Energy Saving Through Smart Home

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***Abstract*-Energy saving is considered as one of the most important issue affects the consumers, power system quality and the global environment. The high energy demanded by home appliances, air conditioning and lighting makes homes to be considered as one of the most critical area for the impact of energy consumption. Smart home technology is a good choice for people not only care about security, comfort but energy saving as well. In this paper, a smart home energy management technique based on a set of sensors is presented. It minimizes the domestic energy waste and can be adapted according to the user habits. A proposed scenario is reported of daily routine and performed by 16 steps. Three assumptions of varying the time spent in each step according to different behavior are examined. The effectiveness of the proposed set is shown based on a static correlation between the power consumption and saving.**

***Keywords*- Energy saving, smart home, occupancy sensor.**

I. INTRODUCTION

Smart home technology started for more than a decade to introduce the concept of device and equipment networking in house. Smart home contains internal network and intelligent control on different home's services. The internal network can be built via wire or wireless communication technique between sensors and actuators .The intelligent control means the entire house is managed or monitored by internet services [1]. Smart home is the integration of technology and services through home networking for a better quality of living. Integrating the home services as shown in figure 1 [2] allows them to communicate with one another through the home controller, thereby enabling single button to control the various home systems according to preprogrammed scenarios or operating modes [3].

Smart homes have the potential to improve home comfort, convenience, security and energy management. Moreover it can be used for elder people and those with disabilities, providing safe and secure environments. A smart home is a good choice for people caring about security, health, energy saving and convenience. The benefits of smart technology at home could be apparent to everyone if this potential is fulfilled. This is when the system will be able to protect habitant's privacy and having low cost. [4]

On the other hand, smart home is somewhere difficult to be implemented due to its high initial cost. Another disadvantage is that elder are more reluctant to try new things or change their way of thinking about the risk of losing privacy due to their feeling of being monitored all the time [5].

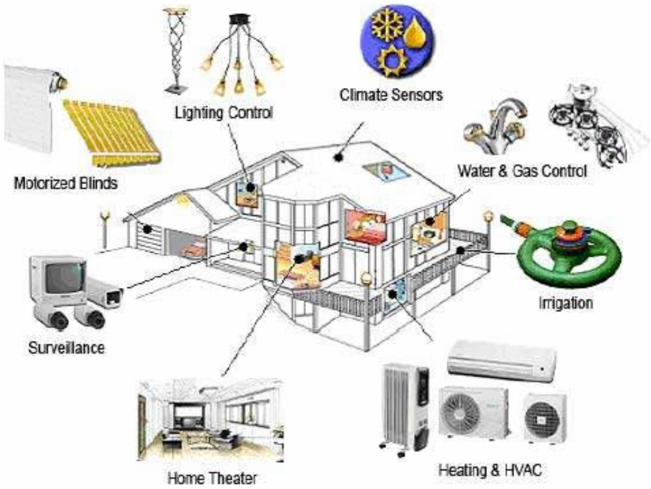

Figure (1): .Smart home Integration services

In this paper a home energy management technique based on a set of sensors is presented that can be adapted according to habitant's behavior. Section I is a brief definition of smart home and its benefits. Section II describes how smart home can reduce the energy consumption via managing intelligently the devices by controlling the lighting, air conditioning (HVAC) and other home appliances. In section III, a case study is reported. Section IV shows the proposed scenario. Section V explains the calculations and the numerical results to provide examples of possible advantages achievable with the proposed system in term of energy consumption.

II. ENERGY MANAGEMENT

One of the major benefits of smart home to consumers is their ability to incorporate energy management features through lighting, air conditioning and home appliances.

A. LIGHTING

The lights in a smart home can be turned on and off automatically based on occupancy sensor. As example , when a person enters a room in the day time, the system will open the drapes instead of turning on the lights, but at night it would make sure the lights came on and they turned off when no one is in the room hence waste of energy can be preserved.

B. AIR CONDITIONING

An appropriate placement of temperature sensors and the use of heating and cooling timers can reduce the energy used and hence saving money and also the house can set to turn off air conditionings when no one is in the room.

C. HOME APPLIANCES

Smart homes can even go further in energy management by keeping track of the energy usage of each and every appliance in the house. The smart house controllers could schedule the operation of heavy power consuming appliances (such as dishwashers and electric water heaters) to take maximum advantage of off peak electric rates. [6]

III. CASE STUDY

Figure 2 shows the apartment which consists of 6 rooms. Their dimensions are listed in table 1.

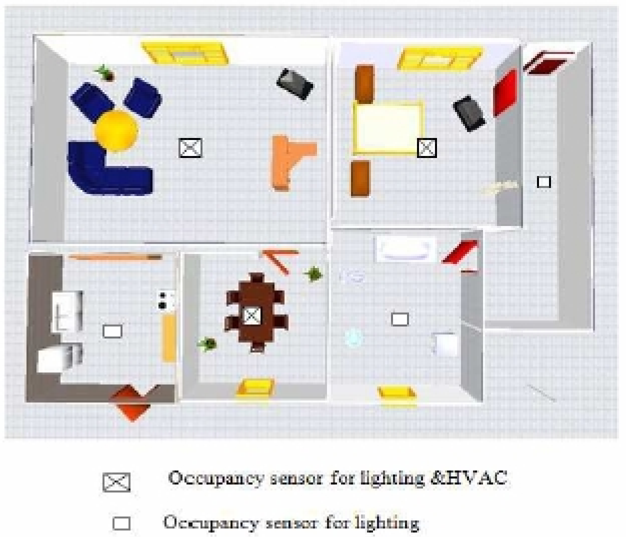

Figure (2): Layout of apartment indicating the distribution of sensors used (Sweet Home 3D software)

total	Kitchen	Dining Room	Bathroom	Room	Bedroom	Entrance hall	Rooms
129	16	16	16	48	25	s	Area/m:

Table 1 simulated home area

The sensors are distributed into home in order to provide accurate information about the occupant's location and activities. Occupancy sensors are used instead of motion sensors because last ones are preferred for security rather than for building and lighting control. They respond only to moving objects, so if an individual in a room working at a desk, motion sensors will often cease to see him [7]. Figure 3 describes examples of the two types of occupancy sensors distributed into the model .The first one is a passive infrared (PIR) sensor that automatically control lights by detecting the heat from occupants moving within an area (900 square feet) to determine when the space is occupied with a low cost [8]. The other, is used to adjust the temperature and lighting level accordingly for better energy management with a high cost [9] .Table 2 illustrates the number of sensor used per room and their distribution through the apartement is shown in figure 2.

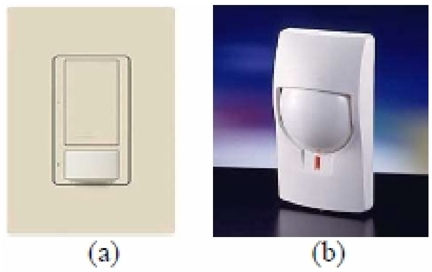

Figure (3) (a): Occupancy sensor for lighting (b): Occupancy sensor for lighting and HVAC

Total	Kitchen	Dining room	Bath-room	Living room	Bed-room	Hall	Target	Sensor type
3	1	0	1	5	0	1	Light Control	
3	0	1	0	1	1	0	Light +HVAC	

Table 2 list of sensor per room

IV. PROPOSED SCINERIO

Scenario management allows users to define a set of behavior rules. A lot of sequences can be implemented according to the habitant's age and its social status. A scenario for an elderly house holder who has a high risk of falling down is proposed in [11]. Furthermore, a scenario for an individual gets back at evening and leaving in the morning is suggested in [12]. In this paper a scenario for a man and his wife getting back home and leaving in morning is presented.

Wrong Behaviors	Action	Husband	Wife	Time	
	Hall is On		Back home	At 14 o'clock	1
Hall is left on for 30 minutes	Bedroom is On		Enters bedroom	14-14:30	2
	Hall is Off			At 14:30	
Bedroom is left on for 30 minute s	Bathroom is On Bedroom still On		Enters bathroom	14:30-15	
	Bathroom bedroom Off			At 15 o'clock	
Living room is left on for 2 hours	Kitchen is On Living room is On		Enters kitchen	15-17	4
	Hall is On	Husband back home		At 17 o'clock	
	Living is On Bedroom is On	He enters bedroom	waiting her husband in living	17-17:30	6
	Hall is Off			At 17:30	
Bedroom is left on for 30 minuets	Bathroom is On Bedroom still On Living is On	He enters bathroom	still waiting her husband in living	17:30-18	7
	Bathroom. Bedroom Off			At 18 o'clock	
Dining room is left on for 30 minutes	Kitchen is On Dining is On Living is On	He is waiting her into living	Enters kitchen to prepare launch	18-18:30	8
	Dining is On	They enter the dining room for launch		18:30-19	9
Dining room is left on for 1 hour	Kitchen is On Dining room still On Living room is On	waiting her into living room	Enters the kitchen	19-20	10
	Kitchen Dining room Living room are Off			At 20 o'clock	
	Bedroom is On	They enter bedroom		20-21	11

	Living is On	They enter living room		21-23	12
Dining Room is left on for 1 hour	Kitchen is On Dining is On Living room is On	waiting in dining room	Enters the kitchen to prepare dinner	23-24	13
	Kitchen is Off Dining room is on	Enter the dining room for dinner		24-24:30	14
Dining Room is left on for 30 minutes	Kitchen is On Dining still On	Back to living room	Enters the kitchen	24:30-1	15
	Dining room Kitchen Living are Off			At 1 o'clock	
	Bedroom is On	Back to bedroom to sleep		1-2	16
	All rooms are Off			At 2 o'clock	

Table 3.Proposed scenario

Actually, the human habit cannot be controlled because it changes according to our life so the change of power consumption is related to the change of numbers of hours spent in each room and thus saving in KWH. The previous scenario listed in table 3 is adjusted three times and table 4 represents the number of hours spent in each room to realize each step of the 16 steps shown before during different habits assumptions.

Hour/step 3rd assumption	Hour/step 2nd assumption	Hour/step 1st assumption	Scenario Steps
1	1	1	1
0.5	0.5	0.5	2
0.5	0.5	0.5	3
2	0.5	l	4
0.5	0.5	0.5	s
0.5	0.5	0.5	6
0.5	0.5	0.5	7
0.5	0.5	0.5	8
0.5	0.5	0.5	9
1	1	1.5	10
1	1	1	11
2	2	3	12
1	0.5	0	13
0.5	0.5	0	14
0.5	1.5	0	15
1	0.5	0	16

Table 4 Time spent in each step

V. NUMERICAL RESULTS AND DISCUSSION

The whole apartment is simulated using **Sweet Home 3D** software according to the dimensions shown in table 1. Each room is simulated using DIALux software to calculate the power required for lighting. The air condition capacity was calculated according to the Canadian standards.[12] The home appliances capacity was calculated according to the U.S. Department of Energy's Office for Energy Efficiency and Renewable Energy (EERE).[13]. Figure 4 shows the living room as an example showing the number of lamps and total power required for lighting. Table 5 shows the power consumption of each room for lighting, air conditioning and home appliances in KWH/Day.

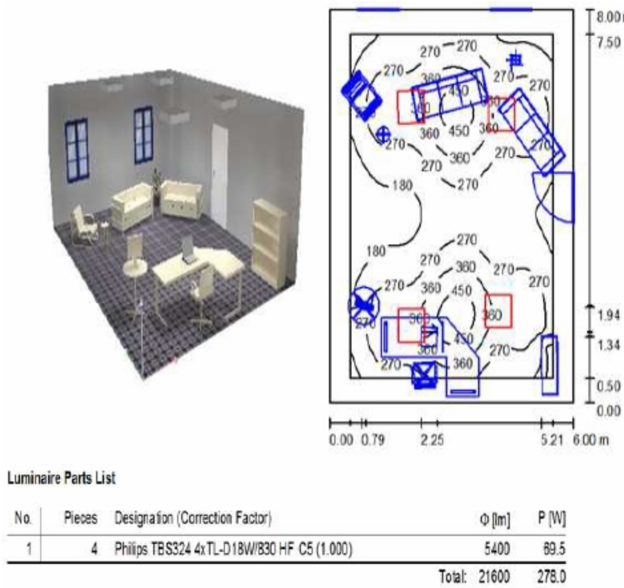

Figure (4): Living room lighting luxes

Total	Kitchen	Dining Room	Bathroom	Living Room	Bedroom	Hall	
129	16	16	16	48	25	8	Area/m^2
0.896	0.133	0.088	0.133	0.278	0.176	0.088	Light KWH/day
7.94	0	2.11	0	3.56	2.27	0	HVAC KHB/day
1200.2	1.200	0	0	0.16	0.11	0	Home Appliances KWH/day

Table 5 power consumption per room

Table 6 is a comparison between the previous assumptions listed in table 4 showing in each, the power consumption, percentage saving in power and consequently in electricity bill.

The results shown in figure 5 confirm that the proposed energy management smart home can be adapted each time the occupant's habit change and thus the saving target.

3rd assumption	2nd assumption	1st assumption	
1549.08	1858.23	935.31	Total KWH/month
619.2	379.47	224.13	Total saving KWH/month
38.58 %	20.42 %	23.96 %	% saving/month
48.82 %	27.44 %	61.36 %	Saving in LE %

Table 6 Comparison between the different assumptions

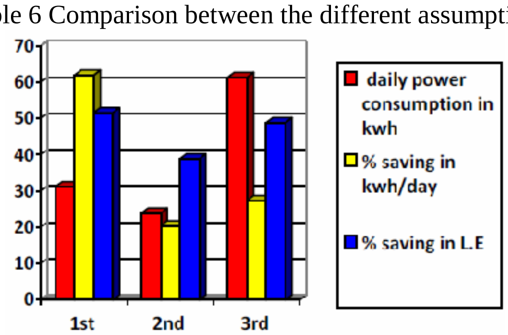

Figure (5): The daily consumption, percentage saving in power and in electric bill for the previous trials.

One of the case study objectives is to evaluate the relation between the power consumption and the saving. Thus Correlation statistical method is suggested for calculation. [14] A correlation coefficient is a single number that describes the degree of relationship between two variables that ranges from -1 to +1, indicating perfect negative correlation at -1, absence of correlation at zero, and perfect positive correlation at +1. Table 7 indicates the relation calculated between two random variables (X, Y) according to the correlation coefficient (r) ant its meaning. [15]

Relationship Between X and Y		
r = +1.0	Strong - Positive	As X goes up. Y always also goes up
r = + 0.5	Weak - Positive	As X goes up: Y tends to usually also go up
r = 0	-No Correlation -	X and Y are not correlated
r = -0.5	Weak - Negative	As X goes up: Y tends to usually go down
r = -1.0	Strong - Negative	As X goes up. Y always goes down

Table 7 Correlation coefficient meaning

Figure 6 shows that the relation between the power consumption (A) and the saving in KWH (B) is weak positive relation (r=0.55). This means that the great increase in power consumption should not be accompanied by a great increase in power saving because the system could be adapted according to occupant's behavior.

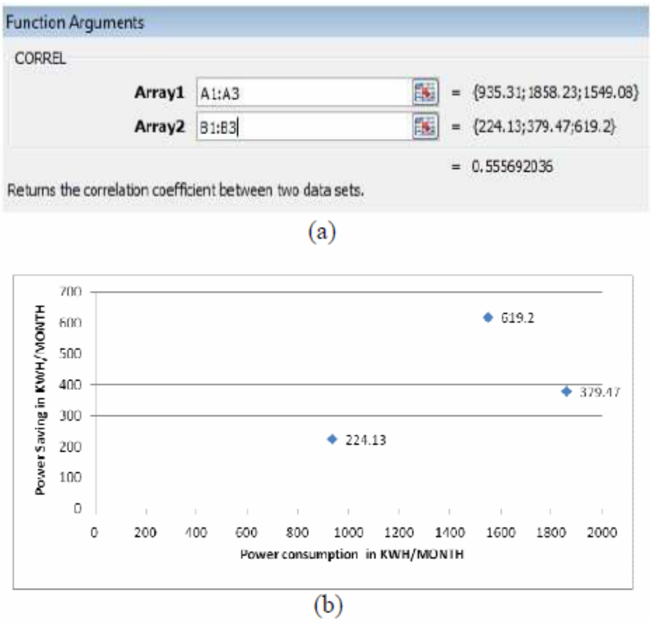

Figure (6): (a): Correlation Coefficient
(b): Correlation between monthly power consumption and saving

Figure 7 shows that the relation between the power saving(C) and the saving in cost (D) is strong positive relation (r = 0.99). This means that the increase in power saving is accompanied by a great increase in cost saving as shown in table 6.

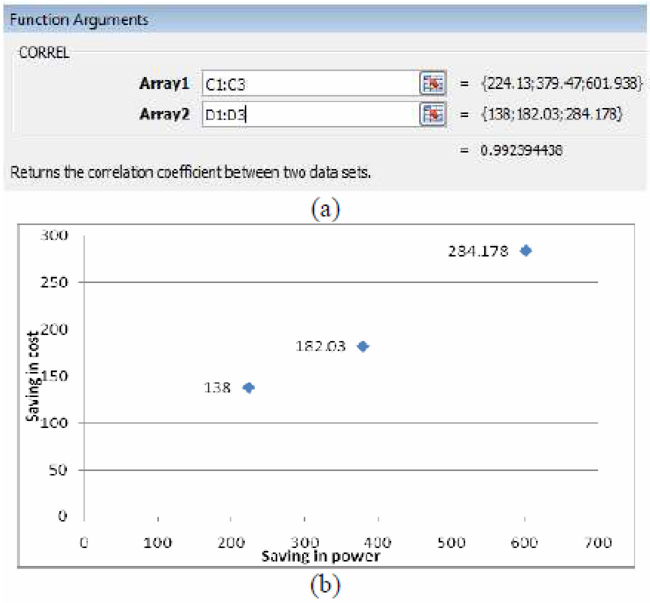

Fig (7): (a): Correlation Coefficient
(b): Correlation between saving in power consumption and cost

The correlation coefficient between (A &B) and (C&D) are calculated using Excel software and then illustrated in figure 6 and 7.

Table8 represents the daily power consumption and the saving in power daily and monthly showing also the saving in electricity bill for the 3rd assumption.

	Total KWH/Day	Total KWH/Month	Total KWH/Year	Budget in L.E.
Electric Power Consumption	51.636	1549.08	18588.96	515.08
Electric Power Saving	20.064	619.2	7430.4	284.178
Percentage Saving	38.85%	39.95%	39.97%	44.82%

Table 8 .Third assumption calculations

Table 8 records that only one family could save about 620 KWH /month. Taking into consideration that Egypt consist of about 17 million family according to the statistics of 2006,thus a total energy saving could be about 3000 MW which is equivalent to 3 power stations each is formed of 3 units and each unit capacity would be 300 MW.

On the individual level, this family saves about 230 L.E/month which is equivalent to 2770.824 L.E/year. The sensors cost about 570$ and communication network about 1000$ thus a total cost would be 1570$ which is equivalent to about 8949 L.E. Thus this initial cost would be covered in 3years. For sure, these values depend on occupant's habit as shown through the different assumption.

VI. CONCLUSION

In this paper a home energy management is presented based on a set of sensors to minimize the domestic energy waste according to human habits. A proposed scenario is suggested for daily routine to maximize the occupant's energy saving. The home power consumption is calculated and the rooms lighting are simulated using DIALUX software. The results are satisfactory and indicate that smart home based on a set of sensors could perform energy management which is not only an individual need but economical target. The relation between the power consumption and saving (power/cost) is illustrated using Excel. A strong relation between the saving in power and saving in cost is obtained.

VII. REFREANCES

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