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طرق حفظ الطاقة للمباني في المنطقة الحارة القاحلة، في العربية السعودية: دراسة حالة

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الخلاصــة

في الآونة الأخيرة أصبح حفظ الطاقة أكثرطلبا نتيجة للأزمات المالية العالمية وكذلك أسعار النفط غير المستقرة. وحتما تحتاج جميع الكيانات إلى التكييف مع الحفاظ على الطاقة واستراتيجية الإدارة. ويرجع ذلك إلى ارتفاع الاستهلاك الشهري للطاقة، وفواتير الطاقة في مباني الاتصالات السعودية هي مثال على ذلك. لتحسين حفظ الطاقة في مباني الاتصالات، فمن الضروري إما توفير مباني حديثة و مصممة بشكل جيد، أو تعزيز القائم مع المزيد من الممارسات الاستراتيجية لتوفير الطاقة. وهذه الورقة تعرض تأثيرخصائص التدفئة والتهوية وتكييف الهواء ، وتصميم فضاء الداخلي للمباني ، واستراتيجية التشغيل، وتأثير الخصائص الحرارية للمغلف الخارجي للمبنى، وتدابير الحفاظ على الطاقة. يتم تصنيف هذه التدابير تحت ثلاثة أنواع: صفر الاستثمار ومنخفض الاستثمار وعالية الاستثمار. وتشير الدراسة إلى أن تدابير الحفاظ على الطاقة التي تتعلق بخصائص نظام التكييف والتبريد والتشغيل تمثل قدرة الأكبر على خفض استهلاك الطاقة، وينبغي للخصائص الحرارية والطاقة الشمسية للنوافذ أن تكون كبيرة ويجب الاهتمام بها في مرحلة التصميم الأولي للمباني في المستقبل. وتحديد نقطة التشغيل لأجهزة التكييف والتبريد والتي توفر التشغيل الأمثل لأجهزة الاتصالات في مبنى الاتصالات. وهذه الورقة تعرض أمثلة الحرارية لمباني مختلفة الحجم في المناطق الحارة والجافة في مدن المملكة العربية السعودية مثل الخبر والمنطقة الشرقية وتأثير إضافة حائط وسقف العزل على طاقة التبريد كان واضحا. وأيضا يتم الحصول على تخفيض إجمالي الطاقة بحوالي ٪20-3 من خلال تطبيق كل من جدار وسقف العزل.

Energy savings approaches of buildings in hot-arid region, Saudi Arabia: case study

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ABSTRACT

Recently, the energy savings have become more pronounced as a result of the world financial crises as well the unstable oil prices. Certainly all entities need to adapt Energy Conservation and Management Strategies. This is due to high monthly consumption of energy; energy bills of Saudi telecom exchange buildings are a good example. To improve energy savings of such installations, it is necessary to either provide well designed new buildings, or enhance existing buildings with more energy saving strategy practices. This paper investigates the impact of heating, ventilation and air conditioning (HVAC) system characteristics, designed spaces of buildings, operational strategies, the impact of envelope thermal characteristics and energy conservation measures. These measures are classified under three types; i.e. zero-investment, low-investment and high-investment energy conservation measures. The study shows that the energy conservation measures (ECMs) pertaining to the HVAC system characteristics and operation represent the highest potential for energy reduction. Attention should be given to window thermal and solar radiation characteristics, when large window areas are used. The type of glazing system needs to be carefully considered in the early design phase of future buildings. The HVAC set points to provide optimal operation of telecom devices in the exchange center. The Paper presents the thermal optimization of centers of different size in the hot–arid regions, Saudi Arabian city of Al Khobar, eastern province and the effect of adding wall and roof insulation on cooling energy is evident. Also the total reduction of around 3-20% is obtained by applying both wall and roof insulation.

Keywords: Energy conservation; exchange centers; hot-arid regions Saudi Arabia; optimization, thermal design.

INTRODUCTION

Energy management and energy conservation have become core issues. Many national and international research projects and conferences on “Strategies for Energy Conservation” have been conducted in the Kingdom and elsewhere. Many private businesses started implementing such energy savings strategies a long time ago; recently, many governments have set a target for reduction of energy consumption by 30%-50% in their buildings during the next five years (Shaw A, 1989). Such commitment from the government’s side encourages many energy clients to follow the same strategy. For several years, many companies such Saudi Telecommunication Company (STC), Saudi Electric Company (SEC), Saudi Aramco and SABIC, various industrial, commercial and residential buildings and companies have felt the fiscal effects of high wastage of energy on their monthly energy bills and have conducted and implemented many energy saving projects. Recently such energy savings became more pronounced as the global financial crises, and unstable oil prices depress demand. Many energy clients are now considering implementing energy conservation measures.

The old buildings of King Faisal University need to adopt such energy conservation and energy management strategies due to the high monthly energy cost. STC has funded project to study and develop savings strategies on their energy bills for each exchange. These developments necessitate the establishment of more centers. All such switching instruments are mostly electronic equipment that consume and dissipate energy to conduct operation. Energy retrofits and the implementation of conservation measures can be a cost-effective means of reducing energy consumption in buildings. Changing building HVAC operating strategies may work equally well and can result in savings through reduced equipment sizes as a result of peak load reductions (Ramanamurti, 2002). For Saudi Arabia, residents take the lion’s share, which could exceed 70% of the total electric energy use in the country (Ramanamurthi, 2003). To keep most of the Telecom exchanges reliable in operation, HVAC systems have to be supplied. The electricity demand is very high during summer, mainly due to air-conditioning consumption, which is high due to a lack of thermal insulation in most of the centers, and due to the absence of other energy efficiency measures and load management strategies. Energy retrofits and the implementation of conservation measures can be a cost-effective means of reducing energy consumption in buildings. Changing building HVAC operating strategies may work equally well and can result in savings through reduced equipment sizes as a result of peak load reductions (Carriere *et al.,* 1999). It is reported that 15%, 19% and 40% annual energy can be saved in large, medium and small office buildings respectively through envelope thermal optimization in the hot–humid climate of the Riyadh area (Zbysek & Robert, 2009). Similarly, for the hot–humid climate of Jeddah, annual energy savings of 8%, 12% and 24% can be obtained for large, medium, and small offices, respectively. For instance, in a supermarket (954m^2 air-conditioned floor area), located in the eastern province of the country, 38% of energy is used annually by air conditioning, 42% is used in appliances, and the remaining 20% is used for lighting (Saudi Electricity company (SEC) report, 2007).

ENERGY SIMULATION, ANALYSIS, APPROACH AND SOLUTIONS

The three primary energy-consuming economic sectors are industry, transportation, and buildings. For example, in an industrialized nation like the U.S., industry and transportation account for about 64% of the total energy use with 37% and 27% each, respectively. Buildings have a substantial share of the energy consumption with as much as 36% of total energy use consumed in residential and commercial buildings. In commercial buildings, about 67% of this energy is in the form of electricity, of which about 33% is generated by fossil fuels (Shaw, 1989; Rathna & Sivasubramanian, 2014). For energy savings reasons, the indoor quality, thermal performance of buildings and hygienic requirements suddenly became the focus of designers and investors. The hygienic quality of indoor space was until this time provided by natural infiltration of exterior air through building envelopes and the thermal losses were fully compensated by heating and cooling systems. However, this state was not sustainable. Because of the rapid increase of heating and cooling expenses, it was necessary to solve the problem of thermal insulation of newly developed as well as existing buildings (Zbysek & Robert, 2009). In Saudi Arabia, buildings account for a major share of electric energy consumption, which reached about 76 % of the total for the year 2002. Industrial consumption of electric energy was 23 % for the same year. This includes the eastern region of the Kingdom which leads in industrial consumption due to the presence of the Saudi Arabian Oil Company (Saudi Aramco) and Saudi Basic Industries Corporation (SABIC). However, even within industrial facilities, part of the electric energy is consumed by buildings serving these facilities. For other regions of the Kingdom with less intensive industrial activities, more than 90% of electric energy is consumed by buildings (Saudi Electricity company (SEC) report, 2007)

With the liberalization, competition, and opening of the many developments and especially with Saudi rapid planning and building, it is necessary to reduce the operating cost of survival. Thus, even for commercial viability and competitiveness, it is necessary to reduce energy bills by employing innovative strategies of energy conservation in the HVAC systems which are considered as the major energy consumer in all businesses today. Due to the hot, humid weather, it is essential to provide a highly reliable, comfortable and energy efficient air-conditioning system in any building. Heating, ventilation and air conditioning systems consume nearly 50 to 65% of the total power in any building, and thus offers huge potential and challenge to reduce the energy consumption by employing various innovative energy conservation strategies

(Shaw, 1989; Ebert *et al.,* 2002). For HVAC systems, some of the previous measures which have been adopted/experimented in one company are, awareness regarding building orientation, architectural features, avoiding overcooling or overheating, high sensibility of air-conditioning system, automation and building management systems, variable voltage and variable frequency drives, heat recovery wheel, panel cooling, vapor absorption machines, minimizing the space for air conditioning application and closing of dampers/drills for areas where air-conditioning is not required (Carriere *et al.,*1999).

The investigative approach

Energy performance of sample of buildings under various retrofitting measures is assessed through an energy simulation model developed based on actual collected data pertaining to thermo-physical characteristics and energy consumption of a sample of typical existing exchange buildings (Mohammad *et al.,* 2014). Conducted a building energy audit and each zone of the building was physically investigated with the cooperation of the building and O&M personnel in order to obtain information about the building lighting, equipment and occupancy.

The VisualDOE energy simulation software was used for formulating the base case models representing the thermal and energy behavior of selected existing buildings. A detailed energy audit was conducted to collect physical, thermal and operational characteristics. Based on collecting audit data, four buildings regarded as a representative sample in terms of size, type of HVAC systems and thermal and operational characteristics were selected and modeled. The models were planned to be adjusted till achieving acceptable performance by comparing its prediction with actual energy consumption data collected as part of the audit process.

Formulation of the base case models

Using the VisualDOE simulation program, a model was developed for each of the simulated buildings. Thermal and operational characteristics of the different buildings were collected through the auditing process, and used as initial inputs for the simulation program. Although all steps were taken to ensure proper data collection, the level of credibility and accuracy of collected data with respect to thermal and operational parameters varies, due to difficulty in objectively assessing some of these parameters. Information related to the geometrical configuration of the building, maximum lighting power, and installed capacity of the HVAC system and to some extent envelope thermal characteristics are fairly accurate and can be treated as stable parameters in the model. Following input assumptions were made: Buildings are assumed at average air tightness with an air leakage rate of 0.2 ACH (change per hour) during occupied and unoccupied periods, since all doors are usually closed and air infiltration can take place only through cracks and openings around windows and doors. An air infiltration rate of 0.2 ACH is used to represent a relatively tight enclosure. However, when considering the relatively large volume of the indoor rooms and halls compared to the area of its exterior envelope, this air infiltration level can be justified. Calibration of energy simulation program with measured data is an essential first step for investigating the impact of thermal and operational characteristics of building on energy consumption and consequently for better understanding of the overall thermal and energy behavior of the building. Through the calibration process, the actual thermal and energy behavior of building over a certain period is modeled through the simulation program producing a reliable base for predicting changes in energy consumption under different thermal and operational characteristics. Generally the energy conversion measures can be classified as 1. Zero-Investment, 2. Low-Investment and 3. High-Investment. Table 1 provides a summary of the energy usage of the base case model of the simulated STC-Exchange Buildings under study.

It can be observed that energy consumption due to space cooling and HVAC fan operation constitute around 47-63 % of the total annual energy use. The electrical lighting account for 7-26% and the equipment consume around 27-32 % of the total annual energy use. Figure 1 illustrates the resulting Khobar building consumes the greatest amount of energy. Many energy conservation measures can be investigated utilizing the base case models already established and described earlier. Total monthly energy consumption due to higher energy use occurs during the summer months of June, July and August, consistently in the buildings.

Table 1. STC-Exchange buildings: summary of building energy usage (segregated) resulting from simulating the base case models- Khobar City

Category of use	**Base case**	
	(KWh)	%
Lighting	145,176	7
Equipment	575,112	30
Space Cooling	682,679	35
Fans	536,754	28
Total	1,939,721	100 263
Space Cooling +Fan	1,219,433	63

Potential energy conservation measures (ECMs)

Many energy conservation measures can be investigated utilizing the base case models already established and described earlier. Generally the energy conversion measures can be classified as 1. Zero-investment, 2. Low-investment and 3. High-investment. These can be applied with respect to the HVAC and lighting system operation and the building envelope characteristics.

CHARACTERISTICS OF SIMULATED BUILDING

The collected data, including information about geometrical configuration, envelope thermal characteristics, window types and areas, occupancy schedules, lighting power and schedules, HVAC system type and operational schedules, served as the database for formulating the energy simulation model. All data used are based on the audit process described earlier and observations resulting from on-site visits and investigations. Some operational and thermal characteristics had to be assumed as close to reality as possible due to the absence of documented records of such data (e.g. air infiltration, occupancy density and schedule).

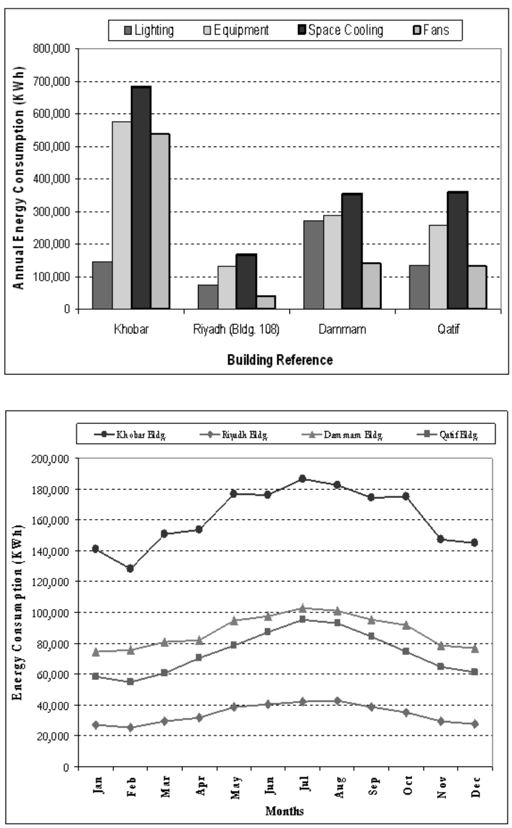

Fig. 1. The resulting monthly total energy consumption

The load and operation profiles of the various thermal and energy processes of the analyzed buildings (including lighting, occupancy, and infiltration and HVAC operation) were mainly based on the actual profiles observed and recorded during the audit processes. Different operational schemes can be applied to different buildings. Other load and energy profiles, such as infiltration and occupancy are subject to daily variations. Therefore, reasonable assumptions had to be made in light of the collected information about the various load and energy profiles. The load profile of some processes such as lighting is firmly constant with time. The lighting profile is assumed to coincide with the usage profiles, where all lights and HVAC system are normally turned on continuously as observed in reality.

CONCLUSION

HVAC systems used in the investigated buildings are variable air volume (VAV) but mixed with many other types of systems that have no controlled ventilation. Given the fact that the operation of the buildings is continuously regardless of occupancy, the use of VAV system and other advanced HVAC system types and control is a viable option for future buildings. The envelope represents the most important contributor to heat gain in buildings. Understanding the relative impact of the various designs and thermal parameters of cooling energy requirements can help in identifying and implementing the most effective remedies and retrofits, when improved energy performance is sought. The findings are limited to energy savings associated with different alternatives in existing Buildings in which basic energy conservation measures such as envelope thermal insulation are not usually applied. It is expected that applying such measures will be economically viable considering the type of climate and the Buildings physical and operational characteristics.

The effect of adding wall and roof insulation on cooling energy is evident. A total reduction of around 3-20% is obtained by applying both wall and roof insulation. The reductions in the monthly cooling energy requirement of the STC-Exchange buildings compared to the base case model are depicted in part (b) of Figure 2, when combined envelope insulation (i.e. walls and roof) measures are used. The monthly cooling energy reductions are shown in part (a) of the above-mentioned Figures. The impact of altering window parameters on cooling energy consumption is less evident. Changing window shading conditions has very limited impact with 1-2% change in annual cooling energy requirements which can be attributed to the small window area relative to the whole envelope of the building.

Although most of the conclusions are applicable to different building types in most locations of Saudi Arabia and similar environment, the quoted numbers and percentages are reflective of buildings operated in hot-arid regions of the central and eastern area.

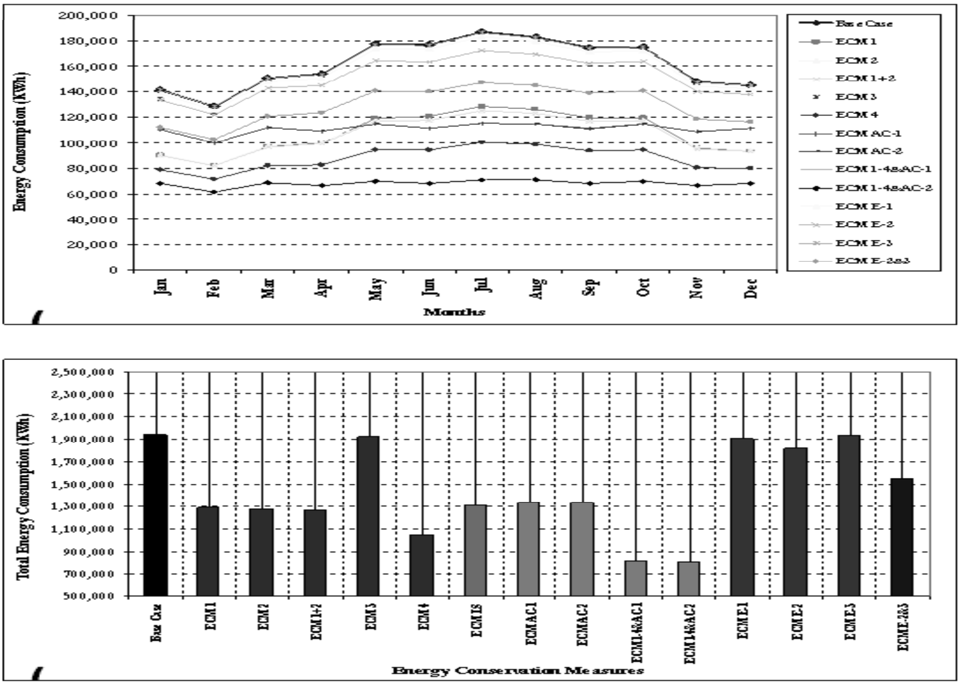

Fig. 2. "Khobar" STC-Exchange building: Total energy consumption (a) monthly, and (b) compared to base case model utilizing the proposed ECMs.

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