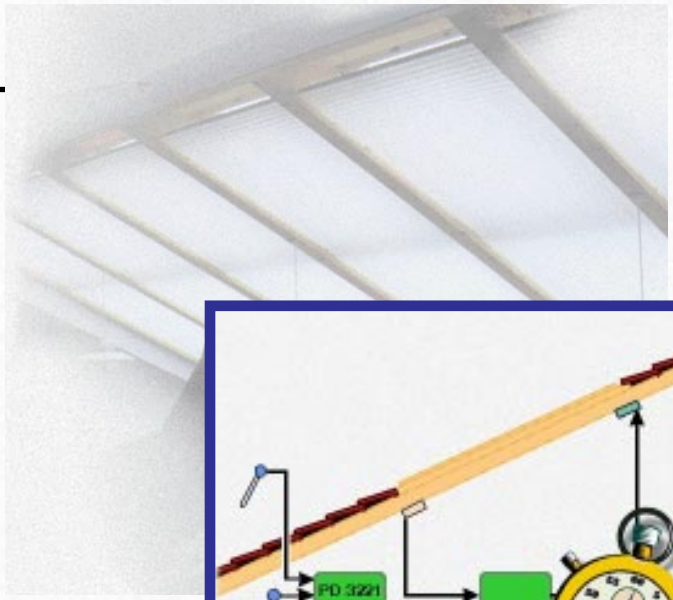
The data used for the automatic control of the Velux-windows, is collected by various modules connected to P-NET. A controller gathers this information and then performs the necessary regulation.



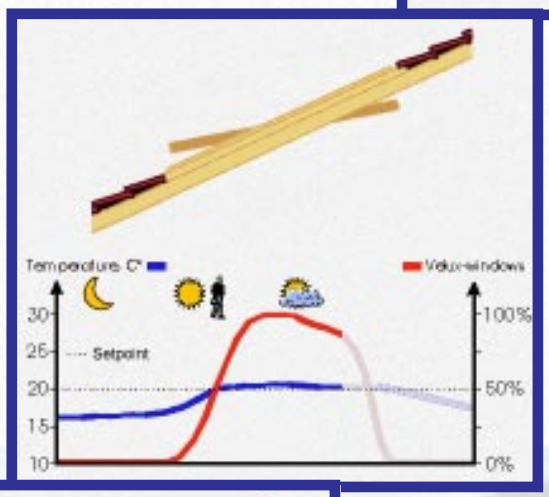
- **Electrically operated windows**
- **Current threshold**
- **Reed-switch**
- **0-100 % position**
- **Rain detector**

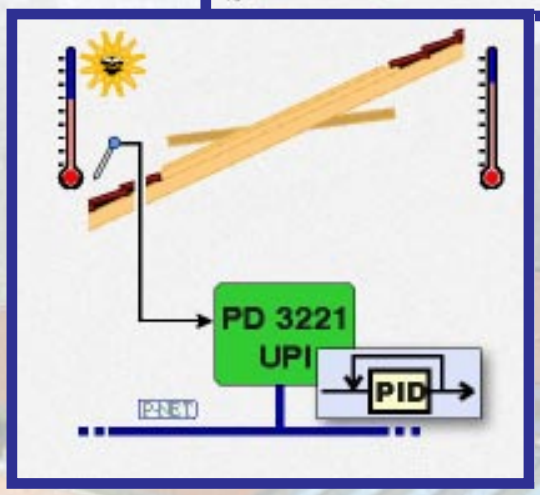
Velux Regulation

The Velux-windows are also used for local climatic regulation. As the windows can be opened electrically, and with a preferred percentage according to the time measurment feature, they are well suited for advanced temperature regulation performed by a PID-regulator, like the one incorporated in the UPI-modules.



During the night and in the morning, the temperature in the building may be lower than the preferred temperature setpoint. As the sun rises higher in the sky, the room is heated, which together with radiated heat from people within the building, results in a rise in the indoor temperature. At the time when the indoor temperature begins to exceed a given preferred room temperature, the windows are slightly opened. At this point, the PID-regulator is trying to maintain the right balance between the open percentage of the windows and the rate at which the room is being heated.





Should a clear blue sky happen to turn into cloudy weather in the afternoon, the level of the sun's heating will fall. This in turn results in the PID-regulator closing the window slightly, to maintain the balance.

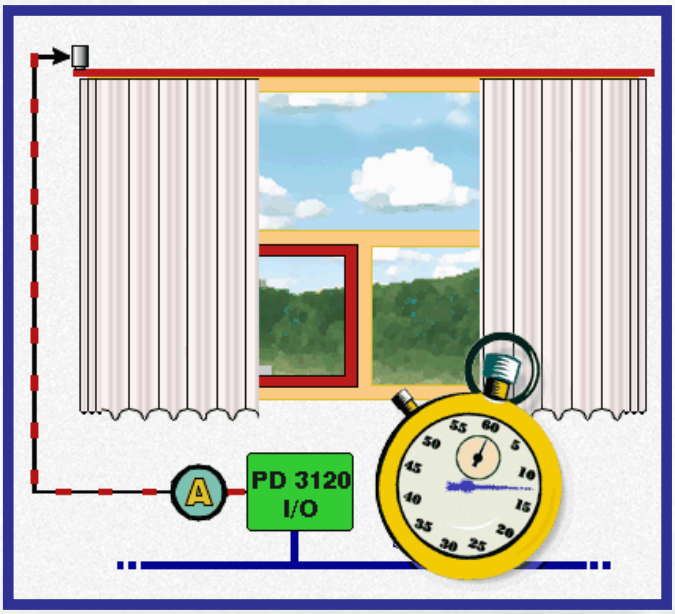
The regulation is of course performed provided that the outdoor air temperature is lower than the indoor temperature.

The purpose of using a PID-regulator is, that it performs the regulation in an attempt to achieve a balanced situation. This also involves the use of weather data such as the outdoor temperature. For example, to achieve a reduction of 3°C in indoor temperature, the windows might happen to be fully opened in the relatively hot summer months. On the other hand, a sunny winters day with below zero temperatures, would result in a very low percentage opening.

- **Local climatic regulation**
- **PID-regulator**
- **Temperature balance**
- **Seasonal regulation**

Curtains

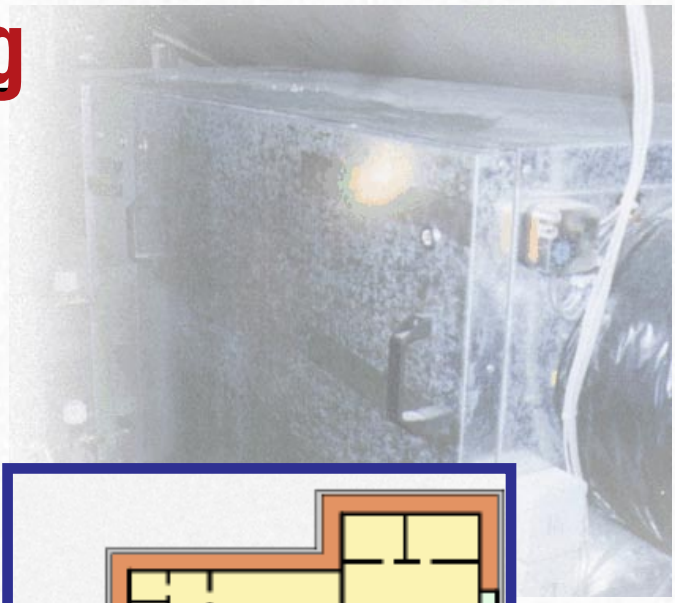
Every curtain in the building is controlled by a 24 Volts DC motor. As with the Velux-windows, two outputs are used, one for activation and one for direction. Again, the extreme positions are registered by monitoring the rising current, and the open/close time is measured and stored in the memory. As the module is aware of the time it takes to draw the curtains, it is possible to change the position of the curtains by only a percentage. This regulation is of course performed via P-NET, which transfers the necessary adjustments requested by a controller, to the module operating the curtain.



As P-NET is accessible from the PC network, the control of curtains is available from all PC workstations within the building, enabling the staff members to locally control their surrounding curtains without leaving their desks.

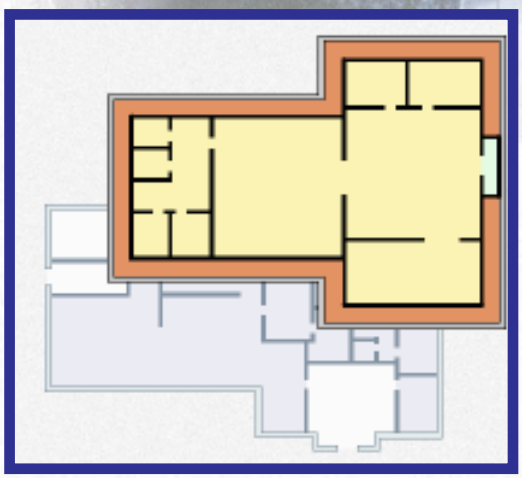
- **Remote controlled curtains**
- **24 Volts DC motor**
- **Current Threshold**
- **0-100% position**
- **P-NET and desktop control**

Room Conditioning

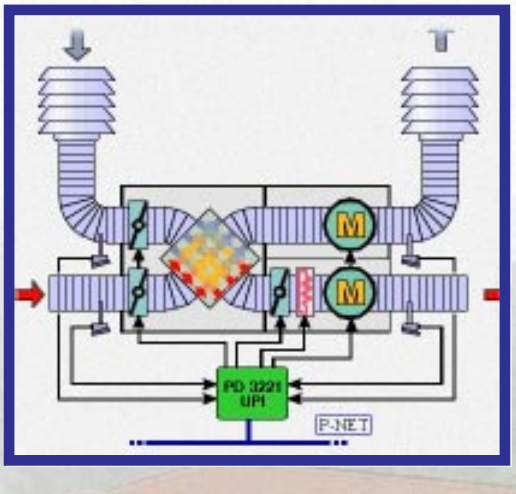


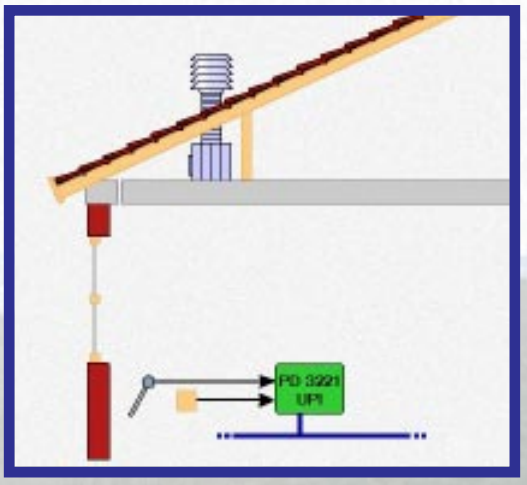
The building is provided with four ventilation units, manufactured by GENVEX. The units are used for ventilation throughout the whole building.

Two units are used for the offices, one unit for he printing room, server room, meeting room and toilets, and finally, one is used for the first floor.



Generally, the air vents are large in order to keep the noise level down, and to ensure minimal loss of pressure. The inner skin of the building is used for this purpose. A gap of 2 centimeters between the ceiling and the outer walls, enables the air to enter and leave the rooms. Air is blown into one side of the room, and is drawn out from the opposite side. Most of the rooms are supplied with a temperature and humidity sensor, which are connected to a UPI module. These are utilized to fine tune the room atmosphere.





The capacity of the four GENVEX units provides the capability of completely changing the air once every hour. The incoming air is warmed by the outgoing air, using a cross exchanger. In addition, every GENVEX is equiped with a heating element, which can further increase the temperature of the incoming air. The controlled speed of the ventilation motor is infinitely variable by the use of an analogue output.

The temperature of the incoming air and the outgoing air is monitored using analogue inputs, and used for regulation.

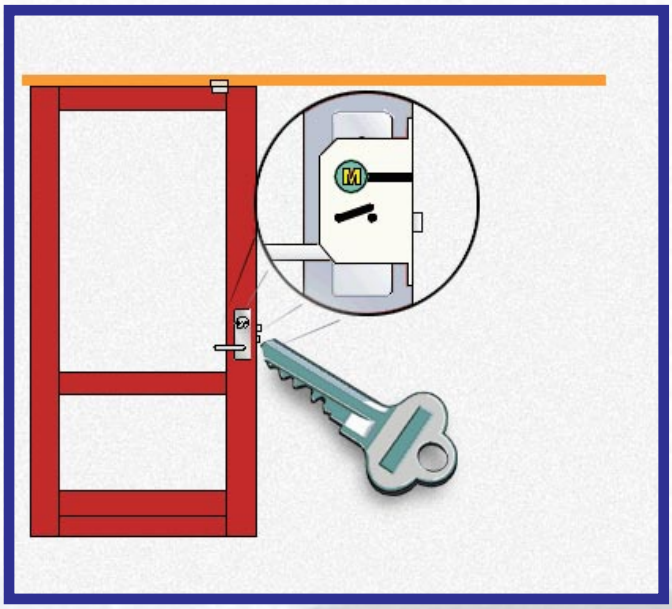
- **Four GENVEX units**
- **Large Air Vents**
- **Air renewal each hour**
- **Cross Exchanger**
- **Heating element**
- **Adjustable ventilation motor**
- **Air temperatures measured**

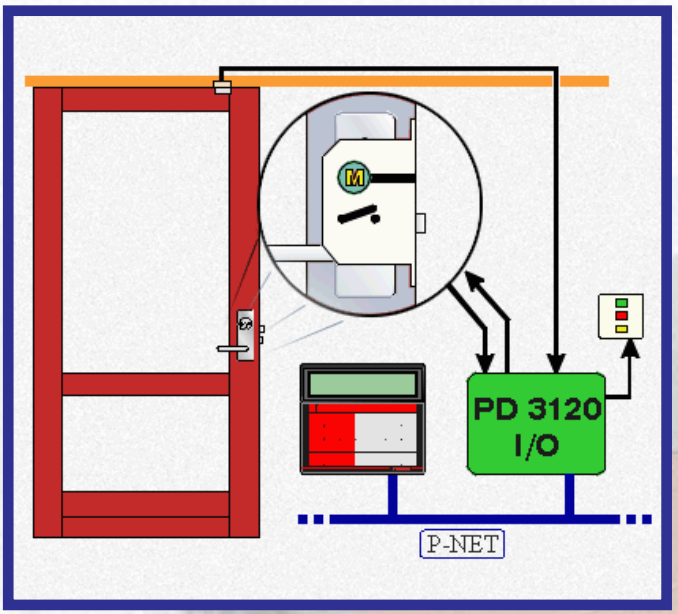
Electric Doorlocks

All outer doors are locked and unlocked electrically. For safety reasons, locks can be operated manually with a key. This makes it possible to unlock the doors during a possible power failure. The locks are connected to a P-NET slave module and are then controlled by messages sent from a master controller connected to P-NET.

The motor and micro switches for each lock are connected to a PD 3120 I/O, which is located close to the door. A calculator program in each module, takes care of the processing of the signals to and from the lock and switches.

A set of status lamps and a beeper, indicating the current status of the doorlock and alarm system, is located at each door.





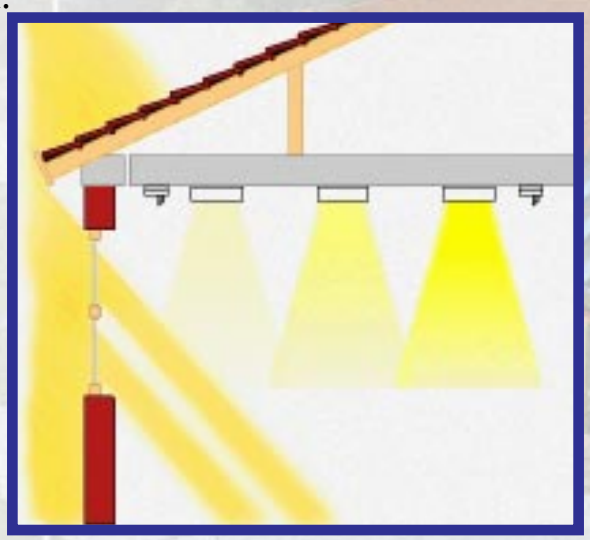
- **Electrical doorlock**
- **Manual operation if required**
- **Door position switch**
- **Status indicators**

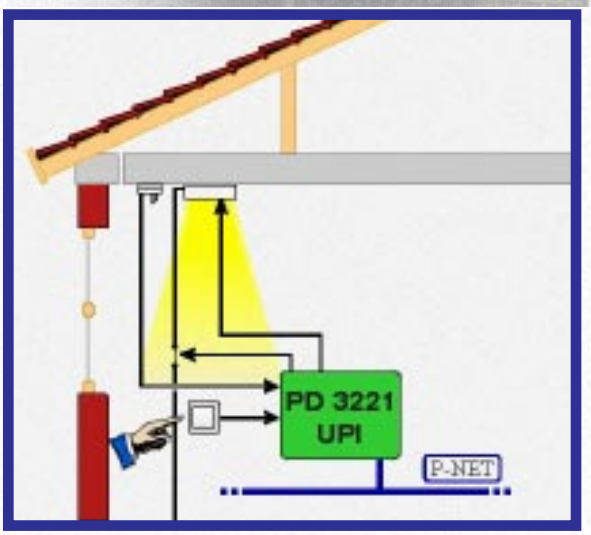
Lighting

The lighting sub-systems throughout the building, consist mainly of one or more fluorescent tubes and a light sensor. Light is regulated in an attempt to keep a constant light intensity in a room. Thus, the light fitments in each room are adjusted using the basis of a setpoint and the input from the light sensor.

Furthermore, the room lighting can be turned on and off by a tip switch connected to the UPI module, which also controls the sensor and fitments. The lamps are dimmed or brightened using an analogue potential, ranging from 0 to 10 volts. The control voltage is generated using a 1 kHz duty-cycle output from the UPI.

In the larger offices there are three rows of lights, and two light sensors, which are located on either side of the rows. Again, a constant light intensity in the room is aimed for. The two outer rows of lights are adjusted in accordance with each of the coherent light sensor measurements, and the central row adjusts to an average value of the other two. When strong daylight enters through the windows, this normally leads to a lower light intensity in the row close to the window, and the other rows produce a controlled light gradient towards the shaded areas of the room.





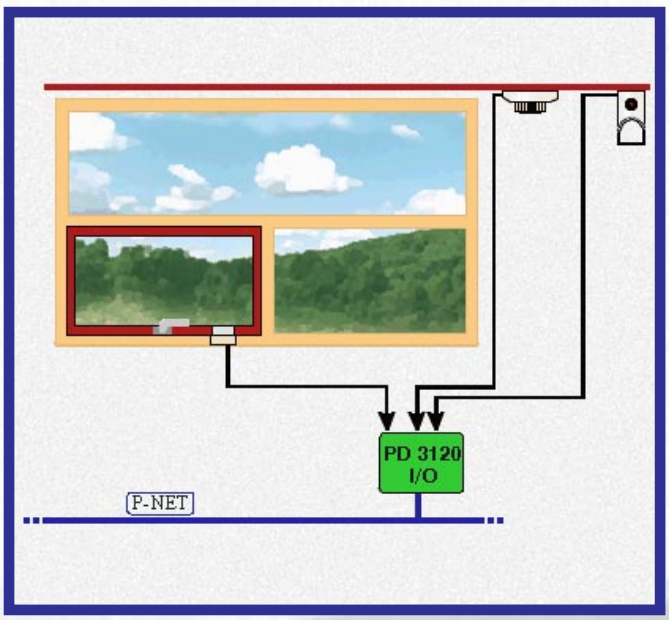
All inputs and outputs are connected to a UPI module having a combined calculator and pulse-processor program installed, which internally carries out the required regulation. Setpoints are uploaded from elsewhere, via P-NET.

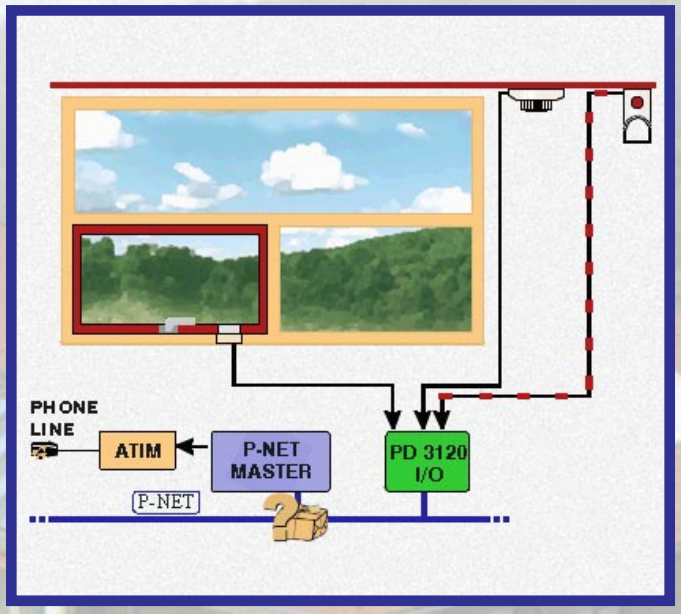
- **Fluorescent tubes**
- **Constant room lighting**
- **Tip switch**
- **Light dimming**
- **Light sensors**
- **Gradient lighting**
- **UPI module**

Alarm System

Every room is supplied with one or more motion detectors and fire detectors. These transducers are connected to digital inputs on P-NET modules.

The fire detectors are monitored 24 hours a day, and any problem results in a periodic activation of the alarm bell. When the alarm system is active, any abnormal signals from window and door switches, motion detectors, and fire detectors, or a possible breakdown in the PC network, and any exceeded criteria for maximum temperature and humidity levels, will cause the P-NET master performing the surveillance task, to send an alarm signal to the ATIM. This in turn passes on the signal to the security company.





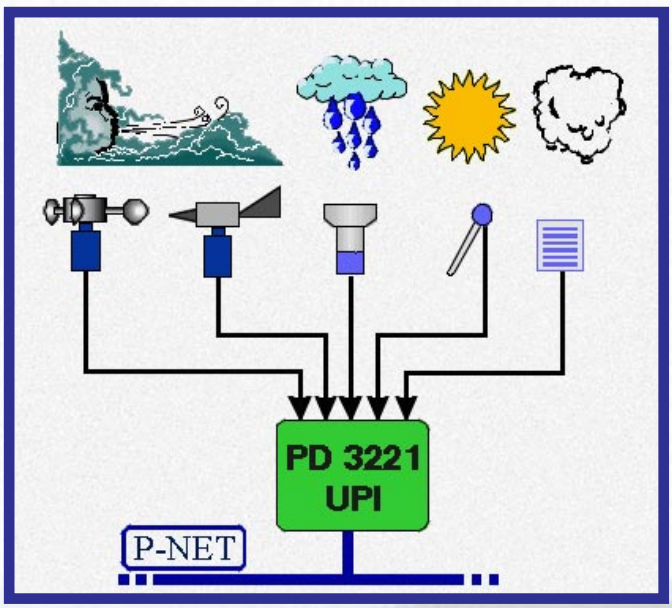
- **Motion detectors**
- **Fire detectors (ION)**
- **24 hours fire surveillance**
- **Door and window switches**
- **Network failures**
- **Temperature limits**
- **Humidity limits**
- **P-NET and ATIM**

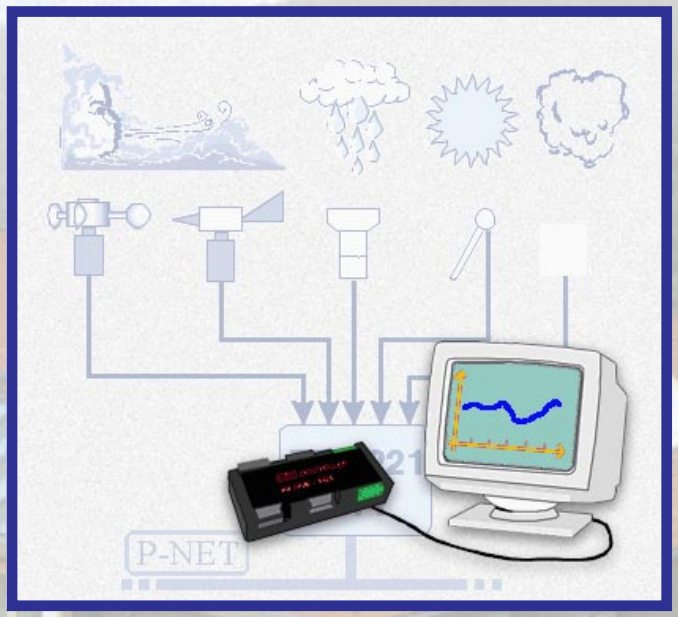
Weather Station

A wide range of weather data is collected by the system. Wind velocity and direction is passed to inputs on a UPI module. The wind direction encoder provides a 4 bit Gray-code signal having a resolution of 16 discrete positions. The resultant direction is calculated over a 2 second period, to compensate for sudden small changes.

The wind velocity signal consists of a pulsed frequency of up to 300 Hz. Both the velocity and direction are processed and converted into metric values inside the module. This task is performed using a calculator program, a pulse processor and a lookup table.

Other elements in the weather station include an outside light detector, a temperature and humidity sensor, a rain sensor and a rain gauge. The most recent weather data is stored in a PD5020 VGA controller, which then graphically displays weather data for the previous 24 hours. The data is also used for the climatic control of the building.

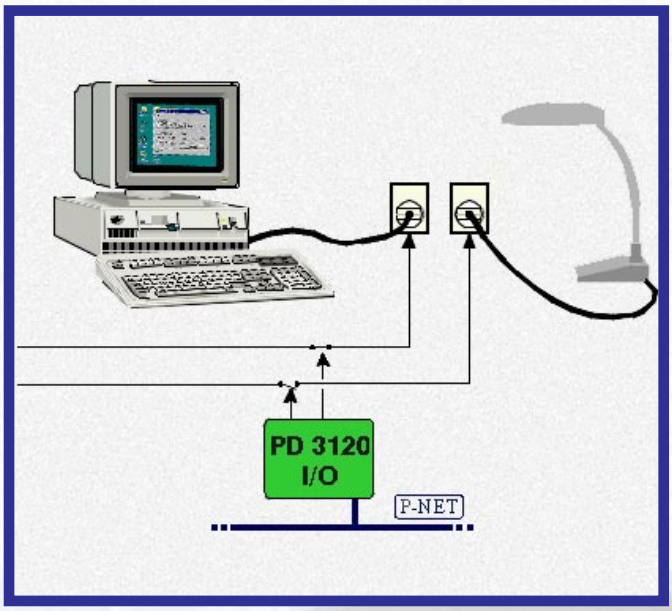


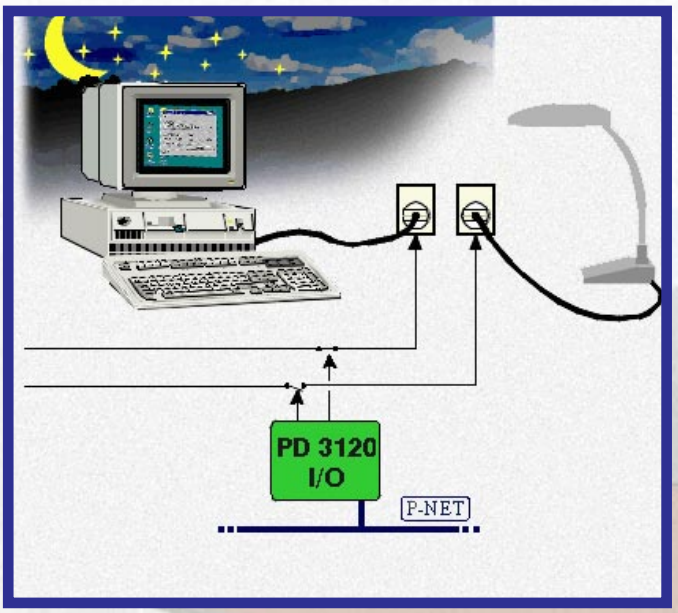


- **Wind direction and speed**
- **Light detector**
- **Temperature and humidity**
- **Rain sensor and rain gauge**
- **PD 5020 graphical display**
- **Previous 24 hours weather**
- **Climatic control**

Power

Every power outlet in the buiding can be turned on and off via P-NET. It is therefore possible to turn off every PC, desk lamp and possible test arrangement on leaving the building. Time schedules can also be set up to control the availability of the outlets. This feature is especially useful when performing automatic overnight backups of the PC workstations.

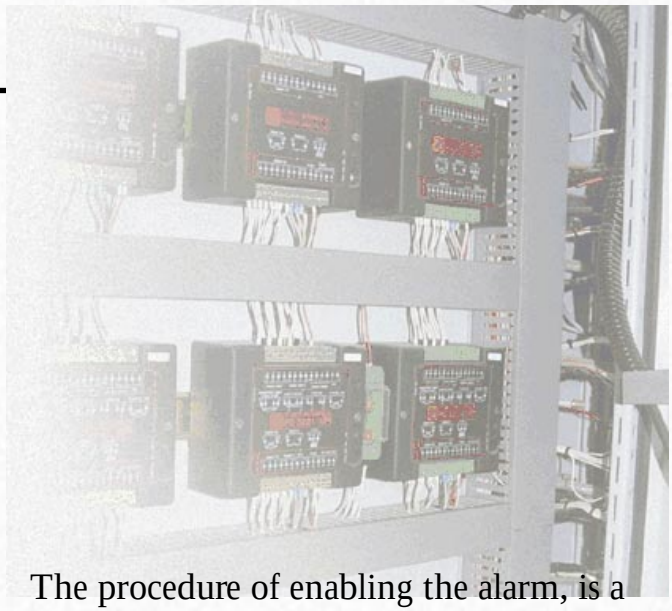


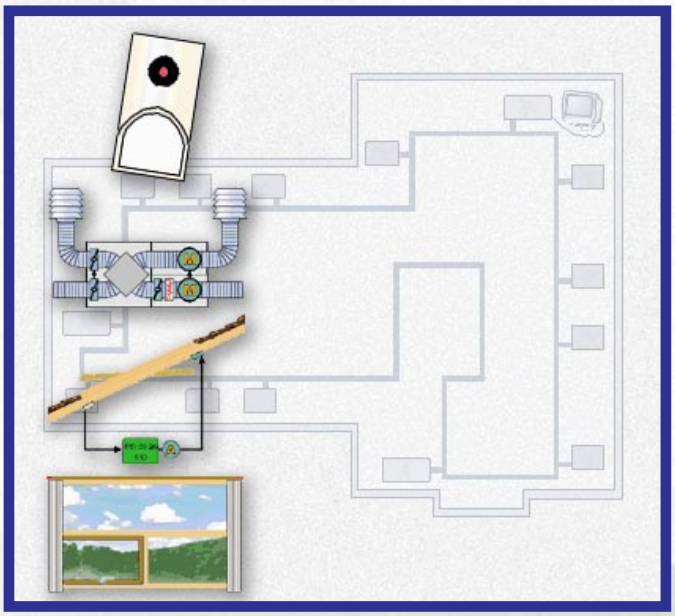


- **P-NET controlled power outlets**
- **Power turned off when enabling alarm**
- **Backup by night**

Central Functions

The distributed slave modules are, by definition, only able to carry out local functions. More complex functions, which may involve numerous modules on the P-NETs, are performed by two PD 5000 controllers incoporating a 68020 CPU. These controllers are downloaded with a Process-Pascal program, which manages the alarm functions, the complicated climatechnical calculations, the velux-windows and curtains, outdoor lighting and so on.

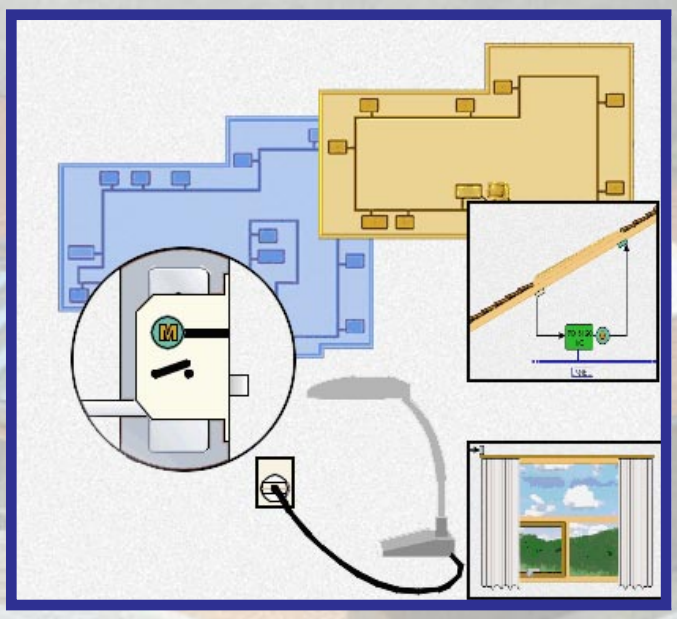




The procedure of enabling the alarm, is a good example of a centrally performed function. The alarm system is divided into sections, which can be independently toggled on and off. When the system is enabled, the chosen section is checked and the Velux-windows are closed. The outer doors, except the one used to leave the building, are locked. On leaving the building, the exit door is automatically locked when it is closed.

The alarm bells are now activated for half a second, to warn anybody left in the building. The lights are then turned off, and after 4 pm, the curtains are closed.

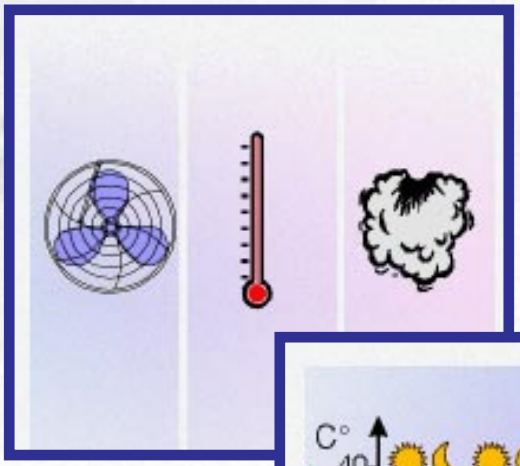
On entering the building, the lights, outlets and curtains are restored to their previous status before the building was vacated.

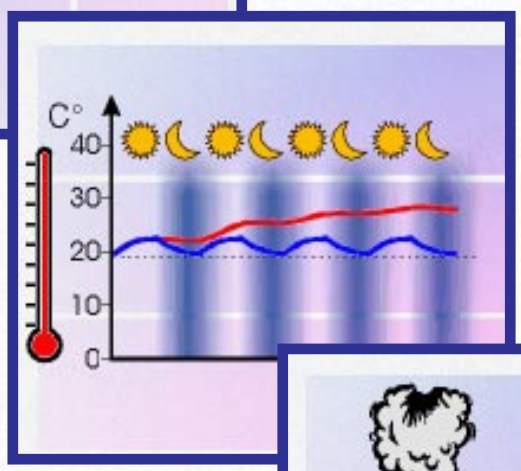


- **PD 5000 controllers**
- **Process-Pascal program**
- **Alarm functions**
- **Climatic technical functions**
- **Velux-windows and curtains**

Central Ventilation

To achieve the superior control of the ventilation system, some complex functions need to be performed. The ventilation system is used for renewing the air in the building and controlling the temperature and humidity.





In the warm summer months, the ventilation system is used to cool down the building at night, when the outdoor air temperature is at its lowest. As the building is thoroughly insulated, the rise in inside temperature during the day is less than 3 degrees celcius. Thus the building is cooled without the need for any energy consuming activity.

This diagram shows the typical variation in the indoor temperature during a hot summer week. The red line indicates the temperature within an ordinary building but the blue line shows the temperature within the intelligent building.

If the humidity in the building is too high, the most efficient reduction is achieved when the difference between the inside and outside temperatures is at its peak. This normally means airation at night.

If the need is to renew the air without lowering the temperature or humidity, the most economic time is when the outdoor temperature is almost equal to the preferred indoor temperature. This is normally the case during the day.

The principles of fuzzy logic are utilised by the controllers, to assess how the various climatic-technical elements of the system should interact.

- **Temperature reduction**
- **Humidity reduction**
- **Air renewal**
- **Fuzzy logic**

Operator Interface

Although most of the functions in the system are controlled automatically, a lot of human preferencies still have to be made. Compact PD 4000 P-NET controllers are used for this purpose. A number of these controllers are positioned around the building, and each one is customized to deal with appropriate functions relevant to a particular area of the building. These functions might be common tasks, such as operating windows or curtains, but could include more specific functions, such as lowering the screen in the conference room or customizing a preferred gradient of the lighting. Useful data, such as the room temperature and humidity, can also be locally displayed.

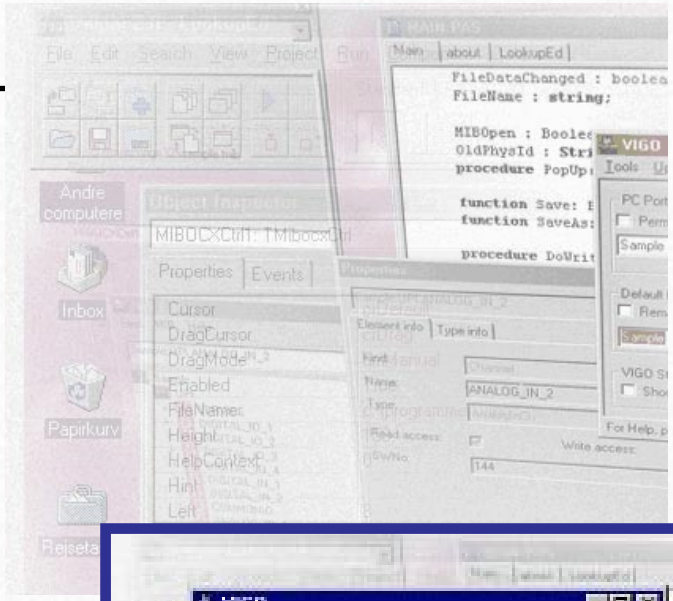
General access to the elements on the P-NET is achieved using a PD 5020 controller, which provides a connection to a mouse, keyboard and a graphical VGA monitor. Symbols drawn on the screen can then be assigned to specific data available within the P-NET system. This provides a very intuitive interface to whatever part of the system is of interest. The system is optimized for speed of response.

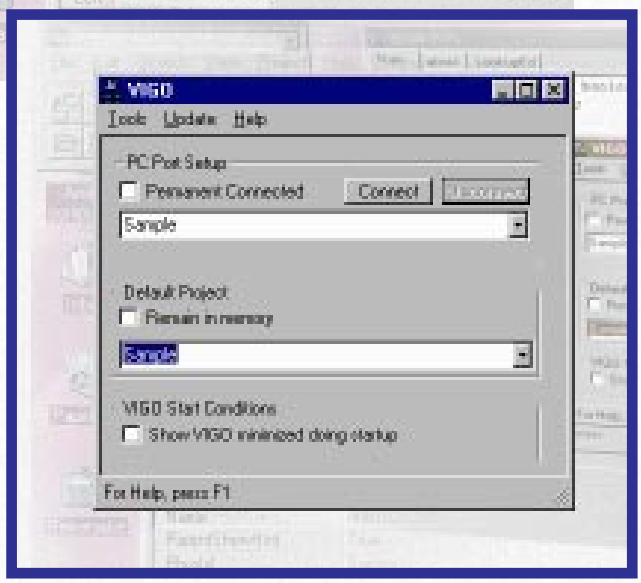
- **PD4000 controllers**
- **Customized functions**
- **Setpoint entering**
- **Data readout**
- **PD 5020 VGA controller**
- **Mouse and keyboard**
- **Fast and intuitive data access**

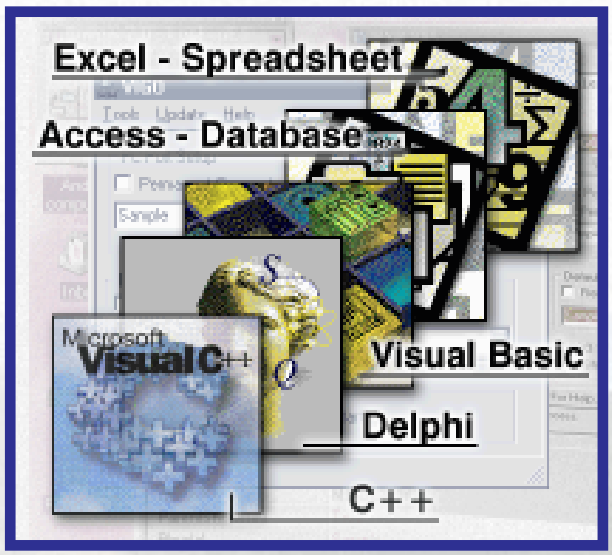
PC interface

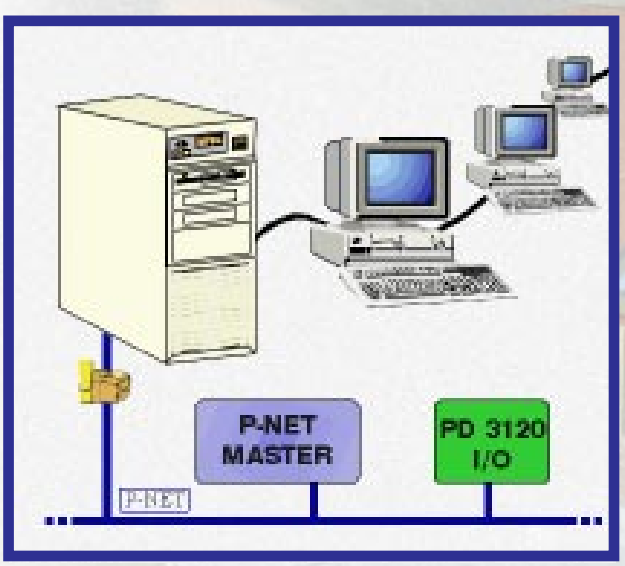
Communication between P-NET and a PC application supporting OLE2, can be achieved using a virtual interface called VIGO. Standard applications supporting OLE2 include Excel - a spreadsheet, Access - a database, and Visual Basic, Delphi and C++, which are application development languages. The data to and from P-NET can be physically conveyed either directly though a PC/P-NET expansion card, or indirectly through a Novell network to a server which provides the physical interface with the P-NET system.

It is possible to control the lights, curtains and so on, from every PC workstation in the building.



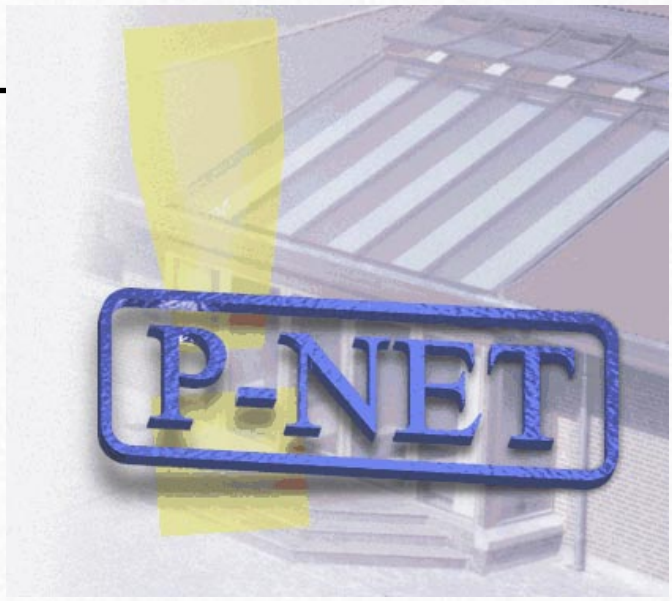






- VIGO
- OLE2 interface
- Excel - spreadsheet
- Access - database
- Visual Basic
- Delphi
- C++
- Direct P-NET access
- Indirect access through Novell
- Desktop controls

Conclusion



The input/output slave modules, which often operate in collaboration with a downloadable calculator program, form very important autonomous elements within the overall automation of the building. The fact that P-NET connects and integrates all slave and master sub-systems together, produces a powerful unification of simpler environmental control and measurement tasks into a complex system, which satisfies the subtle demands of human environmental control.

Due to the open and expandable nature of P-NET, additional modules, including those from a range of manufacturers, provided they conform to the P-NET standard, can be easily integrated into the system when required.

Finally, P-NET is a part of the new European fieldbus standard - EN 50170 Vol. 1.

- **Simplicity in sub-systems**
- **Powerful integrated functionality**
- **Expansion without limitations**
- **Open for new functions**