Design strategies for a Big Mosque to reduce electricity consumption in Kingdom of Saudi Arabia

Abdullah M. Al-Shaalan
Dept. of Electrical Engineering, King Saud University
Riyadh 11421, Kingdom of Saudi Arabia

Abdul Hameed A.Alohaly
Dept. of Electrical Engineering, King Saud University
Riyadh 11421, Kingdom of Saudi Arabia

and

Wonsuk Ko
Dept. of Electrical Engineering, King Saud University
Riyadh 11421, Kingdom of Saudi Arabia

ABSTRACT

This study proposes and analyzes the design approaches for a Big Mosque to conserve electricity consumption in Kingdom of Saudi Arabia. Mosques are characterized by a unique function and operating schedule that are not typical to other types buildings. In this study, the effects of zoning and partitioning are investigated. To demonstrate the effectiveness, one of the Riyadh city grand mosques is identified as a model to explore the most appropriate ways to conserve energy. Three cases are simulated by eQuest which is designed to perform detailed analysis of sophisticated building energy use. First, the mosque with inefficient materials, second the mosque with effect materials and without zoning and finally the mosque with zoning and efficient materials. Simulation results show that some of the important energy conservation techniques should be applied in the construction phase.

Keywords: Mosque, eQuest, Electricity Consumption, Energy conserve, Zoning, Partitioning

1. INTRODUCTION

Mosques are the heart of any Islamic community where people perform their daily and weekly prayers. Saudi Arabia's mosques have a special importance because Saudi Arabia is the center of the Islamic world and every country look up to it as an example in treating mosques and worshipers. Also, the number of mosques in Saudi Arabia is abundant. Mosques are characterized by a unique function and operating schedule that are not typical of other types of buildings. Mosques are usually occupied five times a day all year around. People often come to the mosque at different times, and therefore the maximum number of worshipers is expected to occur during the actual performance of prayers, which lasts from about 20 to 30 minutes each. After prayer, they leave gradually as well. Exceptions to this are weekly Friday prayer and Tarweeh prayer during the nights of the month of Ramadan as well as during other special occasions such as Eid prayers, lecturing and similar activities where people tend to stay longer in the Mosque. Time of prayers frequently coincides with peak energy demand periods. These factors with the importance of thermal comfort for performing prayers in mosques make the design and operation of Mosques very important to all Muslims

This study proposes and analyzes the design approaches for a Big Mosque to conserve electricity consumption in Kingdom of Saudi Arabia. Saudi Arabia's Mosques have an importance because Saudi Arabia is the heart of the Islamic world and the number of Mosques in Saudi Arabia is abundant. The energy crisis, specifically electricity consumption is considered as an issue that challenges the Kingdom of Saudi Arabia (KSA). The Ministry of electricity and water in the KSA reported that the high temperature in summer months sometimes reaches 50 degrees Celsius in the shade, leads to an enormous increase demand in the air-conditioning load. Thermal comfort is an important aspect of Mosques for performing prayers comfortably. Optimum thermal design and operation of Mosques are essential to achieving necessary thermal comfort throughout the day.

In this study, the effects of zoning, partitioning, and thermal insulation material are investigated. To demonstrate the effectiveness, one of the Riyadh city grand mosques is identified as a model to explore the most appropriate ways to conserve energy. The Al Obeikan mosque is chosen and based on specifications of chosen mosque, three cases are simulated by eQuest(Quick Energy Simulation Tool) which is designed to perform detailed analysis of today's state-of-the-art building design technologies using today's most sophisticated building energy use simulation techniques. First, the mosque with inefficient materials, second the mosque with effect materials and without zoning and finally the mosque with zoning and efficient materials. These factors may help in lowering the rates of energy consumption in mosques and hence contribute to energy conservation. Simulation results show that some of the important energy conservation techniques should be applied in the construction phase.

This paper is composed as follows. Chapter 2 shows the climate and Energy Situation in Kingdom of Saudi Arabia. Chapter 3. explains eQuest, Quick Energy Simulation Tool and application for chosen Mosque. Chapter 4. illustrates the results simulated by using the eQuest. Lastly, Chapter 5. presents conclusion of this Study.

2. CLIMATE AND ENERGY SITUATION in KSA

The climate of KSA is hot and dry, characterized by extremely hot and dry summers and moderately cold winters, temperature is extremely high, covering nearly seven months of the year

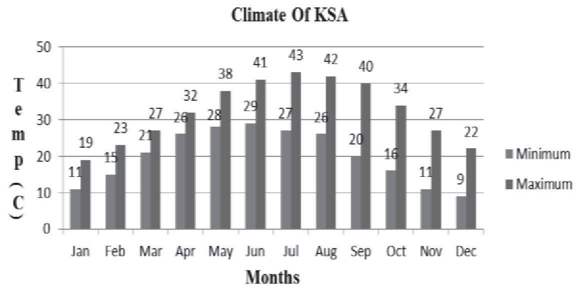

Figure 1. Average monthly temperatures of the KSA [2]

Figure1. shows that the energy consumption depends mainly on the climate changes and reaches to higher peaks in summer.

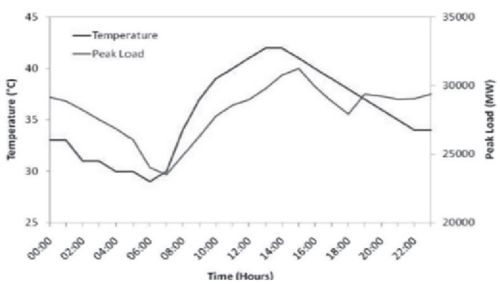

Figure 2. Electricity Consumption vs. Time of Day [3]

The energy consumption in Saudi Arabia has grown significantly over the last 25 years, and it is estimated to reach double the annual consumption by 2030, so energy conservation is a critical issue in KSA. With the increase in electricity consumption, the natural resources will decrease even more, so it requires to reduce the energy consumption and enhance the efficiency of the produced energy.

In KSA, mosques and charities follows the agricultural tariff. Table 1. shows the electricity tariff of KSA for residential, commercial, agricultural & charities, governmental and Industrial, private educational facilities, private medical facilities. Price Unit of electricity tariff is [Halalah/kwh]. For understanding, 100 Halalas is equivalent to 1 Saudi Riyal and 1 Saudi Riyal is equivalent to 0.27 USD.

Table 1. New Consumption for all Categories of Service according to Council of Ministers' Decree No.95 Dated 28/12/2015

Consumption categories (Kwh)	Residential (Halalah / kwh)	Commercial (Halalah / kwh)	Agricultural & Charities (Halalah / kwh)	Governmental (Halalah / kwh)	Industrial, private educational facilities, private medical facilities (Halalah / kwh)
1 – 2000	5	16	10		
2001 – 4000	10				
4001 – 6000	20	24	12		
6001 – 8000	30			32	18
More than 8000		30	16		

3. EQUEST and APPLICATION

eQuest is a large program capable of doing an analysis for even bridges and commercial building. It is a free and powerful program which has many advantages over other programs such as, user-friendly interface, 2D and 3D design tool and detailed hourly analysis over the whole year. It can be used to investigate the effectiveness of different types of roof construction, window glasses and sun shield types on energy consumption in the building. eQUEST analyzes energy based on hourly weather data considering the location. It provides a very accurate simulation of such building's features as shading, fenestration, interior building mass, envelope building mass, and the response of differing heating and air conditioning system types and controls. eQUEST allows the user to perform detailed analysis of today's state-of-the-art building design technologies using today's most sophisticated building energy simulation techniques but without requiring extensive experience in the "art" of building performance modeling. This is accomplished by combining a building creation wizard, an energy efficiency measure (EEM) wizard, and graphical results display module.

Table 2. shows the specification of Al Obeikan mosque which has been chosen to apply eQuest simulation. Figure 3. and Figure 4. show that the zone is completely open to the Friday prayer area, and the full load is on, AC units and lighting.

Table **Error! No text of specified style in document.**2. Al Obeikan mosque specifications

Type of Air Conditioning	Central type
Total Area	Friday's area 30x30m Daily zone 16.5x20m
Door	The mosque has nine large doors, each with dimension 2.4 m x 2 m
Windows	12 windows with dimensions 2×3m 18 windows with dimensions 1×1m
Height	9 m
No. of AC units	8 Large units
No of lights	206 light unit 208 fluorescent tube
No. of refrigerators	6 units

Figure 3. Zone area in Al Obeikan mosque

Figure 4. Friday prayer area in Al Obeikan mosque

Based on Al Obeikan mosque specifications, three cases, from Table 3. to Table 5, are simulated by eQuest. Table 3. uses inefficient materials without zoning, table 4. uses efficient materials but without using zoning, and table 5. uses efficient material and zoning. Efficient material mainly includes lighting device such as LED, and the EEM which quickly describe up to nine design alternatives from eQuest. Using the EEM the energy impacts and tradeoffs of design options, Energy Efficient Ration (EER) can be weighed.

Table 3. The mosque with inefficient materials without zoning

BUILDING	CHARACTERISTIC
Zoning	Two zones used for every prayer
Lighting	2 [W/sq. ft]
Occupancy	7 [ft^2/person]
HVAC	Central (EER=7)
Operation Time	Five different times a day with each time being equal to two hours
Inside conditions	When occupied 76, unoccupied 82 Fahrenheit (24.4, 27.8 C)

Table 4. The mosque with efficient materials without zoning

BUILDING	CHARACTERISTIC
Zoning	Two zones used for every prayer
Lighting	0.5 [W/sq. ft]
Occupancy	7 [ft^2/person]
HVAC	Central (EER=8.5)
Operation Time	Five different times a day with each time being equal to two hours
Inside conditions	When occupied 76, unoccupied 82 Fahrenheit (24.4, 27.8 C)

Table 5. The mosque with efficient materials without zoning

BUILDING	CHARACTERISTIC
Zoning	Two zones, small one for daily and a large zone for Friday prayer
Lighting	Small zone 0.5 [W/sq. ft] Friday area [0.4 W/sq. ft]
Occupancy	7 [ft^2/person]
HVAC	Central (EER=8.5)
Operation Time	Five different times a day with each time being equal to two hours
Inside conditions	When occupied 76, unoccupied 82 Fahrenheit (24.4, 27.8 C)

Figure 5. figure 6 show that the example of eQuest application, and figure 7. shows drawing of Al obeikan mosque. In this simulation, weather of Riyadh in one year, the shell size of building, zone size of building, construction material such as wall, window, exterior insulation HVAC, lightings, operating hours and electricity tariff in table 1. are considered to achieve simulation result.

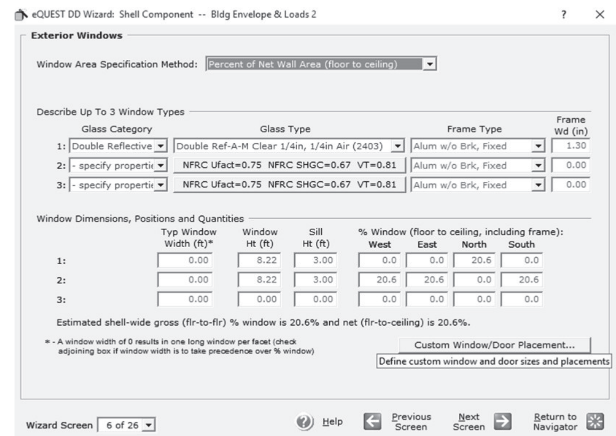

Figure 5. Example of eQuest application for window material

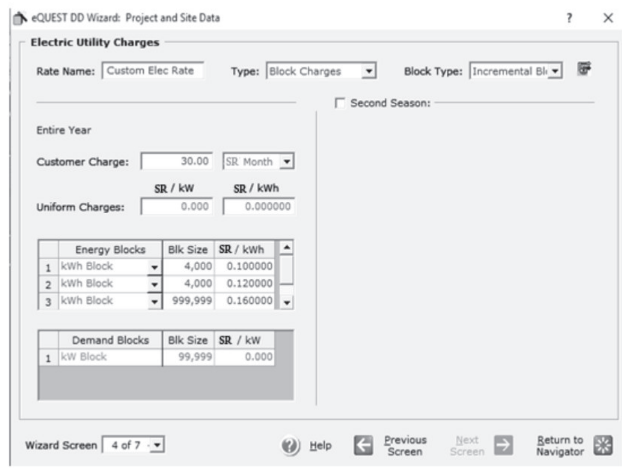

Figure 6. Example of eQuest application for electricity tariff

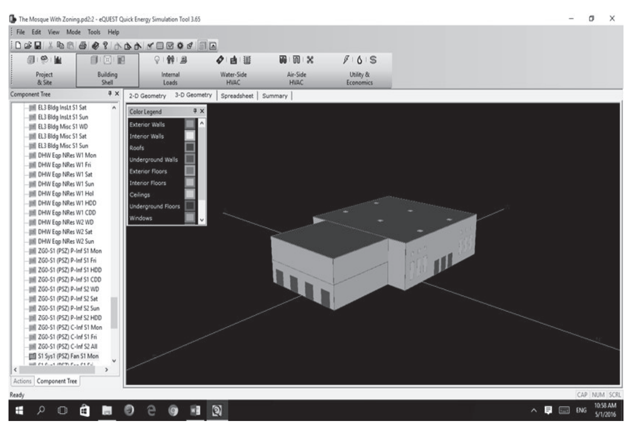

Figure 6. 3D drawing of Al Obeikan mosque by eQuest

4. RESULTS

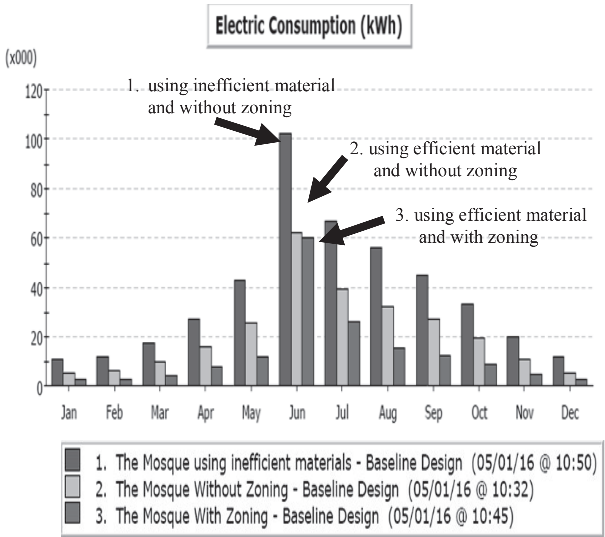

Figure 7. Electric consumption of the three cases

Figure 7. illustrates a whole year electric consumption of three cases. As we can see from the figure 7., there are huge differences between the three cases. Compare to the case 1. using inefficient material and without zoning, case 2. using efficient material and without zoning results 40% of the electric consumption is saved and case 3. using efficient material and with zoning shows another 40% of the electric consumption is saved. In all three cases the biggest peak in the year occurs in June where two peaks (summer and Ramadan) occur at the same time. In June, case 1 electricity consumption estimates 102.39 [MWh], case 2 is 62.30 [MWh] and case 3 is 60.21[MWh].

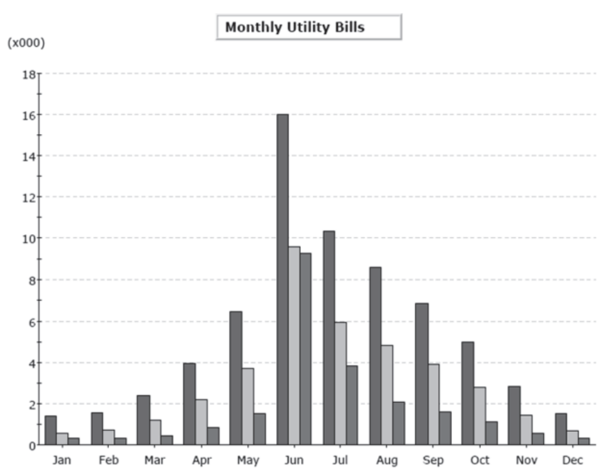

Figure 8. Electric utility bills of the three cases

Figure 8. illustrates that the electric utility bills of one year when we apply electricity tariff from table 1. In case 1 the annual bill is 66,898 SR, which is equivalent to 17,838 USD, considering the low supported tariff in Saudi Arabia. In case 2 we can save up to 44% (37,491 SR, 11,196 USD) of the money paid annually compare to the case 1. Finally, using the zone will decrease the bills even more and we could save 41% (22,157 SR, 6,617 USD) of the money compared to the case 2.

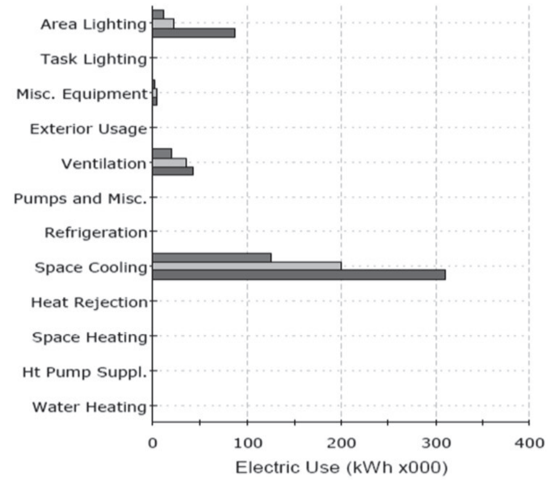

Figure 9. Annual electric consumption by categories

Figure 9. shows how much each category is responsible for the electric consumption. The most of the electrical energy is consumed by the space cooling and that is due to the hot climate and large number of people occupying the mosque in the same time. In case1, a big amount of the energy is consumed by area lighting due to the inefficient use of lighting unlike case 2 and 3 where we used efficient lighting material, LEDs.

Based on the findings from the eQuest simulation, the following recommendations can be suggested:

• Using efficient materials in constructing the mosque results in reduced energy consumption and therefore decreased monthly bills.

• Not using the whole mosque for every day's prayer and using a small zone for that matter will largely decrease the energy consumption and the monthly bills.

• The relatively high energy consumption does not necessarily mean better thermal comfort conditions for the occupants due to inefficient use.

• When A/C operation is combined with an appropriate operational zoning strategy, acceptable thermal comfort can be achieved with less energy use.

• Using LEDs instead of incandescent bulbs lighting saves more energy as well as having longer life time.

5. CONCLUSION

This study develops Design strategies for a Big Mosque to reduce electricity consumption in Kingdom of Saudi Arabia. Energy consumption is a serious concern in the world in general and in the Kingdom of Saudi Arabia. Mosques are those buildings which operate simultaneously at peak times and not enough focus is given to their designing during construction. Hence, these buildings have too much potential to attract the attention of concerned authorities. This study is conducted on just one mosque. However, mosques throughout the Riyadh city are quite common as far as the operation and design. Therefore, the results of the mosque can be generalized, but it should be noted the findings may vary per the mosque type, size, operation, and location. Simulation results show that some of the necessary energy conservation techniques should be applied in the construction phase. Electrical energy conservation in Saudi Arabia can be achieved through the combination of three tools. Firstly, the use of efficient electrical equipment; secondly, the application of energy technology in buildings, such as insulation, ventilation and solar energy; and finally, by supportive tools such as public awareness, energy codes, regulations, energy information, and databases.

ACKNOWLEDGEMENT

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