Demand Response Strategies in a Small All-Electric Commercial Building in Quebec

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Abstract

Commercial and institutional buildings using electricity as their only energy source are common in Quebec and they contribute to a significant portion of the winter grid peak. This paper discusses how building simulation can be used to elaborate optimized demand response (DR) strategies for a small all-electric commercial building. An EnergyPlus model was created and calibrated with the 15-minute interval metered data of the building's total electric power demand. Parametric runs and visualizing tools were used to identify and adjust key parameters. Final calibration was obtained by optimization using a generalized pattern search algorithm. Then, "NSGA-II", a multi-objective genetic algorithm, was used to optimize pre-determined DR strategies for this particular building. Results show that the use of DR strategies can lead to a significant reduction in the building's total power demand during peak periods while maintaining an acceptable comfort level for the building's occupants.

1 Introduction

Demand response has been increasingly used as a means of meeting electricity supply and grid operation challenges (*smartgrid* applications). It involves getting customers to change their electric usage from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when there is a tightening gap between supply and demand. In the case of electricity supply applications, the conditions and time of occurrence are well known in Quebec; tightening gaps between electricity supply and demand occur twice daily (6:00-9:00 and 16:00-20:00) in the winter when the outside temperature is very low (below -20 °C) (HQ 2014).

Residential, commercial, institutional and industrial customers each have their own limitations in terms of market potential, controllable loads, typical demand profiles and grid peak coincidence, etc. In Quebec, a significant amount of commercial and institutional buildings (CI) use electricity as their only energy source (called *all-electric*). This is the result of low electricity rates, high fuel prices and limited distribution of gas in certain regions. These customers are good candidates for demand response (DR) participation. It is estimated that heating in the CI sector alone accounts for 9% of the province's winter peak (HQD 2012).

While literature abounds in terms of studies targeting cooling and lighting DR strategies during the summer in CI buildings (Motegi et al. 2007, Kiliccote et al. 2010), only a few publications address heating loads in a winter context. This is to be expected since the majority of buildings in the world use fossil fuels as their primary heating source. Kiliccote et al. (2009) reported on a winter CI DR demonstration project in the U.S. Northwest. The minimal outside air temperature was -2 °C during the tests and two out of four facilities were all-electric. Even in those conditions, a significant average electric power reduction of 14% (6 W/m^2) was observed for three hours peak periods (occurring twice daily).

DR strategies such as global temperature adjustments (GTA), fresh air intake limiting, system shut-off and cycling of rooftop units during peak periods are expected to provide significant load reductions if the building is well pre-conditioned (pre-heating and pre-ventilating if needed) and if the return to normal operation conditions (rebound) is well managed. A detailed analysis of building conditions under the planned DR strategy conditions is most necessary due to the occurrence of two peak periods daily in order to ensure acceptable comfort levels for occupants and limit rebound effects.

The aim of this study was to demonstrate how building simulation can be used to elaborate optimized DR strategies for a small all-electric commercial building. First, a building was selected amongst the buildings participating in a DR demonstration R&D project that aimed at implementing DR strategies and evaluating their impact on building power demand during grid peak hours in Quebec. The choice of the building for this study was mainly based on the limited number of systems involved (three rooftop units and baseboards), extensive load data history, systems trend logs and abundant information available on the building's characteristics and operation.

An EnergyPlus model of that building was created. This model was then calibrated with the 15-minute interval metered data of the building's total power demand. Parametric runs and visualizing tools were used to identify and adjust key parameters such as infiltration rates, minimum outside air intake, insulation levels, plug loads, etc. Final calibration was obtained by optimization using a generalized pattern search algorithm. Then, "NSGA-II", a multi-objective genetic algorithm, was used to optimize pre-determined DR strategies for this particular building.

2 Building Model

The building used for this study is a 427 square meter single story commercial building topped by a plenum and an attic. The owner provided the floor and elevation plans and a 3D model of the building was drawn using Google SketchUp with the OpenStudio plugin as shown on Figure 1.

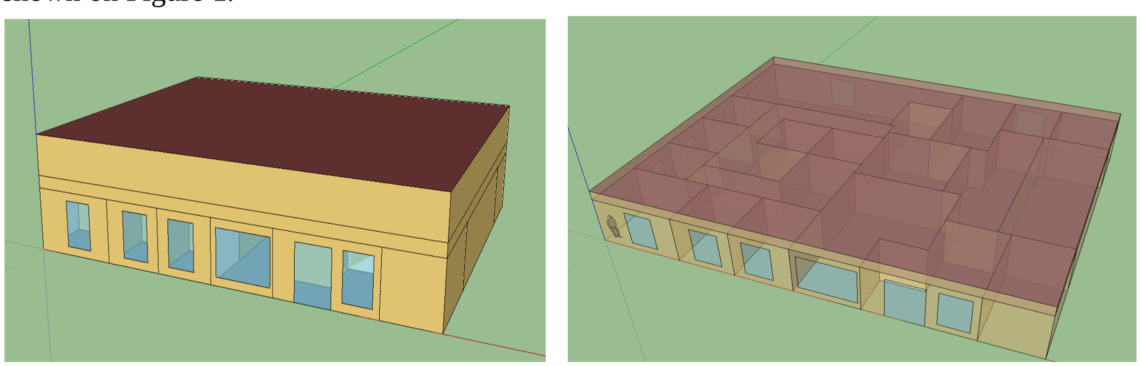


Figure 1: Building model drawn with Google SketchUp and Open Studio Plugin

The first building simulation model was completed in the SIMEB software [SIMEB] to which the geometry was imported.

The insulation level for the walls was set at 3 RSI and 6 RSI for the roof. Those values were determined from vertical section drawings. The windows were modeled as double glazing-Low-E type with 12.7 mm spacing.

The floor plan was divided into 21 thermal zones (see Figure 1). The mechanical and electrical drawings provided comprehensive information about light density, maximum and minimum design zone airflow rates, terminal reheat and baseboard rated capacities. SIMEB default values were used for plug loads and infiltration rates. Those values are based on the default assumptions in the performance compliance method of MNECB (1997).

There are three HVAC systems in this building. Table 1 summarizes the characteristics for each system.

Table 1: HVAC systems description

	AC-1	AC-2	AC-3
HVAC Type	Rooftop	Rooftop	Split unit
Fan type	VAV	VAV	Constant
Max. supply air flow rate (L/s)	1623	920	496
Heating coil capacity (kW)	34	21	-
Cooling coil capacity (kW)	35.2	17.6	10.3
Cooling EER	11	10.8	11
Humidification (kW)	-	-	-
Minimum supply temperature (°C)	12	12	12.8
Economizer	Enthalpy	Enthalpy	No outside air
Fan cycling-unoccupied hours	Yes	Yes	No

The main operating schedules were provided by the building owner and are shown in Tables 2 and 3.

Table 2: Usual schedules

	Occupancy	HVAC	Lighting
Mon-Tue	8:30 to 17:00	7:00 to 17:30	8:00 to 17:30
Wed-Thu	8:30 to 20:00	7:00 to 20:30	8:00 to 20:30
Fri	8:30 to 16:00	7:00 to 16:30	8:00 to 16:30
Sat	8:30 to 15:00	7:00 to 15:30	8:00 to 15:30
Sun	Unoccupied	Off	Off

There is a period of extended operating hours from February 1st to March 4th.

Table 3: Schedules for February 1st to March 4th

	Occupancy	HVAC	Lighting
Mon-Fri	8:30 to 21:00	7:00 to 21:30	8:00 to 21:30
Sat	8:30 to 18:00	7:00 to 18:30	8:00 to 18:30
Sun	Unoccupied	Off	Off

The SIMEB building model was completed using most of the information mentioned in this section. The simulation results were compared with 15-min. interval metered data from January 1st, 2011 to October 10th, 2013. Some of the differences observed can be attributed to limitations of the SIMEB interface. For example, the SIMEB schedules are built on a one-hour timestep basis. They do not use smaller time increments. In addition, all zones served by a same HVAC system must have the same zone heating equipment, etc. Those differences were corrected manually in the EnergyPlus input file (.idf). More adjustments were made after comparing the results with the measured data as discussed in the following section.

3 Model Calibration

In order to analyze and predict the impact of different DR strategies applied to the building, a detailed calibrated model was needed. The model had to be able to capture the daily power profile behaviour during grid peak days. As mentioned in the previous section, the total electric power demand on 15-minute interval metered data between 2011 and 2013 was provided, but no sub-metering or operation data from BAS data were available. The following process was used to obtain the calibrated model.

Analyzing Measurement Data and Selecting Calibration Periods

Selecting a calibration period is not an easy task. As shown on Figure 2, the building's consumption is well correlated with the outside air temperature. It also seems that the building's operation was similar for all three years.

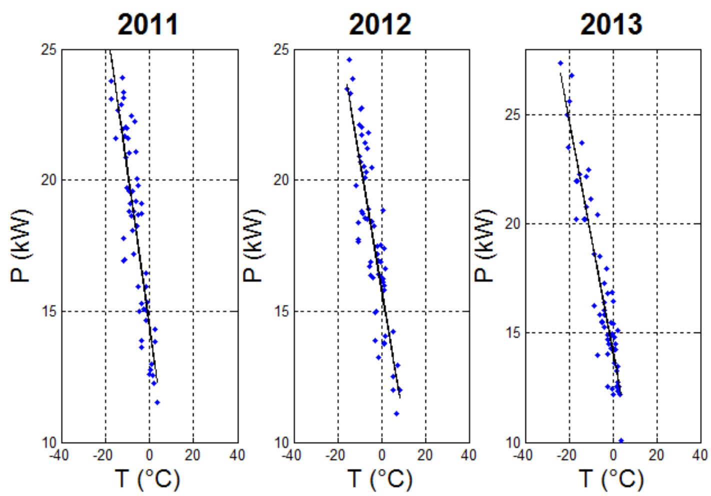


Figure 2: Daily mean building power as a function of daily mean outside air temperature.

The year 2012 was rejected for calibration due to a milder winter. Indeed, the purpose of the study was to establish DR strategies in extremely cold temperatures (for average daily temperatures around -20 ° C). However, the average daily temperature for 2012 never dropped below -16 ° C. The measurement data for 2011 and 2013 were visualized using an hourly daily profile clustering technique as reported by Fournier & Lavigne (2010) in order to diagnose operational problems and verify operation schedules. This visualization tool is embedded in the SIMEB software. Some erratic behaviour was observed at the beginning of 2013; therefore, 2011 was chosen for calibrating the model.

Within the framework of this case study, the data for the entire year were used to calibrate the model. However, it was found that one should consider calibrating for only three weeks during the year. Interesting benefits can be obtained by selecting one week in the winter, summer and shoulder season respectively. Measured profiles during these weeks should follow a predictable pattern and cover different weather conditions. The selection of relatively short calibrating periods also has the advantage of reducing running time and the amount of data generated when launching parametric runs.

Comparing Model Results and Measurement Data

The initial model corresponds to the first EnergyPlus model to which multiple adjustments were applied, including an operation schedule based on 30 minutes and a cut-off schedule for heating devices during the summer. An on-site survey revealed that the receptacle power density had to be increased by about 30-40% for most zones. Those values were corrected in the simulation model. Yet, there was a large gap between the measurements and the results from the simulation that could be minimized by simply increasing the minimum outside air quantities of AC-1 and AC-2. After a discussion with the building operator, it was noted that there was significant outside air infiltration on both AC-1 and AC-2 systems probably due to poor air tightness at the rooftop bases. Moreover, a malfunction of the louvers of the outside air economizer of system AC-2 was noticed as well as a deviation of the measurement of the CO_2 sensor in the same system. To account for those problems, a significant increase of minimum outside air for systems AC-1 and AC-2 was considered and incorporated in the model. Even with those modifications, as can be seen in Figure 3, the initial model did not qualify data according to recognized statistical criteria: CVRMSE and NMBE (ASHRAE, 2002). An optimization of the model was therefore necessary.

Performing Parametric and Optimization Runs

The first step in the optimization process is to identify influent parameters. Some hints can be provided by the assisted calibration module in the SIMEB software. The module has a pre-calibration routine that identifies potential problematic parameters based on monthly bill differences. Combining this information with the level of uncertainty on certain simulation parameters, the following list of parameters was established for calibration: minimum outside air of AC-1 and AC-2, static pressure rise of AC-1 and AC-2, infiltration airflow of all perimeter zones, plug load density of three major zones and insulation thickness of exterior walls and roof. Parametric runs were performed to verify the influence of those parameters. It was noted that the minimum outside air had the most important impact on the results during heated occupied periods. However, each of these parameters had a different impact on the results depending on weather conditions and occupancy periods.

The optimization process was launched in order to get the best fit. GenOpt®, an optimization package developed by the LBNL DOE laboratory, was used for this task. The objective function to be minimized was defined as the coefficient of variation of root mean square error (CVRMSE) between the 15-minute interval metered data and the model results for the whole year of 2011.

Since they were all influent at one point, the parameters analyzed in parametric runs were selected for the optimization processes, constrained with physically feasible minimum and maximum values. Two different algorithms, a genetic algorithm and a generalized pattern search approach were used and gave relatively the same results for each parameter value. Figure 3 shows the results obtained for a winter and a summer week in 2011. It should be noted that the calibration process reduced the coefficient of variation of root mean square error (CVRMSE) and the normal mean bias error (NMBE) assessed on hourly intervals within the limits specified by ASHRAE Guideline 14-2002 (i.e. CVRMSE < 30% and |NMBE| < 10%).

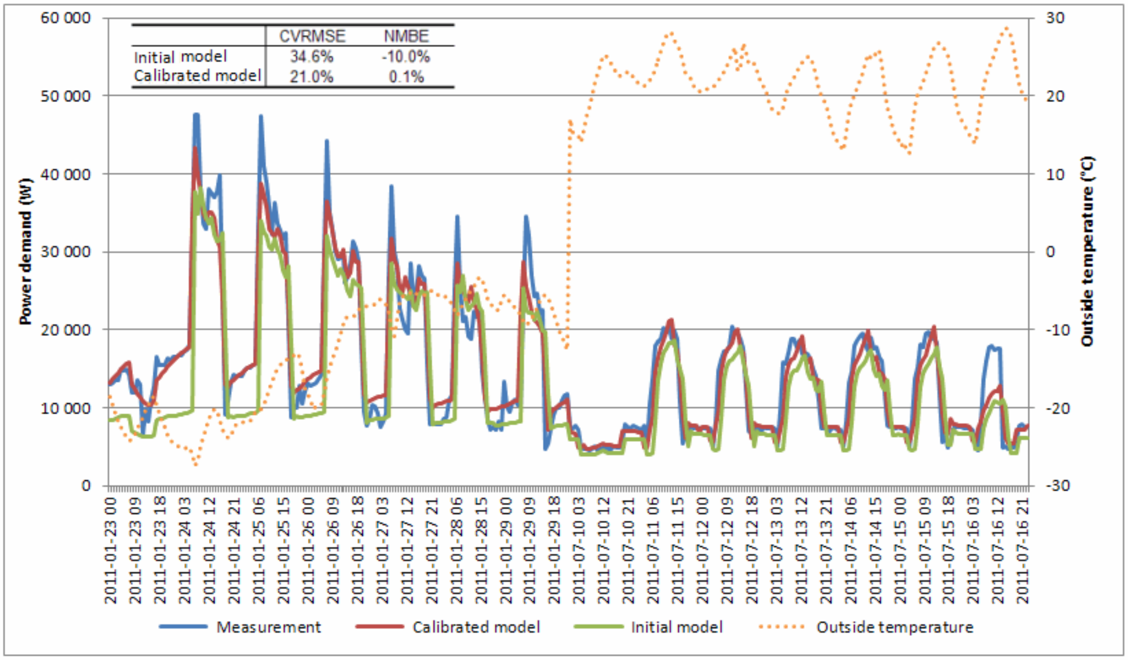


Figure 3: Initial and calibrated model results with the 15-min interval metered data for a winter and a summer week along with the outside air dry bulb temperature and statistical indicators.

4 Optimization of Demand Response Strategies

The calibrated model was then used to optimize the operational parameters of a set of defined DR strategies. The DR strategies selected for this building addressed HVAC systems exclusively. These strategies were applied simultaneously. They included:

- **Global temperature adjustments, GTA (meaning *applied in all zones*)** – Morning preheating of the building and lower temperature setpoints effective during peak periods (as detailed in Table 5).
- **Rooftop unit cycling -** For two rooftop units (the third system is a split unit used for cooling the automated teller machines and would not be affected by the DR strategies). Cycling of the units during peak periods, both units operated alternately for a period of 30 minutes each. This cycling time is typical for such a strategy and prevents early deterioration of the equipment.
- **Fresh air intake -** For the two rooftop units mentioned above since both have a modulating fresh air intake. The fresh air intake was shut off in the morning during the preheating and peak periods of 6:00-9:00 and 16:00-20:00) (as detailed in Table 5) but the original schedule will be maintained during the afternoon peak period in order to prevent air quality deterioration.

The cycling of rooftop units combined with limiting the fresh air intake is an excellent strategy; it ensures that the units are still available during peak periods (though for a limited amount of time) in case of a heating demand, which, in this case, was lower than usual due to a global temperature adjustment (setback). In this particular building, baseboards are also available in the perimeter zones; this ensures enough heating capacity for these particular zones when the rooftop unit serving them is not available.

The optimization of the DR strategies had to take into account three types of objective functions measuring the power demand, air quality and comfort level. In terms of power demand, Table 4 lists the most important power demand indicators used to evaluate the efficiency of the DR strategies (Fournier & Leduc, 2014). Every indicator can be expressed in terms of the daily power demand profile vector components:

$$\overrightarrow{Q_x} = \left[q_{x,0.25}, q_{x,0.5}, q_{x,0.75}, \ldots, q_{x,24}\right] \tag{1}$$

In order to combine the power demand indicators into one single objective function, weights were attributed to each indicator (see Table 4) and then a unique objective function, *power demand of peak periods*, was calculated as a weighted sum of all the indicators. A second objective, *building absolute peak*, was defined as the maximum daily peak of the building, which was independent of the moment of occurrence. It was used to ensure that the new daily peak induced by the application of the DR strategies did not exceed the building's reference daily peak, hence that there would be no implication in terms of billing for the customer.

Table 4: Power demand indicators and associated weight for the *power demand of peak periods* objective function computation

	Indicator	Definition	Power demand objective function (Weight, [%])
AM	$\bar{q}_8$	mean power demand from 7:00-7:59	-
	$q_{AM}^{\max}$	maximum power demand from 6:00-9:00	15
	$\bar{q}_{AM}$	mean power demand from 6:00-9:00	30
	$rebound_{AM}$	maximum power demand from 9:00-11:00	5
PM	$\bar{q}_{18}$	mean power demand from 17:00-17:59	-
	$\bar{q}_{19}$	mean power demand from 18:00-18:59	-
	$q_{PM}^{\max}$	maximum power demand from 16:00-20:00	15
	$\bar{q}_{PM}$	mean power demand from 16:00-20:00	30
	$rebound_{PM}$	maximum power demand from 20:00-22:00	5

In order to evaluate the impact of the DR strategies on the building's air quality, the mean daily concentration of CO_2 at the HVAC systems return was used as an objective function (*mean daily CO_2 concentration*). For the assessment of the thermal comfort penalty associated with the strategies, the mean temperature of the return air of the HVAC systems during occupied periods was used (*mean temperature*). Finally, the total daily energy consumption was also defined as an objective function (*building energy consumption*).

Operation conditions for the DR strategies (Table 5) were optimized for the weather conditions on January 24th, 2013 which was a peak day on the Hydro-Quebec grid. In order to avoid the effect of initial conditions, a run period for the simulation was set to three days beginning on January 22nd, 2013.

The Je+ [Je+] software was used in this study to perform the optimization runs and determine the operation conditions (temperature setpoints trajectory for GTA and fresh air intake strategy) that minimize all the objective functions. It uses a multi-objective genetic algorithm, compared to GenOpt® used for the building calibration, which is a single objective algorithm. Je+ uses a tagged version of the .idf file as a template in order to create, for each optimization iteration, a set of .idf files for which the tagged entries are replaced with values representing the population evaluated. The *power demand of peak hours* objective function could not be produced directly by the EnergyPlus standard output process due to its complexity (weighted sum of generic EnergyPlus outputs). The SQL format output was used and proper SQL queries were executed to calculate the objective functions during the simulation.

The optimization process was time consuming (several hours) even if Je+ allows the launch of simultaneous runs (one for each computer core).

Before launching the optimization process, variable types and operational domains were defined. Table 5 shows the variables used in this study. They included hourly zone temperature setpoints as well as rooftop and fresh air intake availabilities. Cooling and free cooling were not allowed during preheating or during peak periods.

Table 5: Variable operational domains for the optimization algorithm

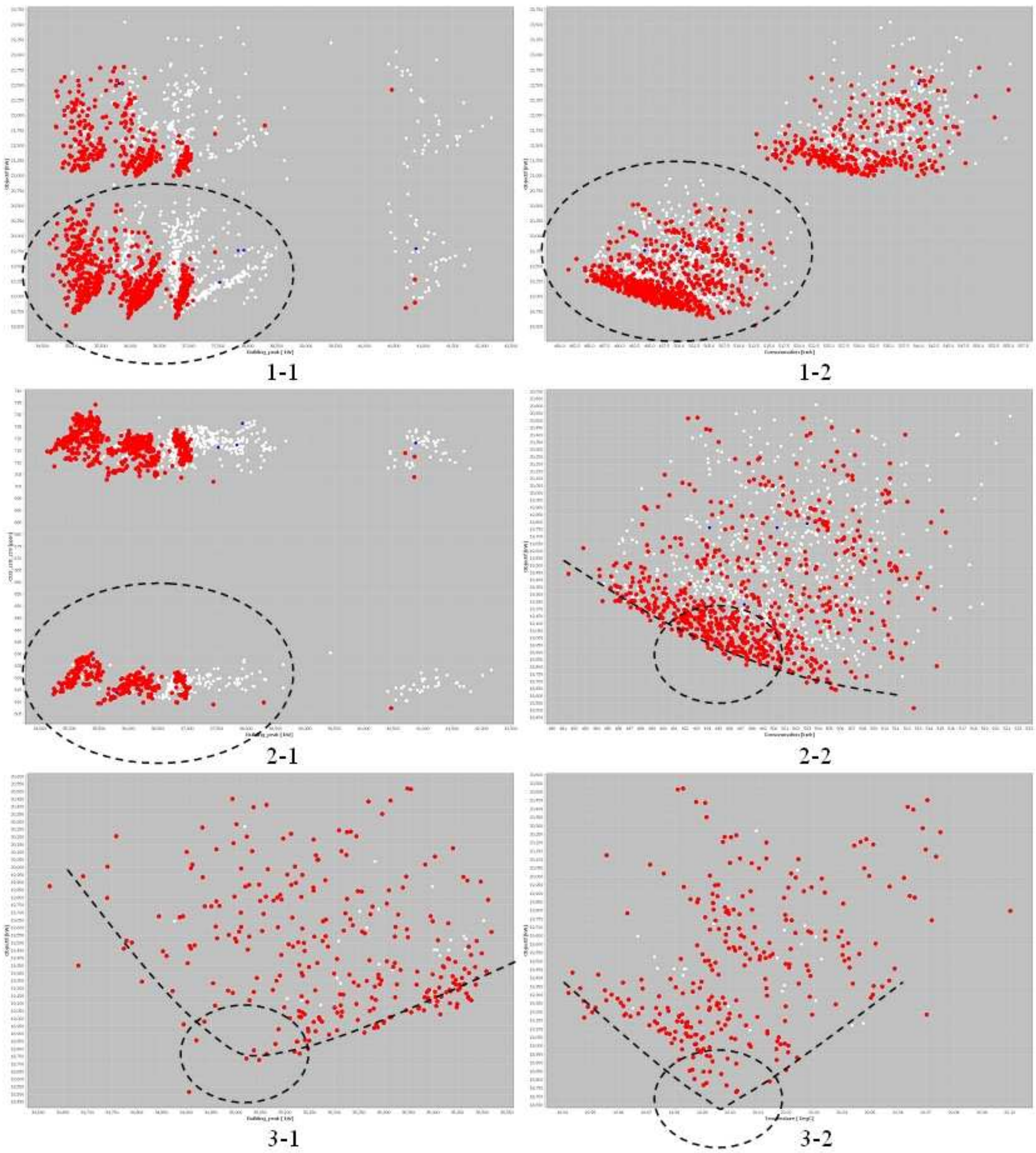
Variable	***Time interval***	*Possible variation*	*Type*
Zone heating temperature setpoint [°C]	2:00-3:00	18-24	integer
	3:00-4:00	18-24	
	4:00-5:00	18-24	
	5:00-6:00	18-24	
	6:00-9:00	19	
	9:00-10:00	19-22	
	10:00-11:00	19-22	
	11:00-15:00	22	
	15:00-16:00	22-23	
	16:00-20:00	19	
	20:00-23:00	18	
AC-1 availability	2:00-6:00	cycling ON / OFF	discrete
	16:00-20:00	cycling ON / OFF	
AC-1 outside air availability [%]	2:00-6:00	0 / maxOA	
	6:00-9:00	0	
	9:00-16:00	maxOA	
	16:00-20:00	0	
	20:00-23:00	0 / maxOA	
AC-2 availability	2:00-6:00	cycling ON / OFF	
	16:00-20:00	cycling ON / OFF	
AC-2 outside air availability [%]	2:00-6:00	0 / maxOA	
	6:00-9:00	0	
	9:00-16:00	maxOA	
	16:00-20:00	0	
	20:00-23:00	0 / maxOA	

NOTE: maxOA is the maximal fresh air intake allowed, for example, 10% of the air supplied.

5 Discussion

Detailed Analysis of Optimization Results

All the simulation runs can be represented in a scatter plot of the search space for each couple of objectives, giving a Pareto front of possible optimized solutions (see Figures 4.1-1, 4.1-2, 4.2-1) for specific objectives.



1-1 : *Building absolute peak* (kW) vs *power demand of peak periods* (kW), sample includes all the simulation runs
1-2 : *Building energy consumption* (peak day) (kWh) vs *power demand of peak periods* (kW), sample includes all the simulation runs
2-1 : *Building absolute peak* (kW) vs *mean daily CO2 concentration* (ppm), sample includes all the simulation runs
2-2 : *Building energy consumption* (peak day) (kWh) vs *Building absolute peak* (kW), filtered
3-1 : *Building absolute peak* (kW) vs *power demand of peak periods* (kW), filtered
3-2 : *Mean daily temperature* (°C) vs *power demand of peak periods* (kW), filtered

Figure 4: Filtering of solutions

In order to target an optimized solution, the simulation runs were filtered to restrain the number of possible candidates according to a defined priority in the objective functions. First, scatter plot 1-1 was analyzed because it plots the two most important objective functions *building absolute peak* and *power demand of peak hours*. These two objective functions were prioritized because the first one ensures the customer is not penalized financially (in terms of $/peak kW on his bill) and the second optimizes the customer's power demand reduction during peak periods. The plot shows four clear groups of solutions. Only the runs forming the group minimizing both objectives (dashed) were retained for the rest of the analysis. The same procedure was then applied on the second scatter plot (*building energy consumption* vs *power demand of peak periods* objective) and the third one (*building absolute peak* vs *mean daily* CO_2 *concentration*).

The analysis of the solutions remaining from this first filter gave three scatter plots (2-2, 3-1 and 3-2). The Pareto fronts were then very clear and a region of possible optimized solutions could be identified (dashed regions).

Effect of Optimized DR Strategies on Zone Air Temperatures (ZAT)

Operational conditions for one of the optimized solutions, identified through the analysis process described in the previous section, will be discussed. In the following figures, the baseline represents the reference case under normal operational conditions.

Figure 5 shows the zone heating setpoints during the peak day for the retained solution. The setpoint was increased gradually reaching 23 °C at 4:00, it was decreased to 19 °C during the first peak period (6:00-9:00). The temperature was then increased gradually reaching 22 °C at 11:00 and decreased to 19 °C for the second peak period (16:00-20:00). The effect of this temperature setpoint schedule on the air temperature is shown on Figure 6 for a perimeter zone and for a central zone. In fact, for the perimeter zone, due to losses through the building envelope, the ZAT was very sensitive to the heating setpoint. The effect of preheating did not last very long. The ZAT was almost at 19 °C at 8:00. For a central zone, the preheating effect was very useful; the minimum ZAT was about 21.5 °C at 9:00. During the day and due to the internal gains, the ZAT reached 23 °C, which was the same as the baseline.

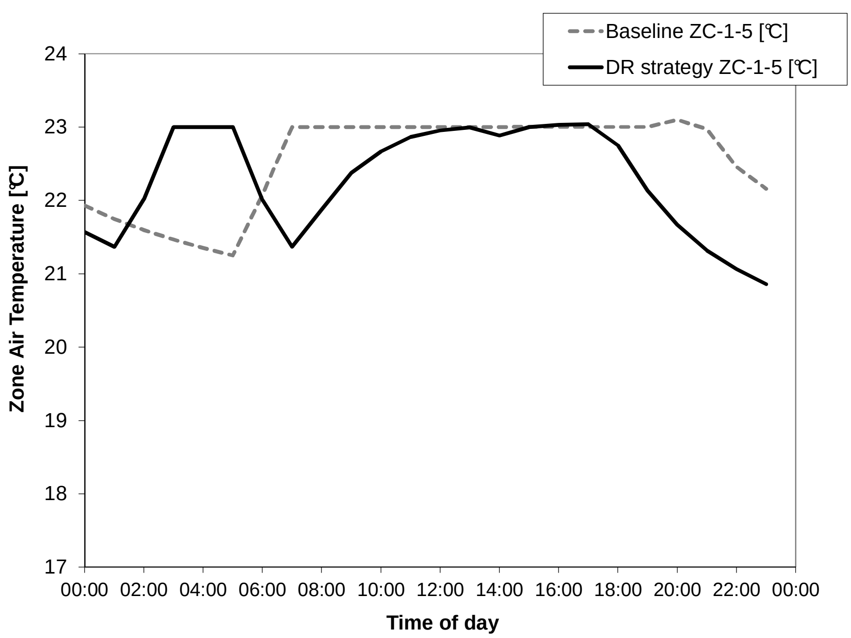


Figure 5: Zone temperature setpoints during the GTA DR strategy

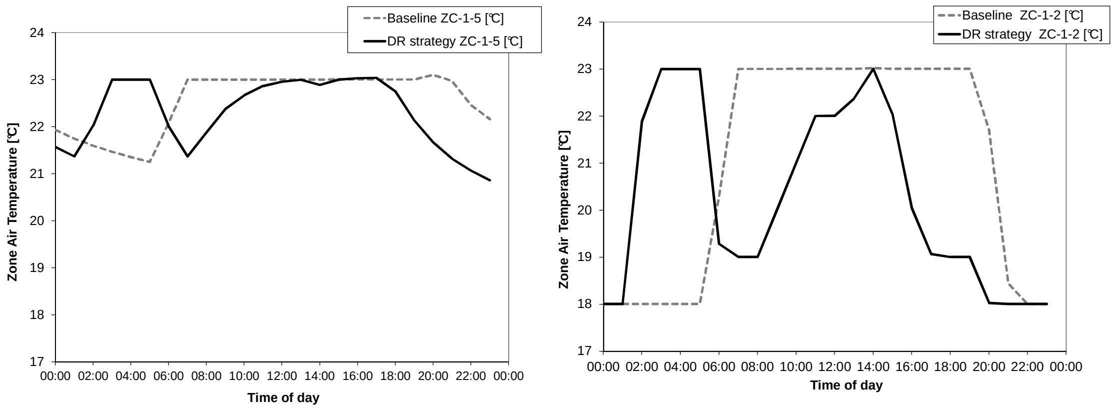


Figure 6: Impact of the DR strategies on the ZAT of a central zone temperature (ZC-1-5) and of a perimeter zone temperature (ZC-1-2), respectively

Effect of Optimized DR Strategies on Air Quality

Table 6 shows the DR strategy related to fresh air intake control. The impact of the DR strategies (fresh air intake and rooftop unit cycling) on the air quality is shown on the Figure 7.

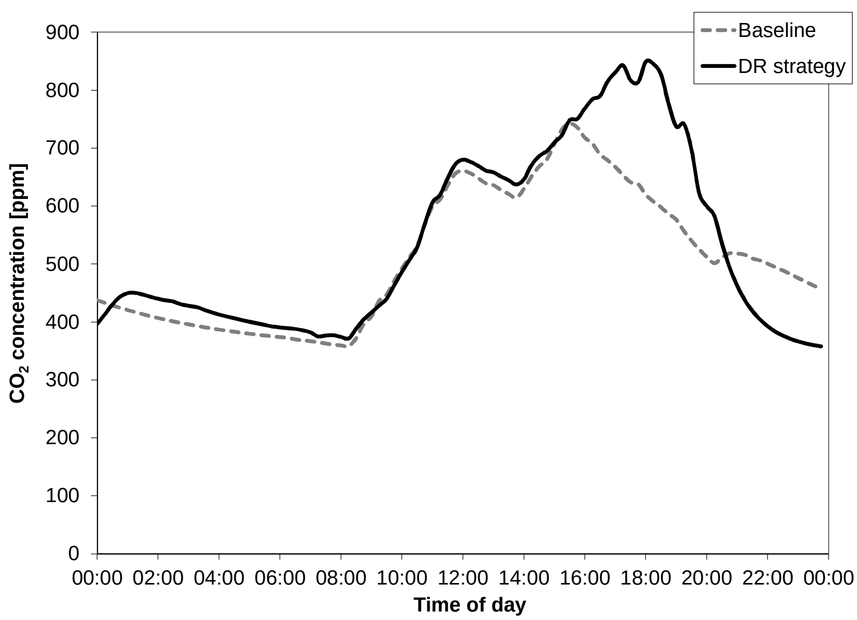


Figure 7: Impact of the DR strategies on the CO_2 concentration in the perimeter zone

It is then clear that the air quality, represented by the CO_2 concentration of a perimeter office zone, decreased mainly due to the cycling of the rooftop ventilation units. In the baseline simulation, the CO_2 concentration reached its maximum (720 ppm) at 15:00. With the DR strategies, the maximum reached 850 ppm at 19:00 but remained under the limit set by the ASHRAE 62.1 Standard for the building's office spaces: 990 ppm (ANSI/ASHRAE, 2013).

Table 6: Rooftop unit cycling optimized DR strategy

Time		*AC1*	*AC2*
	Fresh air availability [%]	Unit availability [ON/OFF]	Unit availability [ON/OFF]
0:00-3:00	0	OFF	
3:00-4:00		ON	OFF
4:00-5:00		OFF	ON
5:00-6:00		ON	OFF
6:00-6:30		OFF	ON
6:30-7:00		ON	OFF
7:00-7:30		OFF	ON
7:30-8:00		ON	OFF
8:00-8:30		OFF	ON
8:30-9:00		ON	OFF
9:00-16:00	max OA	ON	
16:00-16:30		OFF	ON
16:30-17:00		ON	OFF
17:00-17:30		OFF	ON
17:30-18:00		ON	OFF
18:00-18:30		OFF	ON
18:30-19:00		ON	OFF
19:00-19:30		OFF	ON
19:30-20:00		ON	OFF
20:00-0:00	0	OFF	

Effect of Optimized DR Strategies on Power Demand

Figure 9 shows the impact of the DR strategies on the building's power demand. A significant decrease of the power demand is noticeable during both peak periods.

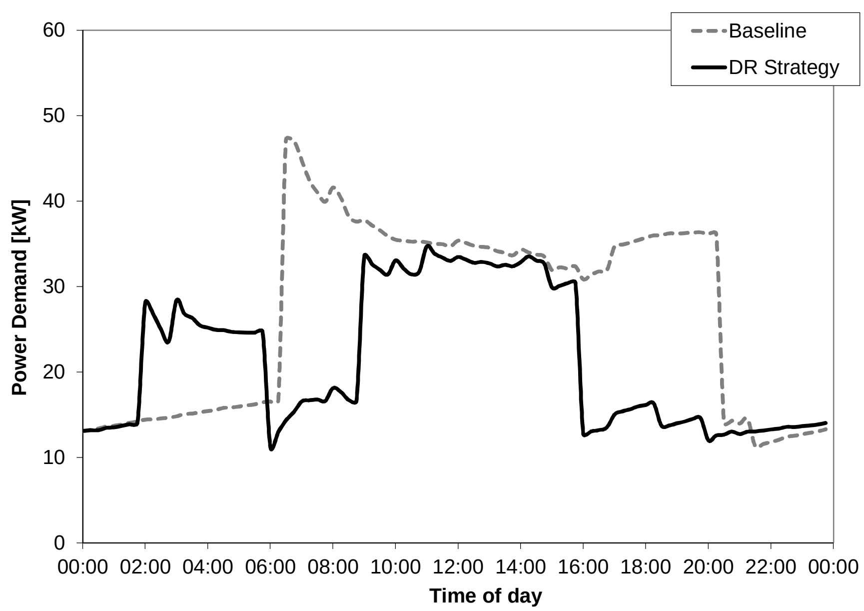


Figure 9: DR strategies impact on the building's power demand

In order to better characterize this impact, the power demand indicators previously discussed were calculated. The results are presented in Table 7. It should be noted that the optimized DR strategies decreased the building's mean peak demand during the morning peak period by 55% ($\bar{q}_{AM}$) and the building's maximum peak demand during that same period by 29% ($q_{AM}^{\max}$). In the afternoon, those values were 59% ($\bar{q}_{PM}$) and 55% ($q_{PM}^{\max}$) respectively. The DR strategies prevented the rebound effect after both peak periods (-8% for $rebound_{AM}$ and -63% for $rebound_{PM}$).

Table 7: Optimized DR strategies evaluation (indicators)

		Baseline [W]	**DR Strategies** [W]	**Impact** [%]
building absolute peak (24h)		47213	34681	-27
AM	$q_{AM}^{\max}$	47213	33548	-29
	$\bar{q}_{AM}$	37769	17139	-55
	$rebound_{AM}$	37771	34681	-8
PM	$q_{PM}^{\max}$	36328	16308	-55
	$\bar{q}_{PM}$	34760	14315	-59
	$rebound_{PM}$	36146	13251	-63
building energy consumption		646 kWh	514 kWh	-20

The impact of applying these optimized DR strategies, using operational conditions as defined in the retained solution, also had an impact on the building's absolute peak (-27 %). If the building's annual absolute peak coincides with the grid peak days on which these DR strategies are to be applied, this will reduce the building's *billing peak* for the whole year, resulting in savings on its yearly electricity bill. In terms of energy savings, the DR strategies had a positive impact on this particular day (- 20%), but this will not result in a significant reduction of the monthly energy consumption since these DR strategies are to be applied only on the grid's peak days.

6 Conclusion

This paper presented how optimized demand response strategies can be determined using a calibrated building simulation model.

A building model of a small commercial building was created using the SIMEB software, which was used to produce an EnergyPlus input file. This EnergyPlus simulation model was then calibrated on an annual basis using the GenOpt® optimization package. The calibrated model fell within the criteria of ASHRAE Guideline 14 (ASHRAE, 2002).

A set of DR strategies addressing only the HVAC systems controls were identified for this building; they included rooftop unit cycling, fresh air intake limiting and global temperature adjustments. Using Je+, those DR strategies were optimized on the calibrated building model. The optimization facilitated the search for a combination of operational parameters for those DR strategies that resulted in reducing the building's power demand and maintaining acceptable air quality (within ASHRAE Standard 62.1) and comfort levels. The optimized strategies induced an average power reduction of 55% in the morning and 59% in the afternoon.

The next step will be to implement these measures in the building control program to identify implementation challenges, validate power demand reductions and verify the impact on the comfort level on cold occupied days.

7 References

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