POTENTIAL OF DEMAND SIDE MANAGEMENT IN NONRESIDENTIAL BUILDINGS

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ABSTRACT

The continuing progress and development of decentralised, fluctuating renewable energy production and cogeneration makes high technological and economic demands on energy production itself. It also requires a shift of paradigms in terms of controlling the energy consumers. Passive consumers, such as buildings and consumers inside buildings can be turned into active participants of the larger power grid.

In a joint study the Technische Universität München and SIEMENS Building Technologies, investigated the potential for smart energy management systems in non-residential buildings. The study focused on building automation, an in-house communication system linking individual consumers into one network. Potential for load management was identified especially in office and administrative buildings, because they provide numerous opportunities for electrical and non-electrical power storage.

MOTIVATION

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) forecasts the installed power plant capacity through 2050 in its publication “Leitszenario 2009” (“Lead Scenario 2009”). It expects the growth of fluctuating, renewable power generation, particularly photovoltaics and wind power plants, to reach a capacity of more than 65 GW in 2020. In comparison to this development it should be noted that the total power plant capacity today is about 140 GW. In the same period, the power plant capacities of today’s base load providers (dispatchable generation), such as coal and nuclear energy, is expected to decline. If the trend of power generation follows this scenario, new requirements for the electric power grid will result, as the grid will have to be able to accommodate large power fluctuation. [1]

This requires a restructuring of the grid, moving away from the current “top-down” structure to a bidirectional energy and communications network. In this intelligent power grid, previously passive consumers (buildings for example) can become active participants in the energy system.

Buildings with an intelligent load management system that can regulate its consumption in response to the current energy production are just one example of consumers that are able to actively participate in the Smart Grid (Figure 1).

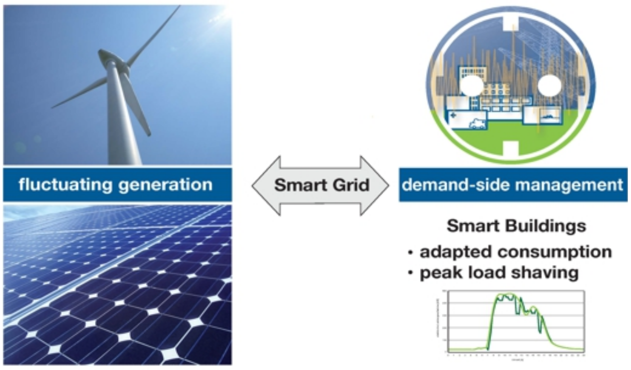


Figure 1: Demand follows generation - demand side management using controllable consumers in Smart Buildings [2]

Making use of the existing communications structure (the building automation system) can be a huge advantage when using non-residential buildings as electrical and nonelectrical storage devices. Building automation systems represent a suitable platform to implement a variable operation of different consumers. These existing systems, particularly in non-residential buildings, are today’s best practices and currently serve to automate operation and control of all the technical building systems such as heating, ventilation, air conditioning, lighting, and security. For these systems the priorities for control and regulation are: maintaining comfort, energy efficiency, and ensuring that standard operating procedures are upheld.

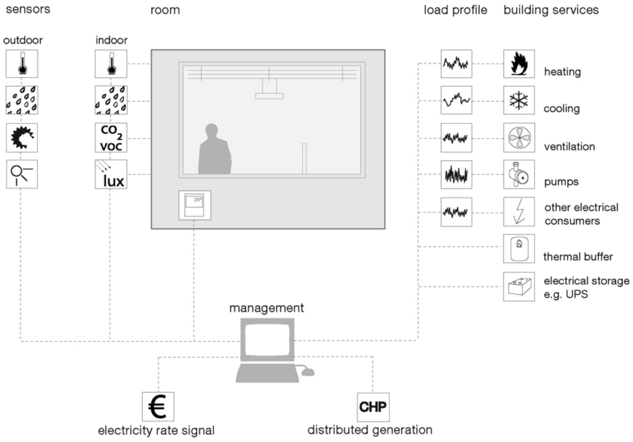


Figure 2: Overview of a simplified building automation diagram with a load management system [2]

Figure 2 shows a simplified diagram of a building with an intelligent load management system. To its role as central instrument of the load management system in buildings the automation system is added to enable optimized operation of individual consuming devices. All the information about the building and individual consumers is used by the building automation system to forecast an overall electric load profile. In this way, an intelligent load management system can identify potential for shifting or reducing peak loads and take appropriate measures to adapt the electric load profile to the target variable, such as an external electricity price signal. This target-variable can be composed of different internal and external signals.

Examples for this process are: smoothing out the load-profile to reduce the demand generated power prices, and an external price signal which is received by a Smart Meter from the Smart Grid to optimize the consumers. Depending on the target-variable the intelligent load management system is able to identify the most efficient way for the building to function and implements that.

ANALYSIS OF INDIVIDUAL CONSUMERS

There are various consumers that can be integrated into a load management system in non-residential buildings. In the cooperative research project between the Technische Universität München and the SIEMENS Building Technologies Division, various consumers were investigated with regards to their potential to be part of a load management system. The investigations focused on electrical and non-electrical storage devices in different building typologies such as schools, public indoor pools, hospitals, and office and administrative buildings. Non-electrical storage devices, besides conventional thermal storage, could be provided by the building's own thermal mass to create temperature time-lags, and the indoor air as a temperature buffer. Different consumers and storage devices in buildings, like elevators or UPS-systems, provide load shift and shut-down potential. Exemplary for all investigations conducted, the analysis of the load management potential of cooling machines in office buildings is presented here. In order to show the influence of the thermal storage mass of the building, a reference building with different boundary conditions was simulated. Different scenarios were calculated varying structural mass, type of cooling distribution system, and cooling medium (water, air). The first building type simulated was a lightweight construction with an idealized forced air cooling system. Figure 3 shows the simulation results in a psychrometric chart. The box represents the comfort zone according to DIN ISO 7730 [3] and DIN EN 15251 [4]. Measurements were taken in 15 minute increments throughout the months of July and August and each value calculated is represented by one dot on the chart. The highlighted area represents the outdoor conditions during the simulation period.

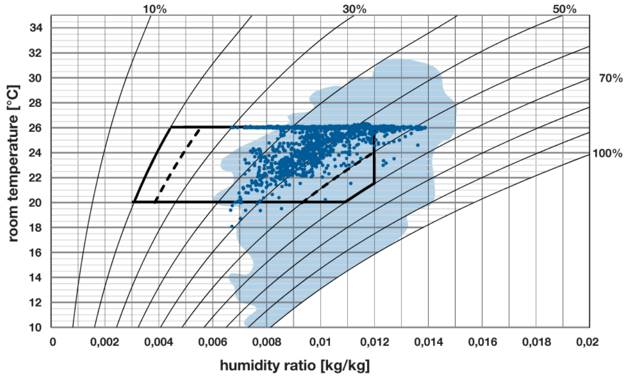


Figure 3: Psychrometric chart displaying simulation results for the indoor climate in an open plan office space (lightweight construction) with forced air cooling, and the outdoor conditions [2]

The simulation results show that an idealized forced air cooling system is capable of providing adequate indoor room temperatures. No additional humidity control systems have been integrated in the scenario so that only the desiccating effects of the cooling systems are considered. This causes absolute humidity levels to occasionally exceed design limits. Implications for the indoor climate conditions if load-management controls are activated (meaning that the cooling system temporarily shuts down) are provided in Figure 4. For Figure 4 all simulation parameters are identical to the previous simulation with the exception that the cooling system operation is discontinued for 30 minutes intervals three times per day.

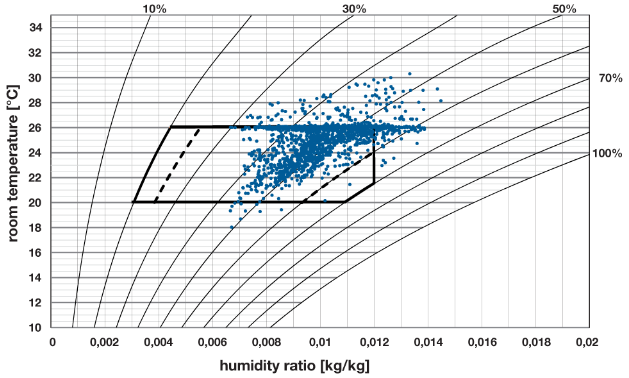


Figure 4: Psychrometric chart displaying simulation results for the indoor climate in an open plan office space (lightweight construction) with a forced air cooling system that discontinues operation for 30 minute intervals 3 times per day [2]

The above simulation shows that in a lightweight office building with open-plan offices, shutting-down the cooling system will cause a reduction of comfort levels to below the standard required by code.

Due to high internal loads as well as peak outdoor air temperatures a maximum indoor temperature of 26°C cannot be guaranteed at all times. A shut-down of the cooling system for up to 60 minutes amplifies the effect accordingly.

If we vary the construction type and specify solid construction instead of lightweight, the amount of hours with overheating can be reduced by 20-30%. Peak temperature compromising the comfort level, however, still cannot be avoided completely. Other strategies for controlling temperature were investigated to try and achieve a comfort range fully within the specified range.

Reducing the temperature for 30 minutes to 24°C prior to a shut-down period of the cooling system resulted in significant reduction of hours of overheating, thereby improving comfort. If pre-cooling is employed, the increased cooling demand prior to shut-down has to be considered in the load-management to avoid additional load peaks.

Limiting room temperatures to a maximum of 28°C can improve comfort, and, in conjunction with pre-cooling, can allow for an overall reduction in the load management potential and should be integrated into the intelligent load management system.

Cooling power delivery systems other than plain forced air systems are better suited for controlling comfort. Figure 5 shows indoor climate conditions for the same 3 times daily 30 minutes shut-down pattern, this time for a chilled ceiling system, where capillary tubes are embedded in the ceiling plaster.

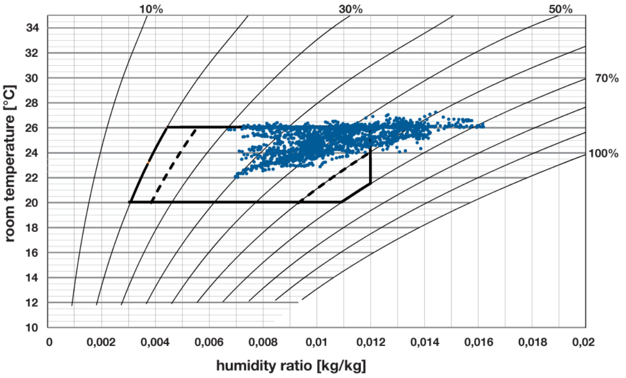
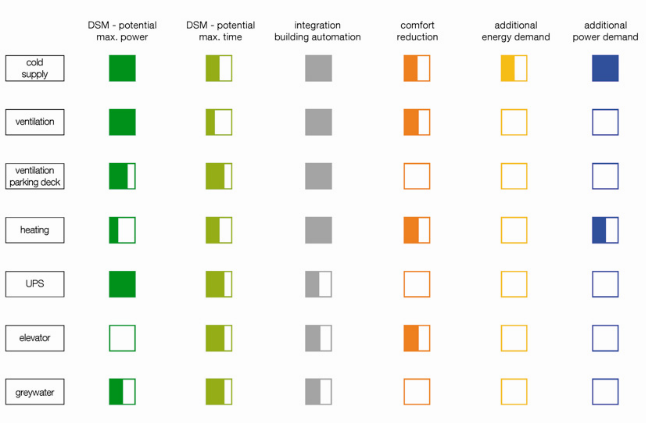


Figure 5: Psychrometric chart displaying simulation values for the indoor climate in an open plan office space (heavy construction) with a chilled ceiling system that discontinues operation for 30 minute intervals 3 times per day [2]

Activating structural thermal mass by cooling the concrete ceiling significantly reduces the impact of the 30 minute shut-downs. Even when extending the shout-down periods to 60 minutes the 28°C threshold temperature is not reached in this building model. However, compared to the forced air cooling, higher humidity levels are to be expected. This is because the supply temperature to the cooling tubes should be chosen warm enough to avoid condensation along the underside of ceiling, whereas condensation is not a restricting factor in air chiller devices.

RESULTS

The investigations show that cooling systems do bear a potential for load management. However, increased loads compared to regular operating loads occur following a shut-down period, because during the shut-down room temperatures rise, thereby increasing cooling loads upon resuming work. This effect has to be considered if shut-down mechanisms are used, in order to avoid the counterproductive effects of a mere time-shift of peak loads. Office and administrative buildings house numerous other devices that bear potential to be included in load management systems and can be integrated into the building automation. Parallel to the simulations presented here, other consumers were evaluated as well. Their potential to be included in a load management system was analysed based on their required input power and demand over time. In addition, the possibility of integrating load management into the building automation and its impact on the provided comfort range were analysed. It should be noted that some devices cause an increase in power demand and have a higher energy demand after a shut-down. Figure 6 provides a summary of the analysis results for the simulations building typology "office and administrative buildings".



	DSM - potential max. power	DSM - potential max. time	integration building automation	comfort reduction	additional energy demand	additional power demand
cold supply	■	◧	■	◧	◧	■
ventilation	■	◧	■	◧	□	□
ventilation parking deck	◧	◧	■	□	□	□
heating	◧	◧	■	◧	□	◧
UPS	■	◧	◧	□	□	□
elevator	□	◧	◧	◧	□	□
greywater	◧	◧	◧	□	□	□

Figure 6: Summary of results for the load management potential simulations for office and administrative buildings [2]

From Figure 6 it can be concluded that many consumers in office and administrative buildings do bear some potential for load management. A filled square represents a high value or a relevant characteristic of the particular consumer. Building services, such as cooling or ventilation systems, constitute the best potential in office and administrative buildings. Depending on make and model, uninterrupted power supply units are another alternative. However, it usually will have to be assured that the batteries are replaced with more cycle-proof battery types. Integrating the devices into the building automation system is relatively simple for almost all devices. It should be noted though, that not all load management possibilities avoid compromising indoor comfort. For example travel times in elevators slightly increase during a load management phase, and a temporary overheating can occur in the main useable areas. The occasional device may cause additional power demand.

CONCLUSION

If the percentage of renewable energies in the power generation sector continues to grow as predicted, we will soon see a shift from traditional energy supply concepts to more intelligent and adaptable systems such as the Smart Grid. A fundamental characteristic of the Smart Grid is the possibility to synchronize instantaneous demand and supply. With this shift in mind, SIEMENS Building Technologies and the Technische Universität München are developing innovative systems that help implement demand side management (load management) in non-residential buildings.

Research in the building typologies schools, indoor public pools, hospitals, and office and administrative buildings shows that there is a potential for load management strategies in non-residential buildings. It became clear that existing building automation systems constitute a network that is suitable to provide access to that potential. In addition to the consumers that are already connected to the building automation, new consumers can be integrated without significant technical effort.

The duration for which devices can be shut-down without compromising comfort is largely dependent on the consumer itself, and the building type and its use. When extending the existing hardware to allow for new consumers to be included in the system, an intelligent coordination is crucial to prevent a reduction in comfort levels or a creation of new peak loads in the implementation of the load management system.

The cooperation SIEMENS Building Technologies and the Technische Universität München has an ambitious goal: to provide innovative strategies that allow to turn new construction as well as existing buildings into an intelligent participant of the Smart Grid, to turn them into Smart Buildings.

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