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Ethernet TCP/IP based building energy management system in a university campus in Saudi Arabia

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Abstract
This paper investigates the effectiveness of the Building Energy Management System (BMS) installed in the typical buildings in the main campus of King Abdulaziz University, Jeddah, in Saudi Arabia. As the domestic electricity and hence the oil consumption in Saudi Arabia is increasing at a very alarming rate compared to the other countries in the world, it is of paramount importance to resort to urgent measures in various industrial, commercial and residential sectors in the country to implement energy conservation measures. The major electrical load in the buildings in the University corresponds to air-handling units and lighting. If the Hajj period, during which millions of pilgrims visit Holy Makah, coincides with the summer, the electricity demand in the country further increases. Considering these issues, the university has taken initiatives to minimize energy consumption in the campuses through the various energy conservation measures. Towards this end, BMS is installed in a few of the typical classrooms and office buildings utilizing the existing campus Ethernet TCP/IP. The data analysis is performed over the period from April to September as it is the peak load period due to summer season. The effectiveness of the BMS in the minimization of the energy consumption in these buildings is established by comparing the results of data analysis with BMS against those before the installation of BMS over the peak period. The investigations reveal that appreciable saving in energy consumption can be achieved with the installation of BMS, the magnitude being dependent upon factors such as building characteristics, type of building, its utilization and period of use.

Keywords: Building; Energy management; University; Saudi Arabia; Energy conservation.

1. Introduction
The accelerated economic growth of Saudi Arabia during the last three decades is directly linked with its supremacy over other countries in the field of oil production. However, Saudi Arabia's place in the world oil market is threatened by the unrestrained domestic fuel consumption. The country currently consumes over one-quarter of its total oil production, which is nearly 4.0 million barrels a day, and the present per capita oil consumption is more than 40 barrels per person per year. Even though the country has increased its generation capacity by 50% during the last decade, it still finds it difficult to meet the

electricity demand in the summer season [1]. The major driving factors which are attributed to this situation are the population growth, hot climate and the low electricity tariff existing in the country. The electric energy consumption in the country is increasing at a very alarming rate of about 7% per year, and the majority of the oil used within the country is for electric power generation.

The current pattern of energy demand leads to wastage of valuable resources, excessive pollution and is vulnerable to economic and social crises. Thus the current scenario in the country necessitates an urgent need for a change in the pattern of electric energy consumption, through various demand side management methods [2, 3]. Efforts for effective utilization of the available resources through energy conservation measures would be the best immediate choice for getting faster results in the reduction of energy consumption. Such measures also provide a cushion for the installation of power generation plants, to keep pace with the increase in load demand and also for future energy diversification activities.

Recently, infrastructural developments are taking place in many of the large universities in Saudi Arabia at an accelerated pace in tune with the increase in the in-take of students and the development of more research facilities, leading to significant increase in the electricity consumption. King Abdulaziz University (KAU) has more than 1,70,000 students in its 12 campuses. The main campus itself has an area of 6,000,000 m^2. Significant energy intensity is required to construct, operate, and maintain the various buildings and research centers in the campus. Majority of total electrical energy in the campus is utilized for air-conditioning and then for lighting purposes. The electric energy consumption in the main campus increases rapidly during the summer period, and hence the university spends a considerable amount annually on electricity consumption, in spite of the low electricity price in Saudi Arabia compared to other major countries in the world. Hence the university gives utmost priority for the implementation of energy management policies to promote the energy conservation in the campus. As a part of these initiatives, the conventional buildings are being converted to intelligent ones by the provision of building energy management system (BMS), through the already existing campus Ethernet TCP/IP. This paper investigates the effectiveness of the installation of the BMS for the automatic monitoring and control of the energy consumption in the typical classroom and office buildings in the main campus of KAU, Jeddah.

The remaining part of the paper is organized as follows: Section 2 discusses the Ethernet based BMS installed in the buildings in the campus, followed by a brief description of the features of the typical buildings considered for investigations in Section 3. Section 4 gives the details of data analysis and the results, and finally conclusions in Section 5.

2. Ethernet based intelligent building management system

The automation of buildings has been accelerating over the past two decades so as to make the buildings more secure, to save energy and to maximize the comfort and safety of the occupants [4, 5]. As a part of the energy conservation activities in the main KAU campus, various buildings in the campus are getting converted to intelligent buildings by the installation of BMS, using the already existing campus-wide Ethernet TCP/IP. The BMS being installed in the building consists of sensors for monitoring the occupancy, duct temperature and air quality in the classrooms, office rooms and the corridors. The damper actuators of the air handling units are also a part of the BMS installed in these buildings. Even though the earlier building automation systems were built upon fieldbus-based systems, Ethernet has emerged as the standard system level network because of its universal acceptance. The increasing demand for user friendliness and the central storage of historical data are satisfied by linking the lighting and the air handling units within the buildings into Ethernet TCP/IP. Further, it is cost-effective to produce controllers and I/O modules that reside directly on Ethernet, providing the benefits of Ethernet connectivity without the need for gateways, terminal servers, or other miscellaneous hardware. As the Ethernet TCP/ IP capability is built into the controller device, it becomes easier to utilize the existing campus network for the main system backbone. This results in significant cost reduction, improved access to data and easier network management. The TCP/IP communications protocol allows the BMS manager to easily transfer their building data over a remote network and to send critical building alarms during abnormal and emergency situations such as short-circuit and fire, via e-mail and mobiles to those involved in the maintenance of the buildings. Ethernet TCP/IP also offers easy connection to the Internet, so that the BMS manager can retrieve real time data from anywhere in the system, make changes to temperature set points and occupancy schedules, and monitor equipment run times and energy consumption. It is possible to switch On or Off any AHU or light either individually or in groups upon the press of a single button from the server computer through the respective light/AHU direct digital controllers. All these operations can also be achieved from a PC or laptop computer from anywhere in the world once these are configured accordingly. The BMS web server converts information from the installation into HTML code to be used by the browser. It is transmitted via the HTTP Internet protocol and a TCP/IP connection to the browser, such as Microsoft Internet Explorer. As the web server supplies all actual information, access is no longer required to the operator workstations should the installation change.

Energy conservation in AHUs is done through appropriate setting of the respective thermostats based on the work schedule in a day. The motors in the AHUs are converted to variable frequency drives so as to enable speed adjustments as the thermostat setting is varied. Energy conservation in lighting is done through the On/Off control based on the occupancy in different rooms, the occupancy being monitored by the motion sensors. As shown in the schematic diagram of the BMS given in Figure 1, the thermostat adjustments of AHUs and the On-Off control of the lights in the building can be performed from the server computer through the respective light/AHU direct digital controllers (DDCs). This paper investigates the effectiveness of the installation of the Ethernet TCP/IP based BMS in the building No.29, No.40 and No.51 in the KAU main campus.

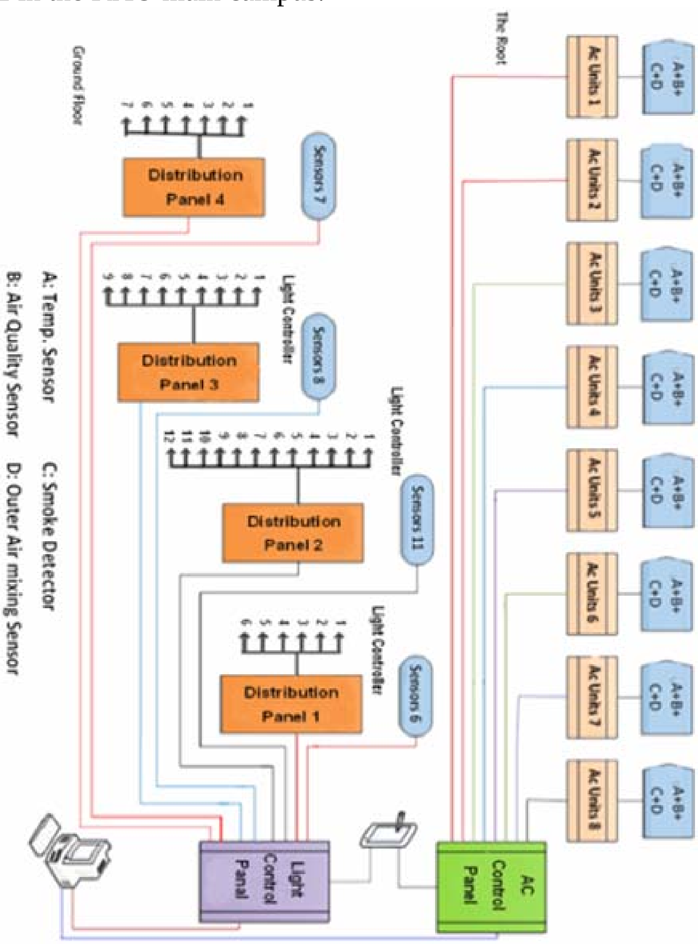

Figure 1. Schematic diagram of the BMS in a typical building

3. Building characteristics

Building No. 29 is one of the relatively new buildings having a total inside area of 4528 m^2. It consists of 11 classrooms each of 247 m^2 and has a height of 11m. Building No. 29 space is utilized as lecture halls by the university, and hence mainly occupied by the students during the class hours. Each of these classrooms is provided with a medium range occupancy sensor covering up to a range of 28 m length. Building No. 29 has sixteen AHUs each of 25 TR rating, each unit catering to the ac requirements of separate groups of four rooms. These AHUs are provided with damper actuators and the sensors for duct temperature and air quality. The compressor motors of all the eight AHUs have been changed over to variable frequency drives of power rating 5.5 kW so as to enable the adjustment of the motor speed as the thermostat setting of AHUs are varied and thus to improve the motor efficiency. The total connected

HVAC and lighting load of 1442 kW in the building is controlled through two separate Direct Digital Control panels. Building No. 40 is one of the relatively old two-storied buildings with a total area of 2480 m^2 and height 9 m. This building has 8 AHUs, with a total of 160 TR. It consists of 20 classrooms, each of which is provided with an occupancy-sensor. The total connected load of this building is 593 kW. Building No. 51, which is a relatively old two-storied building of 2425 m^2 area and height of 11 m., is utilized by the staff of the Security and Safety Department. It has 31 rooms and one conference hall, each provided with an occupancy sensor. It has eight AHUs each of 25 TR rating, each unit catering to the air conditioning requirements of separate groups of four rooms. The compressor motors of all the eight AHUs have been changed over to variable frequency drives of power rating 5.5 kW. Total connected load of this building is 738 kW.

The details of BMS installation in these buildings is given in Table 1. Figure 2 indicates the screen shot of the occupancy status of each location in these buildings. The green color indicates that those rooms are occupied and the lights in these rooms are On-Off. As shown in Figure 3, the screen shot of an air handling unit in the building indicates the unit number, compressor status, temperature set point and current schedule, return air temperature, fan speed and the fresh air damper status.

Table 1. Building data

Details	Bldg. 29	Bldg. 40	Bldg. 51	Total
Inside Area (m^2)	4528	2480	2425	---
Building Height (m)	11	9	11	---
No. of Floors	01	02	02	---
Age (years)	2-3	>20	>20	---
AC Load (TR)	410	160	200	---
Lighting Load (kW)	64	30	35	---
Total Connected Load (kW)	1506	593	738	---
A/C Units	16	8	8	32
DDC Panel (HVAC)	2	1	1	4
DDC Panel (Lighting)	1	1	1	3
Variable Frequency Drives	16	8	8	32
Occupancy Sensors	18	20	32	70
Duct Temperature Sensors	16	8	8	32
Air Quality Sensors	16	0	4	20
Damper Actuators	16	0	4	20

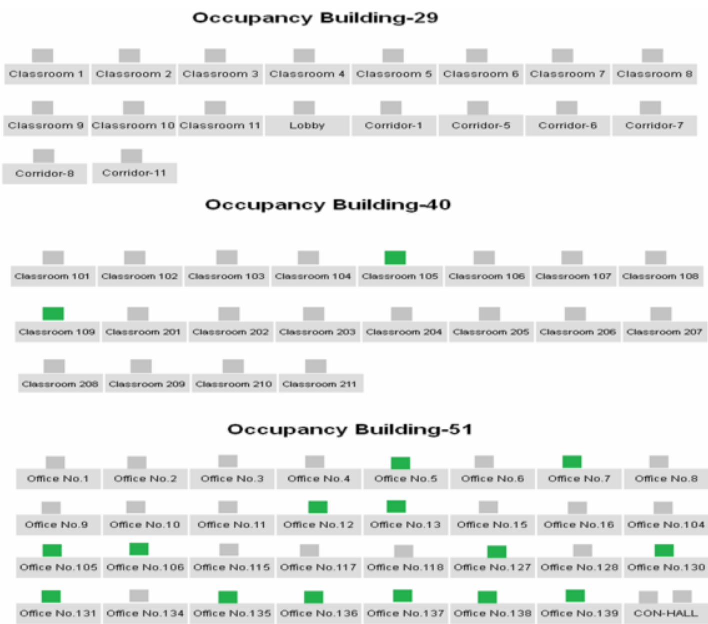

Figure 2. Screen-shot: Occupancy status in buildings 29, 40 and 51

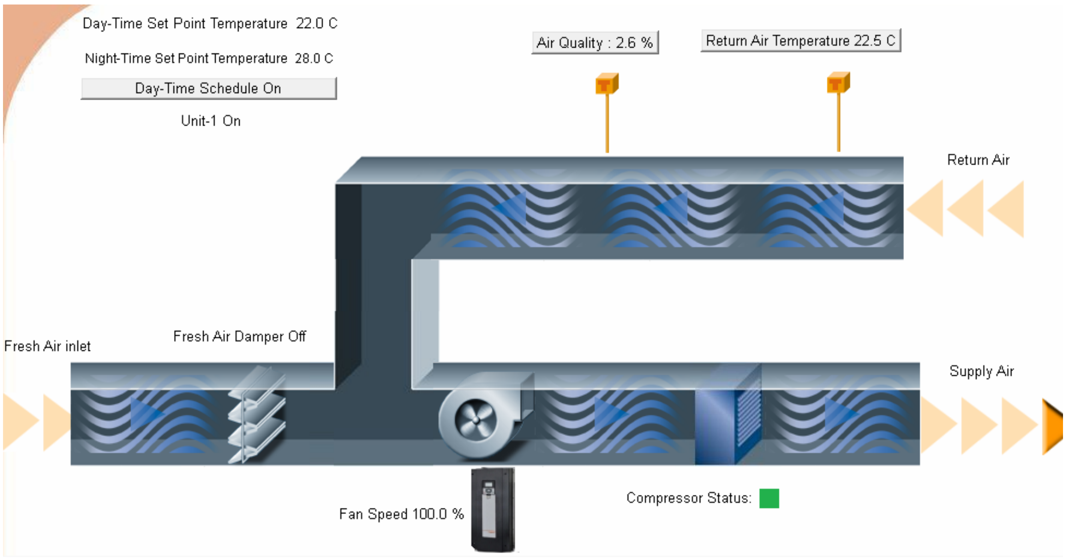

Figure 3. Screen-shot of an air handling unit

4. Data analysis and results

In this section, the effectiveness of the BMS installed in buildings 29, 40 and 51 is evaluated on the basis of the comparison of the results obtained with BMS against those obtained without BMS. From April 2011 to September 2011, the buildings were without BMS. The BMS in these buildings have become fully functional from April 2012. After the installation of BMS, from the month of April 2012, the AHU thermostats in the buildings are set to have the room temperature equal to 22°C during the day time schedule from 6.00 a.m. to 12.00 mid-night and 28°C during night time schedule from 12.00 midnight to 6.00 a.m. The speed of variable frequency drives is set to 50% in the night when the temperature setting is increased. Before the BMS installation, the thermostats were set to 20°C and the compressor motors were running at 100% speed throughout the day unless otherwise these were switched Off manually.

The electrical load demand data of the buildings are monitored continuously at 30 minutes intervals throughout the day and thus throughout the year. These instantaneous interval data stored in the digital meters are later transferred to the personal computers for further analysis. Figures 4, 5 and 6 show the variation of monthly average load demand in the buildings 29, 40 and 51 respectively. These figures compare the monthly average demand in these buildings before and after the installation of BMS. From Figure 4, it can be seen that the monthly energy consumption in Building No. 29 has significantly reduced in all the six months with the provision of BMS. Figures 5 and 6 indicate appreciable reduction in the monthly energy consumption in buildings 40 and 51 also, after the installation of BMS. The major contributing factor to this reduction in the load demand is the reduction in the air conditioning and the lighting loads on these days achieved through the automatic monitoring and control by the BMS. In both the years 2011 and 2012, the monthly average load demand of these buildings was the maximum in the month of July. The monthly and daily average energy consumption in the month of July 2011 without BMS and that in the month of July 2012 with BMS are shown in Table 2. The details of maximum and minimum of average energy consumption in the month of July in these years are shown in Table 3. The minimum average daily consumption in these buildings in each month of our investigations occurs on Fridays, the weekend holidays while the maximum values occur on working days. Further it can be seen that the maximum and the minimum values of the daily average energy consumption gets reduced with the provision of BMS. It can further be inferred that before the installation of BMS, whether it is day or night time, whether it is used or unused, there was significant energy consumption throughout the day. But at the same time, with the installation of BMS, the energy consumption could be significantly reduced in the nights when the classrooms are not in use. During the other periods of the day, the load varies as the pattern of usage changes with the occupancy of the various classrooms in the building. It is seen that, with the installation of BMS, the energy consumption in the buildings can be reduced on all the days, the reduction being more significant during night time. The saving in energy consumption during day time is seen to be significant during weekends also. However, the energy that could be achieved during day schedule of a working day through the installation of BMS is in general not that significant.

This is because during such periods of maximum usage of the classrooms/office rooms, all the air conditioners would be turned On. Whatever little saving that could be expected during these periods corresponds to non-occupancy of some of the classrooms, and thus the consequent switching Off of the lights in those rooms by the BMS.

Table 4 shows the details of total energy consumption for the period from April 2011 to September 2011, the period during which there was no BMS. The Table also shows these details for the same months in the year 2012, the period after the installation of BMS in the buildings. From this Table, it can be seen that the average energy consumption in building No. 29, a relatively new building, could be reduced by 21.51% of the energy consumption during the six months period without BMS. Similarly in buildings 40 and 51, the energy saving during the six months is seen to be 9.27 % and 7.71% respectively. The total saving in energy consumption in this period with BMS thus becomes 265813.53 kWh, which is equivalent to a reduction of 188 metric tons of CO_2 emission. While this reduction in the energy consumption and the environmental pollution itself is significant, system fine tuning and book-keeping can lead to further saving in these buildings. The attitude and the sincerity of the employees involved in the BMS activities also play a major role in the effectiveness of the BMS in the reduction in energy consumption. For instance, the alternate increasing and decreasing trend in the monthly average energy consumption in Building No. 51, shown in Figure 6, is observed to be due to the lack of seriousness of the staff involved in the energy management in the campus.

From the investigations, it is observed that there is significant reduction in energy consumption in the holidays and also after the office hours on working days in all the buildings, irrespective of the type and characteristics of the buildings. Further, the attitude and the initiative of the concerned department can also contribute in making the BMS still more effective. Retrofitting of old buildings by way of provision/change of thermal insulation, glass windows, door dampers, curtains, etc. is being taken up for the effective electric energy utilization. Refinements and regular book keeping of the installed BMS would lead to further reduction in the energy consumption in the buildings. Rules and regulations related to the campus energy conservation are being formulated, and the enforcement of these rules is to be ensured. Campus wide energy awareness campaign is being taken up to inculcate the conservation attitude among the students and staff in the university.

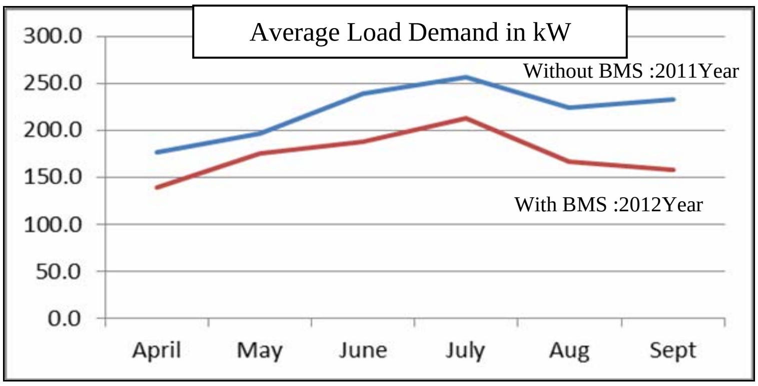

Figure 4. Effect of BMS on monthly average load demand in building No. 29

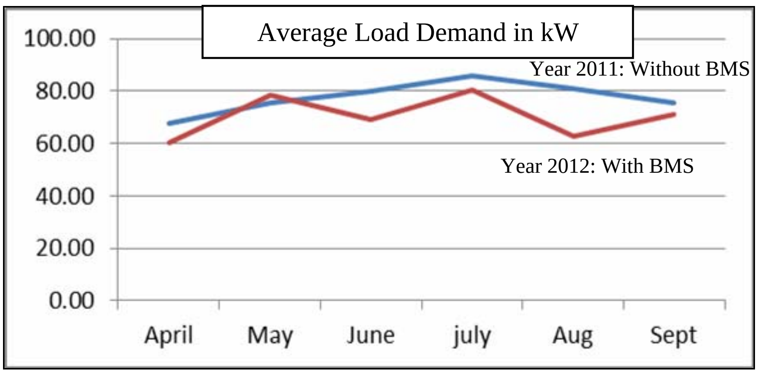

Figure 5. Effect of BMS in monthly average load demand in building No. 40

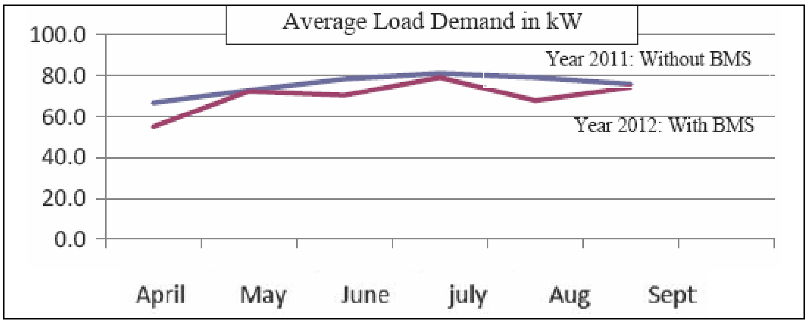

Figure 6. Effect of BMS in monthly average load demand in building No. 51

Table 2. Energy consumption in the peak month

Building No.	Monthly Energy Consumption (kWh)		Daily Energy Consumption (kWh)	
	July 2011	July 2012	July 2011	July 2012
29	190354.05	157937.10	6140.45	5094.74
40	63805.34	59817.72	2058.23	1129.60
51	60391.60	58888.00	1948.10	1899.60

Table 3. Daily average energy consumption in peak month

Building No.	Daily Energy Consumption (kWh)							
	July 2011		July 2012		July 2011		July 2012	
	Max. kWh	Day & Date	Max. kWh	Day & Date	Min. kWh	Day & Date	Min. kWh	Day & Date
29	7495.05	Tuesday, 12	6702.15	Monday, 16	4079.25	Friday, 01	2874.90	Friday, 6
40	2430.02	Sunday, 31	2300.70	Saturday, 14	1567.62	Friday, 01	1110.16	Friday, 6
51	2304.60	Sunday, 31	2145.80	Saturday, 21	1382.20	Friday, 01	1205.60	Friday, 13

Table 4. Comparison of energy consumption before and after BMS installation

Building No.	Without BMS (from April 2011 to Sep. 2011)	With BMS (from April 2012 to Sep. 2012)	Reduction in monthly energy consumption (kWh)	% Saving
	Consumption In kWh	Consumption In kWh		
29	969646.15	761087.70	208558.45	21.51
40	340889.48	309288.30	31601.18	9.27
51	332677.10	307023.20	25653.90	7.71

5. Conclusion

This paper has dealt with the investigations of the effectiveness of the installation of BMS in a few typical buildings in the main campus of the King Abdulaziz University Jeddah. The investigations reveal that the provision of BMS has led to significant reduction in the total energy consumption in the buildings. It would be possible to further conserve energy by appropriate fine tuning and book-keeping of the BMS activities. An experienced energy manager is being appointed for the coordination of various energy conservation activities and better utilization of the BMS in the campus. Each of the new building is being linked with the BMS.

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