Project description for the Ph. D. Thesis of Natasa Djuric:

Real-time supervision of Building HVAC system performance

1. Background
The intent of building design is to achieve the following: the efficient and safe operation, health indoor environment, rational energy use, minimal impact on outdoor environment, and economical operation through lifetime. Practical experiences show that there are discrepancies between the intent and reality. The above problem can be overcome by implementing commissioning process through life time of building HVAC system. Commissioning is a systematic process of ensuring that all building facilities systems perform interactively in accordance with the design documentation and intent. The commissioning process begins at project inception during the pre-design phase and continues for the life of a building through occupancy and operation phase.

This thesis should deal with existing buildings. These buildings could have problems with HVAC systems operation, indoor environment, and increased energy use. In most of these buildings there is no data and information about the designing and/or operation of HVAC system.

Building energy management system (BEMS) is a good means for reducing operation costs by monitoring the buildings operation. These systems can incorporate advanced control strategies that respond to the changing of either weather or building conditions. The performance of HVAC systems can be improved through better local-loop and supervisory control. Recent advances in automatic control technology have made sensor and control signal information from HVAC system more accessible. This development and the development of sophisticated simulation tools, has created a potential for improving supervision of HVAC systems. The control system could operate better when future energy requirements are available. The existing buildings could be improved by applying a better BEMS strategies, based on building simulation.

A Project Life-Time Commissioning for Energy Efficient Operation of Buildings (LTC Project) is running at the “Gemini-Center Energy Supply and Air-Conditioning of Buildings” (NTNU and SINTEF). The project is a network, or a “user club”, of industrial companies, private and public entities, and R&D organizations. The objective of the project is to contribute to the implementation of life-long commissioning in building HVAC systems, so that it becomes a common way for running the HVAC systems.

In 1999, the International Energy Agency’s Implementing Agreement on Energy Conservation in Buildings and Community Systems initiated the activity “Annex 40: Commissioning of Building HVAC systems for Improved Energy Performance”. Ten countries participated and three others had status as observer. In most of participating countries national activities was conducted and national support teams was established. In 2005 the Executive Commitee for the same Implementing Agreement decided to launch a new activity that is a continuation of the previous: "Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings”.

The new Annex is now in a one-year Planning Phase. This work should give the contribution to new Annex 47.
2. Aim
The main objective is to develop, verify, document and implement suitable tools for improving HVAC systems operation during their life. The aim is to show how simulation process (computer based tools) can be used in the commissioning process of the existing buildings. The relations between the inlets and outlets parameters of the building systems can be established by connecting the simulation software and optimization program. This could be useful for evaluating the buildings system performance.

The aim will be to model the problems and failures of HVAC systems in the existing buildings. This will be necessary for defining the feedback of information between the operation and design period. The mathematical models and procedures will be developed for overcoming the problems and failures in HVAC systems. Also, the aim will be improving the operational parameters and the maintenance processes in new building by using the mathematical models and procedures, which will be developed in this study.

3. Scope of work
The problem of the existing buildings commissioning using the computer based tools can be defined as:

- Develop the models of buildings and HVAC systems;
- Develop mathematical models of problems in the existing buildings;
- Form the methods for the evaluating of multi-parametric problem with few objectives or constraints in the buildings;
- Establish the procedures for improving the building operation.

For propose of this work it is necessary to develop the models of buildings and HVAC systems. During modeling, the particular differences between the buildings in question and the HVAC systems should to be noted. The mathematic models of the buildings and the HVAC system will be modeled in existing simulation software.

During the designing of HVAC systems, the assumptions about the building behavior are made. These assumptions are standardized and it is supposed that they lead to energy efficient use of HVAC systems. However, there are discrepancies between the assumptions and final result in practice. Some discrepancies appear because the assumptions are rough. Also, during the sizing of the HVAC systems, we start from the heat loads of building and we follow the demands of building, without feedback on the start. The problems can proceed from either oversized or undersized HVAC components, and from either poor or bad control system. To overcome the above problems, it is necessary to define mathematically the real situation and test it through simulation.

The study considers the commercial/public buildings, which belong to “user club” members, and might have some performance problems. The preliminary step for this study would be to get information from “user club” members about the buildings. Getting the information about the buildings would be through survey with the building caretakers. The first aim of the survey would to make an overview of the most typical buildings, HVAC equipments and their related problems. The second aim would be to establish the criteria for both choosing the buildings in the further research and establishing the existing building commissioning tools.

Based on this preliminary survey the future study should be managed. The building operation problems would be explained as good as possible. The attention should be on the HVAC system performance characteristic. For most of the problems would be found the source. This
implies making the connection between the problems, influenced parameters and design intent. The particular conclusions should be usable for developing the building commissioning standard. The established relations between the problems and results should be used in defining the building maintenance schedule.

Buildings and HVAC system design is multi-parametric problem because it is influenced by different parameters. Usually, the design process has a few objectives and/or constraints. The objectives and constraints could be quite different in nature (for example energy consumption, thermal comfort, etc.). Ordinary optimization methods developed for optimization building energy simulations allows optimization of one-objective problems. Because of that it would be necessary to develop some procedures for optimizing the building operation parameters, based on energy consumption and indoor environment. These optimal procedures should be suitable for evaluating the HVAC system performance. The optimal procedure could be either mathematical or literal written. The optimal procedure would be developed based on existing optimization algorithms and optimization programs. Also, the optimal procedure would include the simulation software.

The following step should be to develop the commissioning tools for overcoming the problems. This means that the most typical problems in the existing buildings should be proceeded by using both the developed simulation models and the optimization procedures. The optimizations should be performed for the operation parameters of HVAC systems. The results would be used to establish the guideline for the HVAC system operation. These results should be implemented for the supervision of building HVAC system performance.

The implementation of these commissioning tools would include the proceeding of particular BEMS data through the optimal procedure to indicate if there are any problems or failures. BEMS data would be collected in the existing buildings, which belong to “user club”. The optimal procedure should indicate if there is any problem. Also, the optimal procedure would indicate how it could be solved. Finally, the developed commissioning tools will give the suggestion for overcoming the problems. This stage of work should show the practical implementation of the developed commissioning tools for detecting the problems in the HVAC systems. These procedures and tools should be adoptable for the building commissioning process. The tools should give the direction for improving the design of new buildings, too.

Through the whole study the contact with the building caretakers would be managed. This would be necessary for real-life feedback of the study results. Finally, the second survey for the building caretakers would be performed. The aim of this survey would be to get the form, which would be the most suitable for the input and output of data in the commissioning tools. This part would be necessary for proving the applicability of these commissioning tools for the existing buildings.

4. Methods of Research
The research is based on acknowledged scientific methods. As the simulation and optimization tools are used already existing programs adopted for that purpose. Used scientific methods are numerical methods for solving the partial differential equations, adaptive time steep method, modeling the energy source and heating/cooling system in simulation program and optimization algorithm that are incorporated in optimization program.
Simulation is used to describe the behavior of building and HVAC system. Also, it is used to analyze the output parameters that are important for utility costs associated with maintaining environment conditions in the buildings. Optimization is used to establish the relation between the parameters that influence the utility costs and environment conditions in buildings. This is necessary for evaluation the HVAC system performance.

5. Expected Results

Expected results are:

1. Make the procedures for sizing the HVAC systems operation parameters for overcoming the existing failures and problems. The procedures have to take in consideration multi-parametric problems with few objectives and/or constraints.
2. Develop the tools for HVAC systems operation to diminish the utility costs and to keep the indoor environment conditions in suitable range.

6. Work Plan

The present work will consist of the following activities, further described below:

1. Literature study.
2. Overview of typical performance problems in existing buildings.
3. Develop models of buildings and HVAC systems.
4. Develop the models of the typical problems in HVAC systems.
5. Evaluate the influence of typical failures and the problems on energy consumption and indoor thermal environment.
6. Develop tools for improving the commissioning process in existing buildings.
7. Implement the commissioning tools in building operation.
8. Documentation of work.

7. References

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