Control Strategies

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Report from the project: IDEEB
Intelligently Designed Energy Efficient Buildings
–assessment and control by an Eco-Factor system

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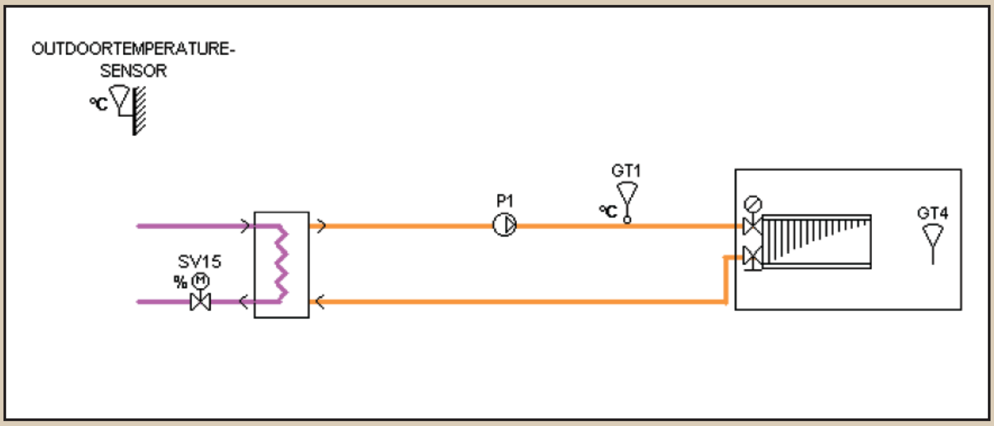

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PREFACE

This report is produced within the research project IDEEB, Intelligently Designed Energy Efficient Buildings -assessment and control by an Eco-factor system.

The holistic approach of the IDEEB project is to adopt comprehensive view. This considers the building itself and its installations as one energy system to achieve the required indoor climate at the same time as reducing environmental impact. Since each building is unique there are no all-encompassing solutions, and therefore the project aims to develop a concept (based on an Eco-factor) that describes the way of working to reach the goal.

The IDEEB project consists of three parts:

1. *A theoretical part* with separate developments of new guidelines and methods for the building process and design of a control system.
2. *A demonstration and improvement part* there the results from the first part should be tested, improved and extended in construction of four office buildings situated in different European climates.
3. *An evaluation and connection part*. Here all the improved results from the second part should be merged into a concept that would describe a way of working to achieve energy efficient buildings with good indoor climate and low environmental impact.

Unfortunately the market situation for construction of office buildings changed after the start of the project and therefore could only the first part of the project be performed. This means that the total project result consists of nine separate reports with theoretical background for guidelines and methods, which are ready to be tested in practice for improvements and extensions into a new way of working.

This part of the project deals with general guidelines of control strategies for energy efficient office buildings in Europe. The basic ground for the control strategies is to reach required indoor climate with minimum impact of the environment and the reach results might be the input for evaluation and control with the IDEEB Eco-factor system.

The authors would like to thank all participating members of the IDEEB-project.

December 2004

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SUMMARY

This report presents a concept on how installations of various types should be controlled in office buildings. Primarily the presented control strategies are meant to constitute guidelines for how office buildings should be controlled in general in Europe and thus concern simultaneously achievement of energy efficient operation and good indoor climate. Secondly, this report presents how the control strategies could be applied in an experimental building.

The choice of building design, and primarily of system solution for installations, has an obvious influence on the choice of the exact control strategy for each building. However, the basic ground for the control strategies is to reach required indoor climate with minimum impact of the environment and the reach results might be the input for both control and evaluation with the IDEEB Eco-factor system.

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1. GENERAL

1.1 Background and purpose

The principal objective with the IDEEB project is to develop new guidelines in order to achieve energy efficient buildings with good indoor comfort and low environmental impact. However, an improvement of indoor climate or energy efficiency may affect the other and vice versa, since they are closely coherent. It is therefore essential that energy optimisation will be integrated with optimisation of indoor climate and that the building is operated with such control strategies.

The concepts presented in this report on how installations in various types in office buildings will be controlled and regulated are intended to be applied in an experimental building. The most important purpose is, however, that the control and regulation strategies will be able to constitute guidelines for how office buildings will be controlled and regulated in general in the Europe of the future. It thus concerns simultaneously achieving energy efficient operation and good indoor climate.

The choice of building design, and primarily of system solution for installations, has an obvious influence on the choice of the exact control and regulation strategy for each building. One way of technically implementing the control and regulation strategies presented in this report is presented in the report Design of a Control System [1].

1.2 Comprehensive approach and ECO factor

To achieve high energy efficiency and good indoor climate, as well as to make the construction process function as smoothly as possible, a **comprehensive approach** is very important. The comprehensive approach entails that during the entire construction process – and then even in the construction process's initial phase – one considers how various system choices affect one another.

It is important that sub-optimisations are avoided. This applies primarily to system choices for installations, but also to choices of control and regulation strategies. Various functions may not counteract one another. Even when it comes to choice of control and regulation strategies, the conclusions that are reached in the IDEEB project's ECO factor study [2] are considered, namely to reach the required indoor climate with minimum impact of the environment.

1.3 Adaptations for local conditions

The EU region is a geographically large region, not the least in the north-south direction. The climate thus varies strongly. This naturally affects the system solutions chosen and subsequently the control and regulation strategy.

The guidelines and concepts on control and regulation choices that are addressed in this report are therefore intended to encompass a wide range of control and regulation for different technical installation systems. In each individual construction project, one naturally has to disregard such parts that are not relevant.

Besides the climate varying significantly between various EU countries (See [3]: Appendix B Climatic characteristics), there are also differences that must be considered when it comes to choices of both technical installation solutions and control and regulation strategies.

An important difference is that norms, rules and directives for both building design and indoor climate are different in different countries, which must be considered.

Among other things, these types differences between different European countries entail that one must presently invest differently in respect to control and regulation equipment in the construction sector. The relationship for investments in control and regulation equipment between different countries and the EU average is as follows (converted to comparable figures):

Sweden	**4 times the EU average**
Finland	**3 times the EU average**
Denmark, Norway	**2 times the EU average**

Another difference that can significantly affect the choice of control strategy is that the energy types that are normally available for supply to office buildings can be somewhat in different countries. Moreover, the cost profile for energy types varies in different EU countries.

1.4 Control and regulation strategy on the whole

Today we have high demands on the indoor climate at our workplaces, in particular at office workplaces. In order to reduce the environmental impact we also must reduce the energy use in the building stock.

Therefore it is very important to install advanced control and regulation systems in new office building as well as in buildings that are to be retrofitted.

In practice, in order to meet the high comfort and energy requirements of today a **Building Management System (BMS)** or a Building Energy Management System (BEMS) is necessary. Of course a BMS/BEMS must be properly commissioned and the staff that will handle it must be adequate informed or educated.

Another trend today is that tenants more frequently ask for possibilities to control their indoor climate locally. Based on different studies, we today know that higher possibilities for **local and individual control** often result in improved productivity. Today control systems can be equipped with remote controls or individual web pages [1] in order to make it possible for the office staff to control heating, lighting, solar shading etc.

However, also when some kind of local control system is used, a central control system is necessary in order to prevent the local control to result in extreme indoor climate or higher energy use. The central control system must set the limits for temperature, CO_2, operation hours etc.

Requirements adaptation is a central concept in an energy efficient method for controlling and regulating buildings. This concept refers to having a satisfactory media supply to premises used, but as much as possible, to reducing media supply when premises are not fully used.

A few examples of what this can entail are:

- No controlled air change rate when premises are not used.
- Airflow adapted to total number of persons present.
- Reduced temperatures in premises when they are not used.
- No cooling in premises that are not used.
- Presence-controlled lighting.
- Lighting that is adapted to sunlight contributions

Control in conformity with such concepts can be considered as obvious. There is, however, a cost aspect that often results in control and regulation of a building's installations not being fully efficient. One often takes an approach that is all too short-sighted when making investment assessments. It is therefore important that one now begins to view things from a slightly more long-term perspective so that energy efficient solutions that require a certain amount of added investments can also be taken into consideration.
This means that one should increasingly adopt the approach with **life cycle costs, LCC_E** [4], which is also central in our thoughts on how one should control and regulate buildings in an energy and environmentally correct manner.

Another reason for present construction installations not always being optimal is that certain solutions are sometimes chosen by tradition or habit.

A way of increasing knowledge and interest among all parties in a construction process, and among property managers and tenants, is to create better conditions for **knowledge feedback**. A step in the right direction here is constituted by the capabilities for computerised operational information for various parties that the IDEEB project's control and regulation strategy will encompass.

Through the IDEEB project, we can hopefully widen our views pertaining to the choice of both technical installation solutions, and control and regulation strategies.

2. ENERGY SUPPLY

2.1 General

Before the control and regulation strategy is determined for the installations in a building, it is appropriate to first perform a study to find out if there are alternatives for energy supply to the building, and if so, which.

The solutions for the building's heating, ventilation and air conditioning (HVAC) control can also be dependent to varying degrees on the form of energy supply that will be chosen.

Obviously, the pre-conditions for design of the control and regulation system for heating will be entirely different if one plans to heat a building with, for example, direct electrical heating instead of a water-borne system. When it comes to the control and regulation solution, the design is also to a certain degree dependent on whether the building is supplied with district heating via heat pumps or via a separate building boiler fuelled by oil or gas, for example.

2.2 To consider

Among other things, the following should be considered in regards to energy supply before the control and regulation strategy is established:

- Is the chosen energy supply economically advantageous on the long-term?
- Is the chosen energy supply sufficiently environmentally correct? (ECO factor?)
- What are the tariffs and costs for the various conceivable energy types? (Annual variation, daily variation, energy tariffs, power tariffs, flow tariffs, environmental tariffs, taxes, etc.)
- Is it appropriate to combine different energy types to achieve the most advantageous operation with respect to both economy and environment? (For example, electricity during the summer but another energy type during the winter.)
- Is it appropriate to install power control to eliminate the largest electrical power consumers? (See **Chapter 8**.)

3. HEATING

3.1 System choice

The preferred system of choice for heating office buildings should be a water-borne system, often a radiator system.

The advantages of such a system are, among other things, that they provide good comfort and can be controlled so that heating is accomplished in an energy efficient manner.

In certain cases, it can be appropriate to install some variant of fan convectors or underfloor heating system.

3.2 Adjustment

To achieve a stable indoor climate and not use more energy than necessary, the heating system must be very carefully designed, dimensioned and adjusted with respect to flows.

It is preferable if the heating system is divided into two (or more) parts with respect to the point of the compass. Thus, rooms along a sunny façade can have a lower radiator temperature than other parts of the same building.

3.3 Radiator systems

The following basic diagram shows a radiator system.

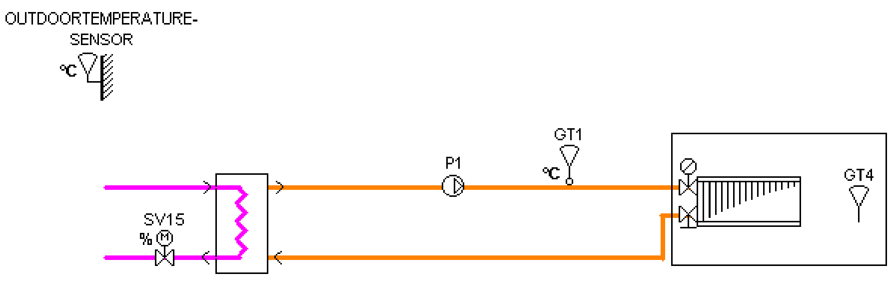


Figure 3:1 Radiator system

To achieve even regulation, the flow temperature to the radiator is regulated in relation to the outdoor temperature.

However, the internal heat loads, as well as the sun radiation heat, can differ from room to room. Therefore, the above-mentioned basic function normally ought to be combined with thermostatic radiator valves, in order to avoid too high indoors temperatures in single rooms.

Thus, we recommend a so-called individual feed-backward control system.

The outdoor temperature sensor modifies the flow temperature (GT1) in accordance with the set regulator curve. The regulator curve is set using a number of breakpoints so that one can achieve the correct room temperature regardless of the outdoor temperature. For increased heating needs, the control valve (SV15) opens for heat. The inverse function applies for reduced heating needs.

It is exceedingly important that the outdoor temperature sensor is correctly located, so that it is not affected, for example, by sunlight.

To conserve both electrical and heating energy, the circulation pump (P1) shall be stopped if there is no need for heating. One should always have a so-called **pump-stop function**. The pump stopping when the outdoor temperature exceeds an adjustable temperature, for example, 17°C, has traditionally accomplished this. When the outdoor temperature is 3°C lower, the pump starts again.

A better alternative, however, is to let the control valve stop the pump when there is no need for heating, which is indicated by the out-signal to the control valve being 0 %. When the pump is stopped for an extended period, it shall be periodically run to prevent seizing.

There are different methods for further optimising regulation. Below, some methods that **can be used** are listed.

In every office-building project one, of course, have to carefully discuss which methods that are most suitable.

3.3.1. WeatherGain

Traditional building control and regulation systems only take consideration to the current situation rather than to that which will occur in the near future. In practice, this means that most buildings' heating systems are regulated by the current outdoor (or sometimes indoor) temperature alone.

A better way to control a building's heating system is to use a function called WeatherGain. WeatherGain considers several external factors, such as temperature, sunshine, wind strength and direction - and the control system receives this information in advance.

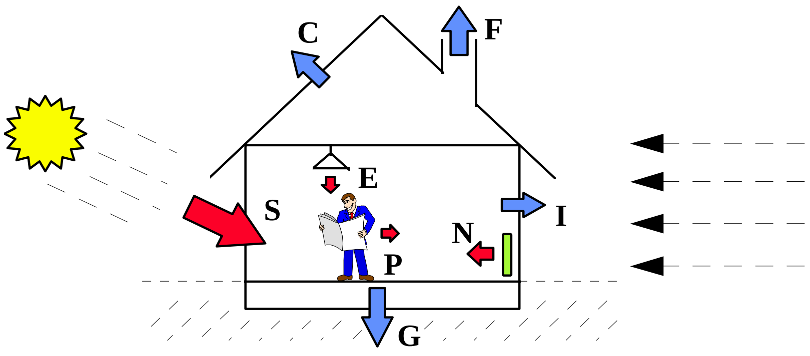


Figure 3:2 External factors in weathergain

WeatherGain is based on utilizing a building's heat inertia. If one knows in advance that a cold night will be followed by a warm and sunny day, the building's heat inertia can become an advantage. Heating can then be reduced several hours in advance without the indoor temperature having time to fall. And vice versa – when windy and overcast weather is on the way, heating can be increased in advance.

Thus one attains a balancing of the energy supply and a more stable indoor climate. This results in decreased energy consumption. Furthermore, due to the more stable indoor climate, people that work in a WeatherGain controlled building become more satisfied.

With WeatherGain the outdoor climate parameters (temperature, sunshine, wind), together with data on the building's characteristics pertaining to position, orientation, properties and method of use are put into a algorithm that results in what is referred to as **equivalent temperature (ET)**. The equivalent temperature value replaces the outdoor temperature signal into the heating regulator.

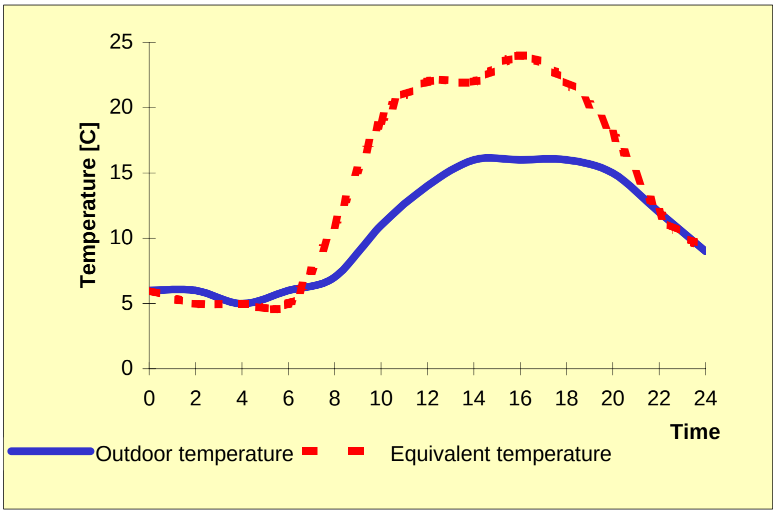


Figure 3:3 Comparison of outdoor or equivalent temperature during one day.

When the WeatherGain function is in use, new prognosis data for the equivalent temperature normally are sent via the Internet daily and each prognosis is for 5 days.

However, like in a building equipped with a heating system controlled based on only the outdoor temperature (central feed-forward control), also when WeatherGain is in use the indoor temperature sometimes can become too high in single office rooms. This is due to the fact that the internal heat loads, as well as the solar radiation heat, can differ from room to room. When a WeatherGain system is to be put into operation we pay attention to the internal heat loads (lighting, people, office machines etc.) in the whole building – but can normally not consider differences between different parts of the building.

Therefore we recommend combining the WeatherGain function with thermostatic radiator valves (individual feed-backward control), so that there will not be too hot in single rooms.

WeatherGain was developed in cooperation with the Swedish Meteorological and Hydrological Institute (SMHI).

3.3.2. Room compensation

To avoid overly high temperatures because of interior heat from, for example, lighting, computers, and above all, from solar radiation through windows, one can let a room temperature sensor influence the control curve in the heat regulator. Constant compensation is thus made of the flow temperature dependent on any deviations between actual room temperature and desired room temperature.

Depending on if it is day operation or night operation according to the time channel, the flow temperature is compensated against a basic desired value; for example, 20°C for day operation and 17°C for night operation. The degree of room influence is adjustable for day and night operation.

When using this function, it is of **great importance that the room temperature sensor be placed so that it measures a representative temperature**, meaning a temperature that corresponds to an average value for the entire space controlled by the regulator. In the event of uncertainty, one should **install several sensors** and use the average value of these as the room temperature.

3.3.3. Night reduction

When there is no activity in the premises, one can reduce the room temperature by reducing the flow temperature (GT1) via a time channel according to values set on the regulator. The reduction amount is dependent on the prevailing outdoor temperature and is adjustable with a curve.

3.3.4. Morning increase

Before day operation is begun, after one has used a room compensation or night reduction, a morning increase of the flow temperature is made to quickly reach the desired daytime desired value. The supply temperature increase and the time for the morning increase is computed based on the outdoor temperature and are adjustable with a curve. The morning increase ends when the room temperature GT4 exceeds the desired daytime value or when day operation in accordance with the time channel occurs.

3.3.5. Curve optimisation

With curve optimisation, a gradual adjustment of a regulator curves is made with six breakpoints. The desired room temperature (RT) is set for the room and 5 hours after the time channel has started, the current room temperature (GT4) is compared with the set desired room temperature. If the deviation exceeds +/-0.5°C, an automatic adjustment of the set curve is made dependent on the size of the deviation. Only one of the breakpoints on the control curve is adjusted; the breakpoint that is closest to the prevailing outdoor temperature.

This optimisation is performed once each day to avoid temporary disturbances influencing the long-term curve adjustment. If the outdoor temperature exceeds +5°C, no optimisation is performed.

When using this function, it is of **great importance that the room temperature sensor is placed so that it measures a representative temperature**, meaning a temperature that corresponds to an average value for the entire space controlled by the regulator. In the event of uncertainty, one should **install several sensors** and use the average value of these as the room temperature.

3.4 Fan-coils and window devices

3.4.1 Fan-coils

A temperature sensor placed in the room is connected to a regulator that controls the temperature by regulating control valves for heating coils or cooling coils (when present).

To avoid unnecessary energy usage, it is very important that the heating and cooling functions are interlocked so that they cannot be in operation at the same time. Room air circulates in the device with the help of a built-in fan that most often can be set to different speeds.

3.4.2. Window devices

These have no built-in fans but rather in certain cases draw the room air through induction action with intake air that is connected to the devices. The temperature is regulated by the room air passing either though the heating coil or the cooling coil (when present) depending on the current heating or cooling requirements. To avoid unnecessary energy usage, it is very important that the heating and cooling functions are interlocked so that they cannot be in operation at the same time.

3.5 Underfloor heating

The following basic diagram shows an underfloor heating system. One benefit with underfloor heating systems is that one can use rather low water temperatures. For example, water that is heated by heat pumps can be utilized.

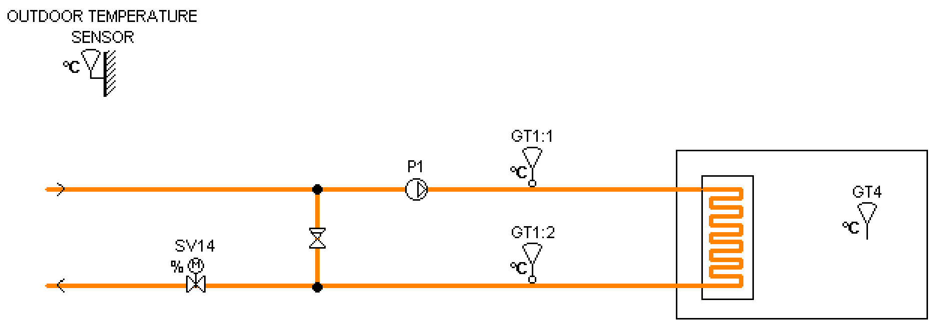


Figure 3:4 Underfloor heating system

By laying water pipes in the floor, one can heat the room temperature with radiation heating.

The outdoor temperature sensor modifies the average value between the supply temperature (GT1:1) and the return line sensor (GT1:2) in accordance with the set regulator curve. The regulator curve is minimum and maximum limited. The regulator curve is set using a number of breakpoints so that one can achieve the correct room temperature regardless of the outdoor temperature. For increased heating needs, the control valve (SV14) opens for heat. The inverse function applies for reduced heating needs.

It is exceedingly important the outdoor temperature sensor is correctly located, so that it isn't affected, for example, by sunlight.

To conserve both electrical and heating energy, the circulation pump (P1) shall be stopped if there is no need for heating. On should always have a so-called **pump-stop function**. This has traditionally been accomplished by the pump stopping when the outdoor temperature exceeds an adjustable temperature, for example, 17°C.A better alternative, however, is to let the control valve stop the pump when there is no need for heating, which is indicated by the out-signal to the control valve being 0 %. When the pump is stopped for an extended period, it shall be periodically run to prevent seizing.

4. HOT WATER HEATING

4.1 General

In choosing a system for hot water heating it is important to choose a solution that is adapted to the scale of operations and usage.
It is energy efficient to utilise as much of the heating system's return line temperature as possible to preheat the water.

On should also always consider if there are any other possibilities for using the recovered heat energy or waste heat to preheat hot water for taps.

4.2 Legionella

To avoid the occurrence of legionella bacteria in hot water, the water must be kept over 65^{o}C. This is especially important for accumulations in larger tanks with little change. The risk should even be considered for showers that are not regularly used.

In smaller facilities, where there is no risk for stationary water for longer periods or where water change is high, the hot water does not need to be heated over 50^{o}C. This entails considerable energy conservation by being able to keep the hot water temperature under 55^{o}C.

4.3 Individual boiler

With heating production using an individual boiler, regardless of the type of energy source, it is important to avoid operation with high outgoing temperatures only for hot water heating. During the summer, it is therefore usually best to choose an alternative such as electrical immersion heating in the boiler for hot water production.

4.4 District heating

Hot water production with district heating entails that no accumulator is needed when needs are low. A good method is to utilise heat return to preheat hot water for taps.

4.5 Electric heater

For large-scale usage, the use of electric heaters is not a good alternative as a sole solution. As a spot measure in combination with another energy source, however, this is a good solution.

Using electric heaters during the summer when no other heat production is needed is thus a good and energy conserving solution.

4.6 Heat from solar collectors

Solar collectors as energy sources for hot water production have been developed into an energy conserving, well-functioning solution. The heat from a solar collector system can often contribute to a large portion of the annual energy usage for hot water heating – even in the northern countries of Europe.

A solar collector system requires special technology for optimal efficiency. There shall be at least two, preferably three exchangers for satisfactory function. It is important that additional heat is placed after the heat from the solar collector so that the solar collector circuit receives water that is as cold as possible to circulate against. Placement of the solar collectors is very important to function. During periods of low usage, for example, during holidays or other inactive periods, consideration must be taken to the fact that water in the solar collectors can reach temperatures in excess of 120^{o}C. One option is to the let circulation over the solar collectors continue at night to avoid problems.

5. VENTILATION

5.1 System choice

There are many different variants of ventilation or air treatment solutions, both for the basic system solution and for the control and regulation strategy.

There is a basic difference between normal ventilation systems and air treatment systems that also are used to heat a building.

Systems that are also used to ensure heating and thus supply air with a higher temperature can primarily be considered as heating systems and are hardly applicable in the IDEEB project. Control of such systems is therefore not addressed here.

Normally, it is the ventilation system's task to instead **ensure good air quality in a building's various areas** – not to heat them.

Sometimes the ventilation system is also intended to cool the premises – see Chapter 6 for more information.
The other large division line when it comes to ventilation systems is between **mechanical systems** and systems that largely utilise natural rising forces. The latter is often referred to as **natural ventilation**. Often some form of auxiliary fan is needed in these cases. When natural ventilation is combined with a somewhat larger utilisation of mechanical auxiliary systems, one sometimes speaks of **hybrid ventilation**.

Natural ventilation entirely based on natural rising forces was common before and is still common in some countries, perhaps primarily in the housing sector.

Natural ventilation combined with smaller auxiliary fans or other forms of hybrid ventilation have in the northern European countries primarily been tried in school buildings – with varying results. Such systems often require that personnel who are regularly in the premises to be active, knowledgeable and interested in the system functioning satisfactorily. There is otherwise a risk for draught problems or the air change sometimes being too low.

Norms and rules when it comes to air quality in, for example, office buildings and the practical implementation of these vary between the different European countries. The norms will probably become increasingly uniform in the future. It is thus hardly reasonable that the requirements be lowered in the countries that presently have the highest requirements, but rather more probable that both norms and practices will be sharpened in many countries. The IDEEB project should seize upon this and strive for the buildings constructed in accordance with the IDEEB concept having air quality that is sufficiently good that the buildings would be approved even if they were built in another EU country.

Modern office buildings, constructed in accordance with the IDEEB concept, should therefore definitely have very good air quality and comfort. With consideration both to concentrations of persons and to internal loads (heat from computers etc.) that exist in office buildings, the number one choice therefore ought to be very well designed energy efficient mechanical ventilation systems. In some cases possibly hybrid ventilation can be an alternative.

However, today in many European countries it hardly can be suitable to install ventilation systems without heat recovery possibilities. These kinds of systems will use much more heat energy than standard mechanical systems equipped with heat recovery.

If hybrid ventilation is to be used, the building must be located in a part of Europe where the heat energy requirement is rather low (warmer countries) or the building must be equipped with some other efficient solution for heat recovery!

It is slightly uncertain if there today exist any economical realistic heat recovery systems that can be combined with hybrid ventilation. The problem is that heat recovery systems normally cause pressure drops on a level that is to high for a hybrid ventilation system.

With ventilation of the natural type, at times the change of air can become too low and/or the indoor temperature too high. This can create discomfort among office personnel and not the least reduced work efficiency. Many surveys have shown a clear connection between poor indoor climate and lowered performance capability.

With today’s technology, a good indoor climate can be combined with high energy efficiency. If one, among other things, makes sure that one has ventilation ducts that are large and that there are no unnecessary bends (to minimise pressure drops), efficient electric motors, transmission via direct-drives or flat drives, the best possible heat recovery and suitable regulation, ventilation installations are created that are energy efficient in regard to both heating and electricity (low SFP value).

In Chapter 5.3, however, there are a few thoughts on how hybrid ventilation systems or other systems with larger elements of natural ventilation can be controlled and regulated.

5.2 Mechanical ventilation

A standard solution for ventilation in an IDEEB building is proposed to have the following basic construction.

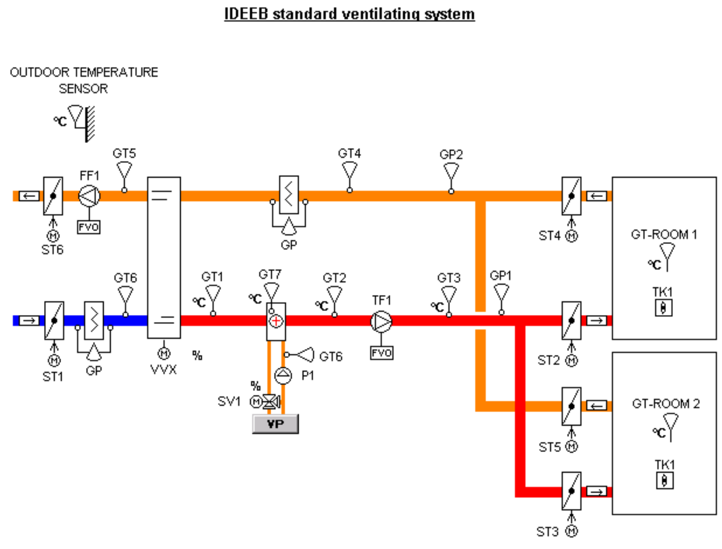


Figure 5:1 Mechanical ventilation system

The total ventilation devices per building and which premises that the various devices shall support must naturally be adapted to each individual building.

The standard solution is constituted by a mechanical intake and discharge air system with efficient heat recovery via a rotating head exchanger (VVX). The intake and discharge air ducts are branched out to the various rooms that are supplied. For each room, or groups of rooms, there are regulator dampers (ST2, ST3, ST4, ST5, etc.) in the intake and discharge air ducts so that the flow to parts of the building can be eliminated when there is no need. The flow is adapted by the intake air fan (TF1) and discharge air fan (FF1) being variable-speed controlled with the frequency converter (FVO). Control is accomplished based on the values from the pressure sensors (GP1 and GP2).

It is exceedingly important that the outdoor temperature sensor is correctly located, so that it is not affected, for example, by sunlight.

Operation principles in IDEEB standard configuration:

- Day operation via time channel and extended operation via pushbutton (TK1) in respective rooms.
- Sequence start of fans to minimise electrical power usage.
- Start-up of discharge air fan and heat exchanger before intake air fan.
- Pump-stop function with motion operation on weekdays of pump for heating coil.
- Night cooling function that cools with fresh outdoor air to load cooling energy into the building framework.
- The discharge damper (ST6) closes when the device is stopped to prevent energy losses.

Regulation in IDEEB standard configuration:

- Constant intake air temperature regulation.
- The fans are variable-speed controlled by frequency conversion.
- The heating coil is kept warm when the device is stopped and it is winter.
- Blast-cleaning function of the heat exchanger.
- Full recovery at start-up of the rotating heat exchanger during the winter.
- The heat exchanger is variable-speed controlled to reduce recovery at higher outdoor temperature.

Safety, alarm and monitoring in IDEEB standard configuration:

- The outdoor air damper (ST1) closes via return spring when the intake air fan stops.
- Anti-freezing monitor function prevents freeze damage to the heating coil.
- Operation fault alarm for all motor groups.
- Regulation deviation alarm.
- Filter monitor with alarm function.
- Monitoring of heat exchanger's temperature efficiency with alarm upon low value.
- Alarm on three levels (classes A, B, C).

The following are some available options:

- Cooling via cooling coil in intake air duct.
- Room temperature regulation.
- Flow control via CO_2 sensors in various rooms.
- Flow control via presence detectors in various rooms.
- Outdoor temperature compensated airflow.
- Fan monitor function.
- Humidity control, if the ventilation system is equipped with dehumidification possibilities. (Will normally increase the building's energy use.)

5.3 Natural ventilation and hybrid ventilation

As can be understood from the discussion in **Chapter 5.1** above, we will not recommend natural ventilation as the first choice for office buildings, because of the internal loads present and the indoor comfort that one reasonably can require. In some cases hybrid ventilation can be conceivable, but not in countries where the winter is cold.

As an opening part of the IDEEB project several existing buildings were described, with respect to, among other aspects, chosen ventilation systems [3]. Some of these buildings are equipped with natural or hybrid ventilation.

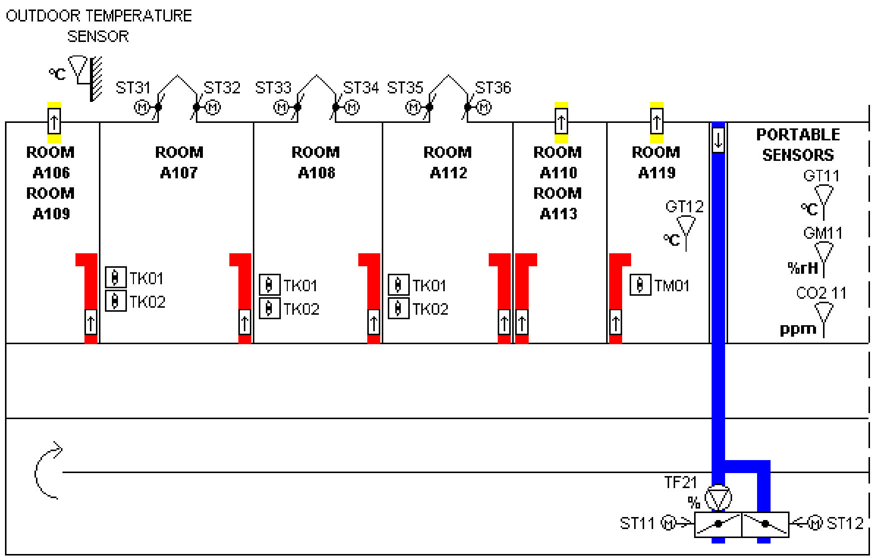
Hybrid ventilation systems can be described as systems that provide a comfortable internal environment using both natural ventilation and mechanical systems, but using different features of these systems at different times of the day or season of the year. A lot of useful information on hybrid ventilation can be read in [5].

If another type of ventilation solution than a fully mechanical solution is to be chosen, one should first ensure that the building is suitably constructed for the alternative solution.

In [5] you can also find a lot of building parameters that must be checked before coming to a decision to install a hybrid ventilation system.

To improve pre-conditions for natural ventilation or hybrid ventilation functioning properly, among others the building should have a relatively open design and preferably open through shafts/roof-lights with opening windows or “ventilation chimneys”. In this way, natural driving forces are facilitated.

The following figure (divided into two parts because of space restrictions) shows an example of an alternative ventilation solution (a school in Sweden).



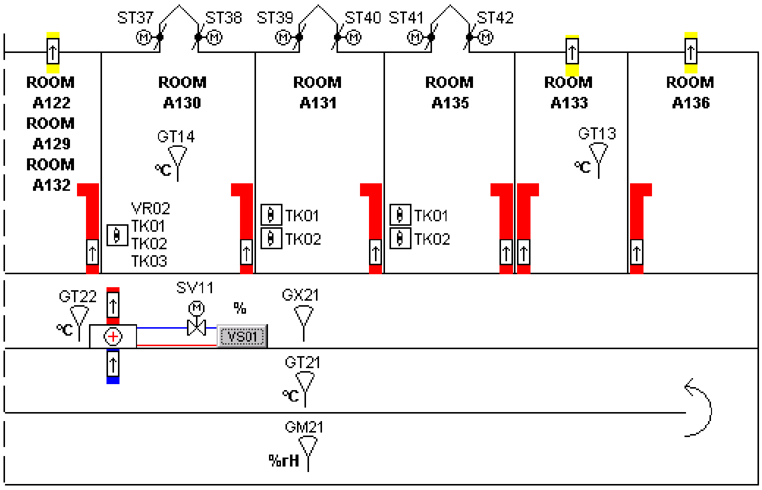


Figure 5:2 Hybrid ventilation system

Somewhat simplified, this ventilation system functions in such a way that there is always some form of air change – either via auxiliary fans or entirely via natural driving forces. The auxiliary fan is planned to mainly be in use in the summertime.

The fan-powered ventilation is in operation between the times that have been chosen in the time channel for the system. The system can also be activated via a timer (TM01). When the auxiliary fan (TF21) starts, the damper (ST12) closes. These are installed in the building's basement.

The air change rate in individual rooms can be adjusted by the dampers in the roof-lights (for example ST31 and ST32) being opened to various degrees. The dampers are controlled with pushbuttons (for example, TK01 and TK02).

The intake air is taken in via a long duct and reaches the building's basement and passes the auxiliary fan (TF21) when in operation.

The air then passes large, site-built concrete ducts in the basement, and in doing so, the air temperature is raised "passively". When needed, the air is ultimately heated via the heating coil connected to a heating group (VS01).

The air is thereafter supplied via relatively large ducts to the respective rooms. All exhaust air is led out through the ceiling in the various rooms via natural driving forces. The airflow is normally outdoor temperature compensated.

During the summer, the temperature in the rooms can be kept at an acceptable level by using the system to cool down the building's frame at night.

The above is only one example of hybrid ventilation. In fact, hybrid ventilation is a collection of different ventilation system solutions.

Therefore a single control strategy that will work in all hybrid ventilation cases hardly can be put into print.

Some factors that can affect the control strategy design for hybrid ventilation are:

- Outdoor climate and weather conditions.
- Building geometry.
- Kind of activity in the building.
- Cellular office or landscape office?
- Mechanical cooling system available?
- Chosen heating system.
- Wanted extent of individual control possibilities.

The detailed control strategy must be brought into line with the unique circumstances in every single building project, where hybrid ventilation is to be applied.

6. COOLING

6.1 General

In new construction of a cooling plant, the system should be designed as a **complete indirect cooling system**. This is because this reduces environmental impact by using as little cooling agent as possible.

The capability to utilise air for **free cooling function** shall always be examined.

When cooling is needed (for example, for computer rooms or kitchens) also during the cold part of the year, **recovery** of condenser heat is made to the heating system.

The installed cooling output in an office building should not be engineered for excessively high outdoor temperatures.

The cooling plant should to a larger extent than what is the case today be controlled via the building's main control and regulation system.

When appropriate, the WeatherGain function can be implemented to control the cooling plant's start and stop, and to minimise operating times.

6.2 Comfort cooling via the ventilation system

In the selection of the ventilation system as a distribution vehicle for comfort cooling for rooms, the cooling coils are engineered for as high heat transfer medium temperature as possible. The control system then controls the heat transfer medium temperature via the outdoor temperature is to be as high as possible. The intention is to achieve optimal energy efficient operation.

There is often no energy efficient solution to design the ventilation plant for cooling needs alone. If this is done nonetheless, the ventilation flow must be possible to control via frequency conversion so that the flow can be reduced as soon as there are no cooling needs.

If there are only a lesser number of rooms that actually require cooling, it is often better to choose other solutions for distribution of cooled air.

6.3 Comfort cooling via chilled beams or fan coils

The use of chilled beams is a very pleasant and energy efficient way of cooling premises. One reason for this is that the heat transfer medium temperature in such systems is normally kept high to avoid condensation water in rooms. In this case, no condensation water drainage is needed. The control system controls the heat transfer medium via dew point regulation.

A disadvantage with chilled beam systems is that they are expensive to install because large cooling surfaces are needed to handle cooling needs.

For this reason, so-called fan coils, which are air coolers with fans, are sometime used instead. Fan coils can also be relatively energy efficient if they are designed for high heat transfer medium temperatures. A disadvantage of fan coils is that the draught problems that can occur can be very difficult. Fan coils also sometimes result in acoustic problems.

7. LIGHTING

7.1 System choice

Preferably, lighting issues should be addressed at an early stage in the construction process. The architectural design should be executed to permit sunlight to be utilised to a high degree. (Of course, other aspects must also be considered – large areas of glass can naturally entail greater transmission losses during the winter and/or greater cooling needs during the summer, for example.)

When it comes to the actual light sources, the natural choice for office premises should be fluorescent tubes, primarily with consideration to their relatively good luminous efficiency (lumen/Watt) and the present wide range of available lighting fittings.

Only where decorative or mood lighting is desired should other types of light sources be chosen. In these cases, compact fluorescent tubes should be the first choice.

To achieve, among other things, high energy efficiency and good control and regulation capabilities, the following are some of the things that should be considered in choosing fluorescent tube lighting:

- The lighting should be of the high frequency type (HF type).
- A suitable type of HF device shall, however, be chosen in relation to method of operation.
- The fluorescent tubes shall be of the full-colour type.
- Preferably, lighting with so-called T5 tubes shall be chosen, i.e. fluorescent tubes with a diameter of 16 mm.
- Indirect lighting (directed upwards) should be avoided.
- The lighting should from the beginning be sectioned into suitable sub-zones.

For control and regulation, one must determine if a bus system or a conventional system will be chosen. If a bus system is chosen, one has significantly greater flexibility in operational adaptations.

7.2 Standard solution (conventional)

If one chooses a convention lighting solution, portions of lighting are normally controlled via pushbuttons/pull-strings, while other portions (common areas) can be controlled via time channels in the building’s main control system. The lighting can also be controlled via the building’s lock system.

Energy optimisation in conjunction with a conventional lighting solution can be achieved, in among other ways, via:

- Presence detection.
- Timer functions.
- Daylight regulation – in certain cases.
- Level segmentation of lighting: basic lighting – stronger lighting

If control with presence detectors shall be implemented, it is usually best that lighting is **turned on initially through active measures** (pushbuttons), but that it is **turned off when the detector has not registered a presence** during a specified period. In this way, one avoids lighting being turned on if someone is only going in to pick up something in a room; or if a person who is working in the room thinks it is sufficient with daylight.

7.3 More flexible solution (bus-based)

To further optimise usage of electrical power and to make lighting adaptive (easy to change when reorganisations are made), one should choose a bus-based lighting system.

This enables control according to need by, in among other ways, enabling the same presence sensor to turn on several lighting groups and to start ventilation, for example.

With a bus system, it is also easier to regulate light via light sensors so that the desired light strength is always obtained. Upon increased solar radiation, the lighting strength is reduced from the lighting fittings.

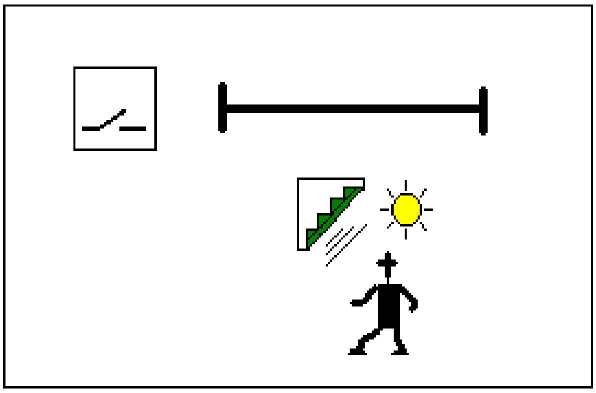


Figure 7:1 Flexible lighting system

The clearly dominating advantage, however, is **the flexibility and opportunities to modify operations in the premises** without exceedingly costly modifications to the lighting installation.

A disadvantage with a bus-based system for lighting control is that it entails **higher investment costs**.

8. POWER CONTROL

8.1 Reasons and local adaptations

Power control in this case refers to control and limitation of the overall electrical power usage of a building.

There are two reasons that it can be an appropriate – if possible – to reduce the maximum usage of electrical power for a building (for a single power subscription).

- Lower maximum electrical usage normally provides lower subscription and/or power tariffs.
- In many countries, the periods for maximum needs for electrical power for individual office buildings coincide with the country’s/region's periods for maximum electrical power needs. This means that electrical production often occurs on the margin, i.e. that even more expensive and less environmentally friendly electrical production techniques are used during these periods. Being able to reduce power usage via power control during these periods is thus especially important for reducing electrical production's environmental impact.

Before one invests in a system for power control, however, the local conditions must be analysed, i.e. on should ask the following questions:

- Is there power usage that is appropriate to control periodically?
- Are the local electricity tariffs configured in such a way that there are any economic benefits with power control?

8.2 Technical solution

There are separate systems for power control, but the best is if the function is integrated into a building’s main control and regulation system.

The exact technical configuration (the programming) must be adapted from case to case. Generally, however, total power usage must be monitored by the control and regulation system, continually and accurately.

In many countries, tariff-based power usage is grounded on hourly values. In these cases, the power control system must “sound the alarm” and reduce usage of devices in ample time prior to the passing of the hour in question.

9. ENERGY AND CLIMATE MONITORING, AND WEB PORTAL

9.1 Level 1 – Information to building owners

9.1.1. Energy and climate monitoring

Monitoring of energy and indoor climate in buildings is planned so that, among other things, a summary report is present on a Web page. On the summary page, general information is present on the building's technical status.

In this way, a unique all-encompassing view is attained and measures can be prioritised. Just as a car has its dashboard with all information collected in one place, the summary report is the building's dashboard where all relevant facts are presented. The report includes information on accumulated media usage compared with that budgeted, key ratios compared to house type, total alarms during the month, and information on indoor climate, temperatures and air quality.

In addition to this summary report, there are usage reports, where individual media usage is presented in separate reports. The usage reports contain, besides numbers and diagrams for media usage, a prognosis that indicates overall usage for the entire year.

Energy reports serve as additional operative tools by showing the periods during which most energy is consumed and how this compares with the subscribed power for the building.

Furthermore, the building's so-called **energy signature** is shown. The energy signature presents a building's power usage for heating in relation to the outdoor temperature and provides information on when the building's heating needs begin. One can thereby see how much a change to the building or its operations affects energy and power needs. The energy signature provides good information for operational optimisation.

9.1.2. Alarm status

In a building, there are often several control and monitoring systems installed for various types of systems, such as for heating and ventilation. The respective control and monitoring systems include a current alarm list for the systems that the control and monitoring device handles. However, to achieve effective operation and administration, a general alarm list for all control and monitoring systems installed in a building is required. This need is met by all outstations (i30-SPC) in the building transmitting alarm information to the central Web portal, which thus always has a current compilation of all alarms in the building.

9.1.3. Alarm forwarding

To minimise operational disturbances for tenants and to be able to keep concerned service personnel informed of a building's status, service personnel must receive immediate notification when an alarm in a building has been activated.

With the central Web portal, information on current alarms can be forwarded directly to the concerned service personnel in a number of ways. The most common is to send alarm messages via SMS, e-mail or fax so that service personnel can immediately take appropriate action.

Depending on the alarm's priority, time of day, etc., the alarm information can be sent in different ways. For example, all alarms activated during the day can be sent via e-mail or SMS to the building's service personnel, while in the evening and on weekends, notification can be via SMS to the service personnel who have on-call duty for the building.

9.2 Level 2 – Information to tenants (feedback to users)

A Web portal is used to provide users and tenants with information on the building in regards to energy and indoor climate. Relevant information is compiled at specially designed Web portals with consideration to users often having no prior knowledge of the building's technical systems or solutions. Simplicity and **pedagogic presentation** are key concepts here.

Information compiled on a page primarily includes:

- A simple presentation of the building's energy and media consumption compared to that budgeted for the building.
- Some form of environmental index, ECO factor.
- Graphical presentation of local weather data that is used for control of the building.
- An overview of the building with dynamic information pertaining to room temperature, air quality, etc.

10. MISCELLANEOUS

10.1 Solar shading

To optimise usage of energy and to achieve a stable indoor climate, solar shading should be installed.

Correctly designed solar shading can eliminate many working hours and thus a lot of electricity use for compressor driven cooling systems.

Talking about solar shading, **the design phase is very important**. Solar shading can be put inside the windows or outside. The latter is normally more efficient and ought to be recommended.

Outside installed solar shading can either be fixed or controlled by the sun and wind.

There do not exist so many possible control strategies for controlling solar shading. Basically one have to measure the sun radiation and preferably also the wind speed and direction. (When it is too windy, the solar shading system should not be in use, because of the risk that it will be damaged.)

The sun radiation values are, of course, used in order to know when to use the solar shading and when not use them. It is very important to put correct desired values regarding sun radiation, as well as wind speed, into the control system.

However, the correct levels of these parameters differ from building to building and are also different for different climate zones. Therefore, one hardly can write down any standard recommendations for these values.

More information on solar shading can be found at www.parasol.se, a web site from where one also can download the computer program ParaSol. By means of this program, which is developed by Lund University in Sweden [6], one can simulate different solar shading solutions. Among others, one can see how the building's energy consumption, as well as the indoor temperature, differs between different solar shading solutions.

10.2 Access system

When one wants to have a lock system that is as adaptive as possible (easy to change), a computerised access system with card readers can be installed.

When a person terminates employment at a workplace, no keys need be returned. Instead, changes are made in the computer for the access system. Authorisation to enter various areas can also be easily changed via the computer. In the event of loss of an access card, authorisations are removed in the computer and a new card is produced at low cost.

11. MEASUREMENT POINTS FOR AN EXPERIMENTAL BUILDING

11.1 General

The control and regulation systems for a experimental buildings should be equipped with and include a large number of sensors and measuring devices of various types. The prerequisites for accurate assessment of the project will thus be good.

Because measurement data and information on the building will be able to be accessed via a Web portal (with various authorisation levels), good capabilities are for created for ongoing monitoring.

In this section, proposals for suitable measurement points are presented for an experimental building. Certain measurement points have been included because it is meant for experimental buildings (pilot project). The majority, however, are also recommended to be prescribed for future, fully commercial “IDEEB buildings”.

It is proposed that the values from all measurement points presented here be accessible from the Web portal and the majority of measurement points should be logged.

Naturally, not all measurement points are appropriate for all types of buildings and system solutions.

The scope of the measurement points must be considered before the concerned technical installation system is planned.

Certain measurements of heating and electricity can often be attained with the help of fictive differential measurement devices.

11.2 Heating energy

Recommended measurement points at comprehensive level:

- Flow measurement of total oil usage. Each boiler separately if there are multiple boilers.
- Flow measurement of total gas usage. Each boiler separately if there are multiple boilers.
- Purchased remote district heating energy: Measured via integration works. Flow shall also be registered.
- Heating energy obtained from solar collectors.
- Heating energy obtained from heat pumps.

Additionally, heat energy (regardless of originating energy type) is measured for the following sub-functions in the building:

- Hot water heating.
- Heating coils for ventilation devices. Each device separately.
- Heating systems. Each shunt group, etc. separately.

Moreover, where appropriate, the following should be measured:

- Recovered heat from discharge airflow.
- Recovered condenser heat from cooling processes.

11.3 Electrical energy

In regards to electrical energy (and electrical power), the following should be measured:

- Total supplied electrical energy to the building.
- Electricity for electric boilers. Each boiler separately.
- Electricity for heat pumps.
- Electricity for radiator systems or other distributed electrical heaters. By system.
- Electricity for hot water heating.
- Electricity for cooling devices. Each cooling device separately.
- Electricity for air treatment devices. By device. Smaller devices and fans excepted.
- Electricity for larger circulation pumps.
- Electricity for lighting.
- Electricity for usage in office areas; for computers, etc.

If the building owner desires that tenants be charged individually for electrical consumption, the measurements are adapted for this.

In cases where the electricity subscription includes fees for reactive electrical usage, reactive energy and power is also measured.

11.4 Temperatures

The following temperatures should be measured and logged:

- Outdoor temperature. Carefully consider placement of sensor!
- Supply and return temperatures for the heating system's primary section in systems with district heating, individual boilers and heat pumps.
- Supply and return temperatures on the secondary section of each subsystem (shunt group, etc.) of the heating system in the building. Also applies to heating circuits for air heating in ventilation devices.

- Hot water temperature: Incoming coldwater and hot water circulation.
- Room temperatures: Total and placement adapted to chosen layout and system solution. In some rooms it can be desirable to install temperature sensors at different heights.
- Air treatment device: Sensor placed after each component where the air's condition is changed through heat recovery, heating, cooling, moistening, mixture, etc. Applies both to intake and discharge sections. See figure in **Chapter 5.2**.
- Cooling system: Supply and return temperatures for heat transfer medium sections for both cooling and heating.

Using the values from the temperature sensors, other amounts can also be calculated and presented, for example, temperature efficiency for heat recovery systems.

11.5 Miscellaneous

Among other measurement points that can be appropriate, the following can be chiefly named:

- CO_2 content in rooms having air transfer controlled via CO_2 content, but also in at least one area in another building to enable checks of air quality.
- Humidity in buildings there this parameter is important and/or dehumidification equipment is installed.
- Presence in the premises where air change and/or lighting is controlled by presence detectors (IR detectors).
- Total incoming cold-water flow and total water flow that is heated for hot water to taps.
- Liquid flow for heat transfer medium for both cooling and heating sections for each cooling system.

Furthermore, all quantities that are included in the WeatherGain delivery are present at the Web portal.

12. DISCUSSIONS AND CONCLUSIONS

There are many ways to design control systems, the choice of building design and system solution has a large influence on this. Also local conditions affect due to difference in climate and different cost for energy types. A comprehensive look is important for an energy efficient building together with more long-term perspective of the buildings, there is the life cycle cost a tool in right direction. Through the IDEEB-project there is a great opportunity to get towards more energy efficient buildings in Europe.

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