Buildings Stock Load Control

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Abstract: Researchers and practitioners have proposed a variety of solutions to reduce electricity consumption and curtail peak demand. This research focuses on electricity demand control by applying some strategies in existing building to reduce it during the extreme climate period.

The first part of this paper presents the objectives of the study:

- to restrict the startup polluting manufacturing units (power station),
- to limit the environmental impacts (greenhouse emission),
- to reduce the transport and distribution electricity infrastructures

The second part presents the approach used to rise the objectives :

- To aggregat the individual loads and to analyze the impact of different strategies from load shedding to reduce peak power demand by:
- Developing models of tertiary buildings stocks (Schools, offices, Shops, hotels);
- Making simulations for different load shedding strategies to calculate potential peak power saving.

The third part is dedicated to the description of the developed models: An assembly of the various blocks of the library of simbad and simulink permit to model building.

Finally the last part prensents the study results: Graphs and tables to see the load shedding strategies impacts.

1. INTRODUCTION

High peak demand and lack of supply growth create electricity shortages and resulted in high cost and economic inefficiency. In France, building sector occupies 61% of electricity consumption.

A variety of solutions have been proposed to reduce the overall electricity consumption and curtail peak demand but in local form: building by building. Few developments are carried out for multi sites management. Multi sites management is essential in crisis and/or peak periods (large energy demand in particular during rigorous winter and canicular summer).

Electric load aggregation is considered an effective means of maximizing savings and mitigating risks in today's emerging power markets. Load aggregation is the process by which individual energy users band together in an alliance to secure more competitive prices than they might otherwise receive working independently. Aggregation can be accomplished through a simple pooling arrangement or through the formation of clusters where individual contracts are negotiated between the suppliers and each member of the aggregate group. The candidate buildings do being on the same utility bill with demand charge applied is enough.

Our research focuses on the load control by applying some strategies . The optimization problem in this research is multi-objective in the sense that we aim to reduce building electricity demand while maintaining an acceptable service level – a reasonably comfortable indoor environment.

2. OBJECTIVES

Many approaches have been developed to assist the building designer in arriving at more energy-efficient solutions. The outputs of these models are the energy loads and consumptions of building. In this study, we propose a simplified models. The simulations allow during the most severe periods:

- To estimate consumption of electric heated/air-conditionned buildings stocks;
- To estimate the power demands;
- To analyze the load shedding strategies allowing electricity demand reduction.

The final objective of our research would be to restrict the startup polluting manufacturing units (power station), to limit the environmental impacts (greenhouse emission), as well as to reduce the transport and distribution electricity infrastructures dimensioned to support the peak demand. This study is the first step to rise this objective by load shedding in tertiary buildings (schools, offices, shops and hotels).

3. APPROACH

The study consists in analyzing the impact of different strategies from load shedding to reduce peak power demand by aggregating the individual loads. This study is applicated on a stock of tertiary buildings located in region PACA in south of France, more precisely the Alpes-Maritimes department during the periods when the weather conditions are most severe (the coldest week in winter and hottest in summer).

The means implemented to meet these aims consists:

- To develop models of tertiary buildings stocks (Schools, offices, Shops, hotels).
- To make simulation for different load shedding strategies.
- To calculate potential peak power saving:
  - By use: load shedding strategies on heating, air-conditioning and lighting.
  - By building type: load shedding strategies on different building types (buildings of the tertiary sector: schools, offices, trade, hotels).
  - By performance: load shedding strategies on different energy performances defined as a preliminary by building classes (good, bad).

SIMBAD (SIMulator of Building And Devices) is selected as simulation tool. The flexibility of this tool concerning the implementation (easily multiplication of the buildings) justifies this choice. SIMBAD is HVAC toolbox developed under the MATLAB/SIMULINK environment. This toolbox provides a large number of ready to use HVAC models and related utilities. The toolbox is made up of 12 groups of models and utilities and 1 group of pre-defined examples of installations with various HVAC heating or cooling systems.

An assembly of the various blocks of the library of simbad and simulink permit to model building with all its equipments, and to define the inputs and the outputs (Fig.1)
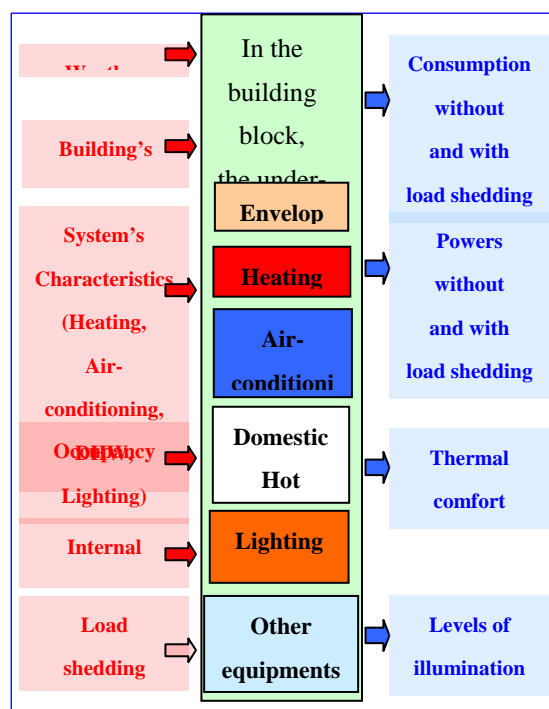
Fig.1: Structure of building model

4. DESCRIPTION OF MODELS

The simplified approaches are commonly employed. Firstly, the use of these approaches is justified by the compromise between the accuracy of results and the consuming time and hardware requirements for numerical simulations. Secondly, based on a lower number of input parameters as possible, the simplified models are versatile. There are 4 types of buildings implemented: schools, offices, shops, hotels.

For each homogenious stock, the number of buildings is defined by the user after that the corresponding inputs must be seized. An assembly of the various blocks of the library of simbad and simulink permit to model building with all its equipments, and to define the inputs and the outputs.

Fig,2 shows the interface of the prototype of the tool. There are 4 types of buildings: schools, offices, shops, hotels. For each homogenious stock, for example for teaching stock, the number of buildings is defined by the user after that the corresponding inputs must be seized.

Fig. **3** shows that each building model include the elements of envelop, heating, air-conditioning, lighting, domestic hot water equipment, ventilation, regulation and occupation profiles.

Fig,2: Tool interface

Fig. 3: Modeling of building

5. HYPOTESIS

ICEBO2006, Shenzhen, China   Building Commissioning for Energy Efficiency and Comfort, Vol.VI-9-4

Simulations are done for two categories of

Schools	1 855 970	5%	92 798	8%	148 478
Offices	4 894 675	30%	1 468 402	30%	1 468 402
Shops	2 580 876	31%	800 072	35%	903 307
hotels	2 558 502	26%	665 211	30%	767 551

performances (good envelop and lighting, bad envelop and lighting. The values used are taken for the "RT2005" [1], french thermal rules, sectoral guides ADEME-AICVF [2] and "DPE method" [3].The worst practice is defined by assimilating the building to an old building without insulation and with single glazing.

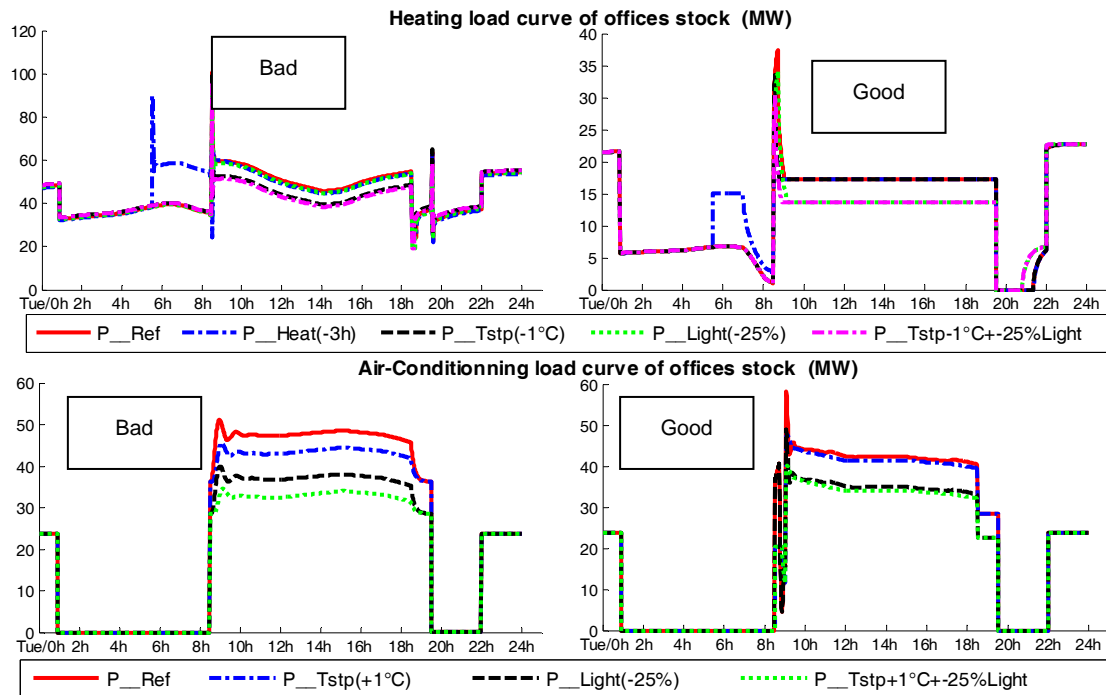|					
hotels	2 558 502	26%	665 211	30%	767 551

The **Error! Not a valid bookmark self-reference.** presents the Instructions for the comprehension of the graphs. On the graphs which follow, the x-axis represents time in hours for one day (the coldest day) and the axis of ordered represents the power called in MW in 5 different cases.

Tab.1: Worst practice

Walls	Windows	Ground floor	Upper ceiling
20 cm stone	Single glazing : g = 0.85 x 85%	20 cm concrete	1 cm wood
U = 3.5 W/(m²·K)	U = 5 W/(m2.K)	U = 2.9 W/(m²·K)	U = 3.64 W/(m²·K)

The best practice is derived similar to a "passive standard house". The building elements composition associated to the best practice are exposed in the next table.

Tab. 2: Best practice

Walls	Windows	Ground floor	Upper ceiling
1 cm wood, 15 cm insulation 20 cm concrete, 1 cm gypsum	Low e argon filled double glazing g=0.7 x 85%	15 cm insulation 20 cm concrete	20 cm concrete 1cm wood
U = 0.23 W/(m²·K)	U = 1.3 W/(m²·K)	U = 0.25 W/(m²·K)	U = 0.2 W/(m²·K)

6. SOME RESULTS

The stock considered is the Alpes-Maritimes French department. The Tab.3 prensents Surface area of the simulated stock buildings.

Results exemple : Stock offices

Tab.3: Electrical surface area of the simulated stock

Buildings	Total area (m²)	% Electrical heated area	Electrical heated area (m²)	% Air-conditioned area	Air-conditioned area (m²)
Schools	1 855 970	5%	92 798	8%	148 478
Offices	4 894 675	30%	1 468 402	30%	1 468 402
Shops	2 580 876	31%	800 072	35%	903 307

Tab. 4: Graphs legend

	Winter period	
1	————	P_Ref :Total reference power called in MW
2	▬ · ▬	P_Heat(-3h):Total power called in MW by applying a heating revival 3 hours before the occupation
3	▬ ▬ ▬	P_Tstp(-1°C):Total power called in MW by decreasing the set point temperature of heating of 1°C
4	········	P_Light(-25%):Total power called in MW by decreasing the lighting power of 25% when the minimal limit of visual comfort for each type of building is assured
5	▬ · ▬	P_Tstp-1°C + 25% Light : 4 + 5
	Summer period	
6	————	P_Ref: Idem Sc 1
7	▬ · ▬	P_Tstp(+1°C):Total power called in MW by increasing the set point temperature of air-conditionning of 1°C
8	▬ ▬ ▬	P_Light(-25%):Idem Sc 4
9	········	P_Tstp-1°C + 25% Light:7+ 8

For each building type, the summury of results are expressed in a table to express power demand: The maximum power called for each tariff time slot is expressed in this table.To measure the impact of each strategie on the power demand, a gain is calculated with the following formula:

$$Gain(scenario_i) = \frac{(Power_{reference} - Power_{scenario_i})}{Power_{reference}}$$

Heating load curve of offices stock (MW)

Air-Conditionning load curve of offices stock (MW)

Fig. 4: Offices stock load curve

On the graph (Fig. 4), for heating and for offices with bad thermic performances, the first peak of power demand is more reduced by application heating revival 3 hours before the occupation, then power decreased of the of lighting followed by the decrease of the heating set point temperature by 1°C. For offices with good performances, the needs of heating are only for the first hour of occupation and that then the internal gains are sufficient to maintain the heating set point temperature.

For air-conditionning period, the 25% lighting power reduction attenuates more the power demand. For the buildings with good performances, the heat stored during the day is not evacuated during night cooling because the envelop insulation is very good. For the buildings with bad performances, heat is evacuated by night cooling. So at the revival time, power demand for buildings with good performances is more important than power demand for buildings with bad performances.

Tab. 5: maximal power demand of offices stock

Offices		Heating										Air-Conditionning									
		Good Performances					Bad Performances						Good Performances					Bad Performances				
		Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri		Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
	Power (MW)											**Power (MW)**										
Peak hours "8h to 10h" and "18h to 20h"	P_Ref	37,4	37,5	37,5	37,5	37,5	99,2	100,9	100,9	100,9	100,9	P_Ref	43,0	47,4	47,4	47,4	47,4	33,8	34,1	34,1	36,3	36,3
	P_Heat(-3h)	24,4	24,4	24,4	24,4	24,4	78,0	78,0	78,0	78,0	78,0	P_Tstp(+1°C)	38,2	43,0	43,0	43,0	43,0	31,7	31,7	31,7	32,9	32,9
	P_Tstp(-1°C)	33,8	33,8	33,8	33,8	33,8	98,5	100,3	100,3	100,3	100,3	P_Light(-25%)	37,8	42,1	42,1	42,1	42,1	27,4	27,4	27,4	29,0	29,0
	P_Light(-25%)	34,1	34,1	34,1	34,1	34,1	94,1	95,8	95,8	95,8	95,8	P_Tstp+1°C + -25% Light	32,9	37,7	37,7	37,7	37,7	24,7	24,7	24,7	25,7	25,7
	P_Tstp-1°C + -25% Light	31,0	31,0	31,0	31,0	31,0	93,4	95,2	95,2	95,2	95,2											
Day hours "6h to 8h", "10h to 18h" and "20h to 22h"	P_Ref	17,3	17,3	17,3	17,3	17,3	57,6	58,3	58,3	58,3	58,3	P_Ref	30,0	30,0	30,0	30,7	30,7	34,2	34,2	34,2	34,2	34,2
	P_Heat(-3h)	17,3	17,3	17,3	17,3	17,3	56,6	58,6	58,6	58,6	58,6	P_Tstp(+1°C)	29,4	29,4	29,4	30,2	30,2	32,1	32,1	32,1	32,1	32,1
	P_Tstp(-1°C)	17,3	17,3	17,3	17,3	17,3	50,4	51,4	51,4	51,4	51,4	P_Light(-25%)	25,2	25,2	25,2	25,8	25,8	27,7	27,7	27,7	27,8	27,8
	P_Light(-25%)	13,6	13,6	13,6	13,6	13,6	56,5	57,2	57,2	57,2	57,2	P_Tstp+1°C + -25% Light	24,6	24,6	24,6	25,4	25,4	25,2	25,2	25,2	25,2	25,2
	P_Tstp-1°C + -25% Light	13,6	13,6	13,6	13,6	13,6	49,3	50,3	50,3	50,3	50,3											
Off_peak hours "22h to 6h"	P_Ref	21,5	22,8	22,8	22,8	22,8	47,6	54,2	54,5	54,5	54,5	P_Ref	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9
	P_Heat(-3h)	21,5	22,8	22,8	22,8	22,8	89,5	89,5	89,5	89,5	89,5	P_Tstp(+1°C)	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9
	P_Tstp(-1°C)	21,5	22,8	22,8	22,8	22,8	48,5	55,3	55,5	55,5	55,5	P_Light(-25%)	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9
	P_Tstp-1°C + -25% Light	21,5	22,8	22,8	22,8	22,8	47,6	54,3	54,5	54,5	54,5	P_Tstp+1°C + -25% Light	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9
	P_Tstp-1°C + -25% Light	21,5	22,8	22,8	22,8	22,8	48,5	55,3	55,5	55,5	55,5											
	Gain											**Gain**										
	Heat(-3h)	35%	35%	35%	35%	35%	10%	11%	11%	11%	11%											
	Tstp(-1°C)	10%	10%	10%	10%	10%	1%	1%	1%	1%	1%	Tstp +1°C	11%	9%	9%	9%	9%	6%	6%	6%	9%	9%
	Light(-25%)	9%	9%	9%	9%	9%	5%	5%	5%	5%	5%	Light(-25%)	12%	11%	11%	11%	11%	19%	19%	19%	20%	20%
	Tstp-1°C + -25% Light	17%	17%	17%	17%	17%	6%	6%	6%	6%	6%	Tstp+1°C + -25% Light	24%	21%	21%	21%	21%	26%	26%	26%	29%	29%

For the heating period, the heating revival 3 hours before the occupation gives the most important gain for both levels of performance of building. If we consider only the peak hours tariff, the heating revival 3 hours before the occupation gives for buildings with bad performances a gain of 23% (100*[100.9-78]/100.9). This gain does not appear on the table because the power demand of the strategie "heating revival 3 hours before the occupation" is more important on off_peak hours than on peak hours.

7. CONCLUSION

This paper deals with the reducing peak power demand by analyzing the impact of different strategies from load shedding.The results of simulations are resumed on the following tables.

Tab.6: Legend

P_Heat(-3h) /C_Heat(-3h)	Total power called/consumption by applying a heating revival 3 hours before the occupation
P_Light(-25%) /C_Light(-25%)	Total power called/consumption by decreasing the lighting power of 25% when the minimal limit of visual comfort for each type of building is assured
P_Tstp(-1°C) /C_Tstp(-1°C)	Total power called/consumption the set point temperature of heating of 1°C
P_Tstp(+1°C) /C_Tstp(+1°C)	Total power called/consumption by increasing the set point temperature of air-conditionning of 1°C
+	Best practice
-	Worst practice

Tab.7: Maximal gains in coldest week

gain (%) Coldest week										buildings	
	+	-	+	-	+	-	+	-	+	-
P_Heat(-3h)	23%	-3%	35%	11%	22%	14%			17%	10%
C_Heat(-3h)	-4%	-5%	-4%	-5%	-4%	-6%			-3%	-4%
P_Tstp(-1°C)	5%	2%	10%	1%	6%	1%	4%	5%	8%	5%
C_Tstp(-1°C)	8%	6%	2%	7%	1%	6%	8%	10%	3%	7%
P_Light(-25%)	3%	3%	9%	5%	12%	6%	3%	3%	9%	4%
C_Light(-25%)	3%	1%	14%	2%	15%	2%	7%	2%	12%	2%

Maximal	Schools	Offices	Shops	Hotels	All

According to the Tab.7, we deduce for the power demand in winter what follows:

- In the 3 sectors schools, offices and shops:
  - Major Gain more than 20% without deterioration of comfort (+3h of heating revival) but with overconsumptions less than 4% for the buildings with a better thermal performance (envelop) and with a good lighting.
  - Gain between 1 and 10% by reducing heating set point temperature (-1°C).

- In the Hotels: Gain about 4% by reducing set point temperature (-1°C) and 3% by reducing the lighting power.
- In general: The heating revival 3h before occupation gives a considerable gain for the buildings with a better thermal performances (envelop) and with a good lighting.

Tab. 8: Maximal gains in warmest week

Maximal gain (%)	Schools		Offices		Shops		Hotels		All buildings	
Warmest week	+	-	+	-	+	-	+	-	+	-
P_Tstp(+1°C)	11%	18%	11%	9%	8%	8%	2%	4%	5%	9%
C_Tstp(+1°C)	7%	13%	2%	7%	1%	6%	5%	8%	2%	6%
P_Light(-25%)			6%	17%	12%	20%	11%	21%	10%	16%	13%	21%
C_Light(-25%)			11%	18%	15%	20%	16%	20%	18%	23%	16%	20%

According to the Tab. 8, we deduce:

- In the 3 sectors schools, offices and shops:
  o Gains between 6% and 21 % by reducing in the lighting power, buildings with bad performances having the greatest gains because lighting part is important because the lighting equipment is less powerful than in the case of the buildings with good performances.
  o Profit between 2% and 18 % by increase the air-conditioning set point temperature (+1°C).
- In the Hotels: Gain between 10% and 16% by reducing in the lighting power.

8.   FUTURE   WORK :   SITE EXPERIMENTATION IN PACA REGION

- To find a source adequate station representative of the stock selected.
- To modelise/caracterise tertiary buildings supplied by using SIMBAD.
- To find/validate gains obtained on the theoretical cases.
- To seek the means/products/softwares and/or hardware systems to put in the buildings to carry out the shedding strategies.

- To test then by measuring the powers and consumptions and to correct according to the results obtained.

REFERENCES

[1] : RT 2005, French termal rules, CSTB, Juin 2006.

[2] : Sectorial guides for offices, schools, shops and hotels, ADEME-AICVF, 1993.

[3] : Millet R., " Hourly method to calculate heating and cooling demand for EP regulations", CEN TC89 WG4, CSTB, July 2004.