District level control center - a possibility for on-going commissioning

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Abstract

The first district level control and monitoring center in Finland started in year 2010 - when it will be completed in 2013, the public building stock of 4 communities belongs to the system covering more than 150 000 dwellers (schools, office building, kindergartens, admin buildings, health centers). The biggest problem was to match up the various existing building automation system together - now one maintenance person in the operation room can take care of all the buildings in the system. No new sensors have been installed; this may be in question in the next stage. Also the data processing for suitable information for different group of users (energy and facility managers, decision makers etc.) is still in progress. The essential thing in data collection is that one can measure the right things (KPI factors) in the right places by the right ways. Another application which started 2012 is s c Eco Campus-project, in which 4 buildings in Otaniemi Campus-area in Espoo, Finland has been equipped with numerous wireless sensor connected in a control center. Attention has paid to positioning of sensors; and the data processing to match user’s needs. More buildings will be connected during 2013 into the system. One goal of the project is to create new business models based on experiences and results of the project. Building owners are interested in to have additional value for the buildings; data processing itself is not new but what could be created on that. In the paper the control and monitoring centers are introduced, and also the first results of the projects. The problems in existing systems are 1) Lot of data but 2) Less information for the needs of users and 3) The systems does not discuss with each other. District level monitoring system can be commercialized for the use of building owners. The crucial thing is the procedure and how to utilize the data for facility and energy management in evaluating the total performance of a building and the location on life-cycle curve.

About the Authors

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1. Introduction

There are some service providers in Finland, who offers monitoring services of buildings, the number of buildings depends on the company, but the biggest enterprises have targets from 200 to 1000 buildings. The data collection and processing depends on the contracts and customer’s needs. The data collection is based on the solutions of service provider; or the service provider collects the data from various building automation systems using its own procedure. Previously and in most cases the data collection and the integration of the data must be done by human labor, when collecting systems did not exist. The expert of energy management got to make conclusions about the data generated by various systems. From this data is aimed to generate proposals for measures, investments and improvements of energy efficiency and indoor conditions. Generally, the aim is to produce information for building owner and for maintenance organizations, by means of which one can manage the facility and its use.

One of the main goals of service providers is to transfer the information generated by different systems and the centered professional skills to the every-day use for building maintenance organizations and to support decision making. The service providers think, that using different tools and by their own activities the building maintenance level can be improved; and that way also can have effected on indoor conditions and energy efficiency. It is needed to have easy to use and easily followed processes, that the findings and notices can be moved to everyday practice of maintenance organizations and building owners. The problems of service providers have been installations of building automation systems or reprogramming, which caused dropouts of fixed points.

Municipalities have had their own control centers. The practice has been checkered, and in small communities could have many different building automation systems and no centered data collection. Lately cities and regions have shown increasing interest in creating district level control centers, which could also take care of checking and surveillance. The first regional control center project was carried out in the city of Kuopio – the public buildings of Kuopio and public buildings 4 surrounding communities are connected in district level control center.

Energy efficiency does not mean to minimize the energy consumption – it is a question to optimize it. Indoor air quality and indoor conditions must be in proper level, and energy saving (e.g. shortening the running time of ventilation) can cause bigger problems for indoor environment and this way also for work efficiency. Figure A shows the average costs of an office building:

- Wages: 86 %
- Space costs: 9 % (including energy costs)
- Furniture 1 %
- ICT & office machines 4 %

Energy costs in cold climate conditions (Finland) are approximately 30 % of space costs = 3 % of the total costs. Wages costs include the efficiency factor – the indoor climate and conditions
plays the key role. If one saves 20% of energy costs, it is only less than 1% of the total costs. But if the indoor environment is not satisfactory, the effects through possible weakening of work efficiency are more significant (but more difficult to measure).

The main reason for increased interest in remote control of buildings (in conjunction of declining and tightening economy of municipalities) is Energy Performance of Buildings Directive (EPBD) of European Union. After Energy Performance of Buildings - directive (EPBD) came into operation inside European Union, also in Finland began the work to adjust building codes matching the new directive; one new issue was energy efficiency, and the new building code dealing with energy efficiency came into the requirements. Energy Performance Directive caused increasing actions in the building trade. Energy labeling became mandatory for new buildings with a building permit in 2008. Other buildings when rented or sold must have an energy performance certificate from 1 January 2009. New buildings should have energy class C or better. Figure B shows the single E-values (energy efficiency values) for office and commercial buildings as an example. The legislation has been adjusted and new version is going to be valid from June 2013.
2. Background – City of Kuopio, Finland

2.1 The long-term program to improve the energy performance of public building stock

The population of Kuopio is 100 000 before new consolidations of municipalities. Kuopio is located in Eastern Middle-Finland. The buildings are connected with district heating system. The heating energy is produced by economical district heating CHP- power plant. The fuel was peat from 1975 on, today peat and wood chips. Modern burning technology can reduce CO2-emissions and small particles-, SO2- and NO-emissions. The city has been years one of the most energy efficient cities in Finland. Table 1 shows the energy and water consumption of the city from 2010 compared with the other cities. Figure C shows the general perspective of the downtown. The city has followed a consistent line in energy efficiency and energy saving over years – the energy saving measures was started after the first oil crisis in the year 1975. The systematic work with various development projects and programs has continued from 1995 on. The results can be seen in the table 1. The building stock of the city is presented in the table 2. There are 548 public buildings of different age in the city, the total area is near to 600 000 m². The annual maintenance cost of the building stock is 5 M euros (= $ 6, 5 million) and annual renovation investments 10 M euros (= $ 13 million). These figures include also energy efficiency repairs. In Finland renovation are very rarely based on energy efficiency only; mostly the main reason for repairs is change of use, structural damages and indoor air quality problems.

Table 1: Energy consumption in Kuopio and in Finland

<table>
<thead>
<tr>
<th></th>
<th>Public buildings of Kuopio</th>
<th>Average*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(municipal buildings)</td>
<td>in Finland</td>
</tr>
<tr>
<td>Heat</td>
<td>30,4</td>
<td>42,9 kWh/m²</td>
</tr>
<tr>
<td>Electricity</td>
<td>13,6</td>
<td>18,6 kWh/m²</td>
</tr>
<tr>
<td>Water</td>
<td>100,9</td>
<td>127,7 l/m²</td>
</tr>
</tbody>
</table>

Figure C: Overview from the City of Kuopio
Table 2: Public buildings in Kuopio

<table>
<thead>
<tr>
<th>Type of buildings</th>
<th>Number</th>
<th>Area total-m2</th>
</tr>
</thead>
<tbody>
<tr>
<td>School buildings</td>
<td>91</td>
<td>97 604</td>
</tr>
<tr>
<td>Social and health care buildings</td>
<td>122</td>
<td>138 565</td>
</tr>
<tr>
<td>Cultural buildings (library, museum, theater) and sport halls</td>
<td>78</td>
<td>119 991</td>
</tr>
<tr>
<td>Fire and rescue brigade</td>
<td>15</td>
<td>19 699</td>
</tr>
<tr>
<td>Offices</td>
<td>23</td>
<td>32 610</td>
</tr>
<tr>
<td>Garages</td>
<td>13</td>
<td>38 152</td>
</tr>
<tr>
<td>Commercial buildings</td>
<td>12</td>
<td>3 272</td>
</tr>
<tr>
<td>Industrial buildings</td>
<td>26</td>
<td>41 311</td>
</tr>
<tr>
<td>Free time buildings</td>
<td>13</td>
<td>1 696</td>
</tr>
<tr>
<td>Houses (homes)</td>
<td>21</td>
<td>2 162</td>
</tr>
<tr>
<td>Other buildings</td>
<td>134</td>
<td>97 925</td>
</tr>
<tr>
<td>Sum</td>
<td>548</td>
<td>592 987</td>
</tr>
</tbody>
</table>

The book value of the public building stock is 200 M euros ($ 260 million). List of energy saving activities in the city is as follows:

1975:
- Technical repairs: windows, thermal isolations, water saving taps (warm water), heating and ventilation repairs

1990:
- Building automation: 1 office block at first 1990, then to 160 buildings or groups of buildings until 2010
- Operation and maintenance manual for every building, at first in printed from, from 2010 on in digital form
- Renovation projects, structures, new heating- and ventilation installations, new electric installations, BAS, in the whole building stock

2000:
- Team work of the maintenance and cleaning personnel
- Education and training for energy saving

Development projects and programs:
- Energy audits systematically from 1995 on
- Pilot project in Thermie–program of EU, one school building, 1996-2000
- The 1st Energy Saving Agreement, Kuopio and The Ministry of Trade and Industry 2001
- Energy efficiency agreement of Finnish municipalities and energy program for 2008-2016, between Kuopio and Ministry of Employment and the Economy
- National energy efficiency–project, 2010-2011, VTT Technical Research Centre of Finland
- District level control center, started 2011
The need and realization of district level control center was a logical consequence of the development and efforts in increasing energy efficiency. By the same the building stock of three other communities were connected in the project.

2.2 District level control center

The layout of the system is presented in the figure D. The project started 2010 (installations began in October 2010) and the system is planned to be completed in the end of 2013.

One challenge for indoor conditions was the big difference of weather conditions: The maximum temperature in the summer can be +35 °C and in the winter -35 °C and the indoor temperature should be + 21 °C.

The aims of the project were

- to save energy costs
- to save resources and climate protection by reducing heating energy and electricity consumption
- to improve the productivity and quality of facility management and

The practical, measurable goals were

- to reduce consumption of heating energy and electricity 3 650 MWh/year in the three communities which joined the center
- to reduce energy costs 180 000 €/year ($ 235 000) in those three other communities

The practical, measurable goals for climate protection were

- reduction of CO2–emissions in the first stage approximately 590 000 kg/year
- in full scale reduction of CO2– emissions 1 088 000 kg/year
• in electricity production reduction of CO2–emissions 700 kg/MWh and in district heating production 220 kg/MWh

The planned use of district level monitoring center was the use of building automation system for
1. Monitoring and control of building services (HVAC-systems: Heating, ventilation, lighting, other electrical devices) and 2. Alarm surveillance, receiving and transfer

In the first stage the existing building automation systems were replaced by 3 systems after
competitive bidding (figure D). No additional instrumentation was installed (at the moment). One person/shift is controlling the whole connected building stock. In practice there are three different display systems in the operation room and these systems are not connected with each other yet. The most important use of the collect data would be to process and analyze it for different users and decision makers. This work is just in the planning stage.

In Kuopio 175 facilities or buildings have been connected to the system. The number of control points is 23 000. The building stock of three other communities connected with the systems consist 90 facilities or buildings, and the number of control points is 10 400. The evaluated operating costs in the beginning of the project were 60 000 €/year (≈$ 78 000) including personnel costs, travel and communication rents. If operating costs are compared with reasonable energy savings costs, the evaluated net savings were 2/3 of the operation costs/year. The final figures will be found out when the system has been one year in the use in full scale in the end of 2014.

All the possibilities of the center are not used at the moment, because it needs to solve some technical problems – it is question about data processing and development. These kinds of procedures are under discussion in many other cities and regions. The main tasks and benefits of the monitoring center deal with building operations, maintenance and as a background for renovation solutions and new building.

2.3 How to exploit the use of district level monitoring center

In many cases there is facility management software above the building automation system, which collects and analyses the data; the reporting is organized according to customer’s needs, or based on the service providers standard report sheets. In this particular case the first stage was focused to solve the technical problems caused by many different level and different type building automation systems. In many regions the decision makers are planning same type of solutions which has already been installed in Kuopio area. The first problem is the varying level of existing building systems. In a small city or community could be several different systems in use. Some of them can be technically outdated.

Studies have shown in Finland that:
• The average building can use 20 percent more energy than needed
• Predictive maintenance can reduce the energy cost by 5 to 10 percent
• Equipment upgrades and tune-ups can save 5 percent to 15 percent
In Finland, public (state & municipalities) properties cover 40 Mm2
- 5% reduction in heating costs turns to 15 M€ annual savings
- 5% reduction in electricity bill means 20 M€ annual savings
- Public buildings can easily act as demonstrators and first customers

District level monitoring platform can help communities and other large building owners to manage their energy efficiency investments and improve their facility and energy management practices - instead of one-time energy improvement, focus can be reached on sustaining and improving energy use over time without risking the IEQ. This requires continuous monitoring, analysis, and reporting of building performance. There are two main goals: Technical and data processing concepts.

### 2.4 The energy use of public buildings in Kuopio

Figures E and F show how a systematic work for energy efficiency has evoked. While the heating energy consumption in other cities has remained in the same level, the specific heating energy consumption of Kuopio has continuously decreased. The trend in other cities in the last few years has also been decreasing; the consumption of electricity has increased, respectively. In Kuopio the consumption of electricity has been succeeded to keep in a relatively constant level.

More attention must be paid on submetering of electricity; what cannot be measured cannot be managed. New energy efficiency requirements in the building code will set some new demands for submetering. In Kuopio case there are no additional instrumentation installed. In the future (in the next stage) in connection of data processing development also additional instrumentation will see the light.

![Figure E: Heating energy of Kuopio](image)

![Figure F: Electricity consumption](image)
3. EcoCampus Otaniemi

3.1. KMEG-project – EcoCampus Otaniemi

KMEG-project started in 2011. It is an international project with South Korean partners. Location of the area is shown in figures G. The aim of the project is to contribute to increased energy efficiency in districts and buildings by innovative management and control systems, capable to optimize the local consumption without compromising the indoor environment, occupant comfort and building performance, and by introducing new ICT enabled business models. The quantitative objective is to save 15 % of delivered energy including electricity and district heat. This should be possible based on on-going commissioning. The pilot area is south of Otaniemi Campus-area of Aalto University. Otaniemi is a part of City of Espoo, which is a neighboring city of Helsinki, capital of Finland. In Otaniemi EcoCampus pilot area there are

- Installed LOC "District level control center-server" in a VTT Building
- Installed K-MEG wireless sensors approximately 300-400 pieces in 4 buildings
- Installed NIALM meters 9 pieces (electricity)
- Integration of building automation system to LOC in two pilots under construction

Figure G: Location of Otaniemi Campus

3.1.1 The project tasks in pilot area

From the area 8 buildings (mainly university buildings and dormitories) were selected for further analysis. Walk-through energy audits were carried out in those buildings. Based on energy audits and consumption and indoor environment monitoring also commissioning reports will be made. At the moment the data from additional sensors and NIALM meters is under processing; the big amount of data need special processing tools that the results can be utilized. The same problem can be generalized concerning the most part of existing building automation systems. The pilot buildings have been built from 60’s to the present day – the newest building is a researcher hotel, which was taken into the use in March 2013 and which has the most advanced building
automation system with additional wireless sensor installation. Various repairs and renovations are carried out in older buildings. The age of building automation system varies, and some systems are renewed, but the level of the systems represents the design intent of prevailing time.

Based on walk-through audit and assessment of building automation systems, there are lot to do to improve the functioning of the systems up to date; the owners of the buildings (Aalto University Properties Ltd, Aalto University Student Union AYY) are interested to improve facility and energy management in co-operation with service provider (maintenance company). The first step is to examine the performance and specifications of BAS.

3.1.2 Performance verification

The age of system varies, generally at least 10 years old after repairs and represents the measurement practice of its time. Based on the results of walk-through audit, for instance in case of ventilation systems, there must be at least following additional measurements if one will use the metering in commissioning:

- The temperature of exhaust air after the heat recovery unit (indicator in the operating room in the wall of the unit+transmitter to BAS)
- The fresh (incoming) air should be measured from the air supply chamber – not on the roof
- The temperature of exhaust air before the heat recovery unit
- Pressure indicator over the fans in the operation room and transmitter to BAS (for air flow indication)
- Calculation algorithm in the BAS system, with k-values of fans (to convert the pressure drop over the fan to air flow rate)
- Calculation algorithm for efficiency of heat recovery
- Metering for heating and cooling energy of the ventilation
- Indoor environment sensors (RH+CO2) in specified positions
- Report system for ventilation that the users, operators and managers can see in few sheets the performance of ventilation system

4. Commissioning tools: Energy audits, monitoring and submetering

In Otaniemi EcoCampus-area in 8 buildings walk-through energy audit was carried out. Walk-through audit is based on existing documents, consumption figures and one-day visit in the building. In these pilot buildings also the building automation system was audited. As a result of energy audits in general level it is relatively obvious that an instrumentation protocol is needed – what are the minimum/necessary requirements and what it does mean in practice – submeters etc. Other important topics are for new buildings that what design intent is. Are OPR’s and KPI’s properly set? For old buildings one must know what is possible and reliable to do. What must be
measured (OPR’s – KPI’s)? How the factors should be measured (reliability)? How and where the results are reported? How data processing is organized.

If the performance monitoring of a building is based on BAS, the results must be correct -

In the figures below one can see some faulty installations (not from our pilot buildings in Otaniemi area). Air flow meter is installed in a place where interference distance is too short; the signal is distorted, as it is also in case of temperature measurement of rotating heat recovery unit (wrong positioning). The lower left picture shows a negligent installation of heating energy meter (water flow meter) and the lower right picture shows a pressure-difference transmitter over a fan; the installation is properly done but in substation the k-values of exhaust and air supply fan have changed places – so the building automation system used a wrong algorithm and the air flows diverged over 20% from the correct values.

Figure H: Some faulty installations

5. Conclusions

The main problems in existing systems are

- Lot of data but….
- Less information for the needs of users and
- The systems do not discuss with each other.

District level monitoring system can be commercialized for the use of building owners. The crucial thing is the procedure and how to utilize the data for facility and energy management in evaluating the total performance of a building and the location of the building on life-cycle curve. In Finland there are service providers which have 200 – 1000 buildings connected in their remote monitoring and control system. In remote control system (typically retail chains, building owners of large building stock) the solutions are based on the systems of the service provider. The remote control of public building stock of larger areas is just in the beginning, new plans in progress in several areas. Some cities have city-owned companies for monitoring, facility
management maintenance, and surveillance (full service). It is obvious that remote control of large building stock is a trend in the near future. The expected benefits for property can be divided as follows:

- Almost real time remote control via standardized data collection and processing. Improved efficiency and quality of facility and energy management
- Modes and procedures will come more systematic and time management will become more efficient
- Micro-level benefits: Practices of various manufacturers will become more uniform – benefit for users – two-level benefit (alarms, data processing), data security and protection issues
- Biggest advantages will be reached in areas with large building stock
  - Flexible and tailor-made service for building owners and various users
  - Applicable for all kind of buildings
  - Basis for new type service businesses and value chain creation

Various enterprises have systems covering one part of the planned concept – companies have also systems used in connection with/on building automation systems in energy- and condition management.

- Systems are mainly closed, however and the data generated by different vendors are not integrated and converted into a form that the effective use would be possible (from data to information)
- Municipalities and other building owners do not necessary want to engage themselves with one hardware supplier- framework model as a solution – they need concepts for bids for solutions (technical and data processing)
- Marketing views must be sorted out – private enterprises have own solutions and they have their own business logic
- Municipalities as target group have lot of common problems but also challenging operational environment

More attention must be paid to the audit of building automation system and also to additional instrumentation. The instrumentation level is designed for technical use and for daily operations; from facility and energy management point of view additional instrumentation and submetering (especially for electricity) is needed, the most important topic is to improve the data processing.

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