ELECTRICITY LOAD PROFILING FOR COASTAL HOUSING COMPLEXES BASED ON THE MEASUREMENTS OF FLATS ACTUAL LOAD

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Abstract: In this paper, a methodology for estimating end-use load shapes using the hourly whole-house metered load data, the household demographic survey data and the weather data (temperature) is presented. End use load shapes presents a method of generating realistic electricity load profile data for some of city of Tripoli domestic buildings. This method could help in predicting the daily load profile from individual flats to community. The results obtained show that the overall methodology provides an effective means for end-use load shape modeling and estimation.

Keywords: Electricity consumption; Load profiles; Domestic buildings; Appliances; Occupancy; Dwelling characteristics; Metering Equipment.

I. INTRODUCTION

Distribution systems obviously exist to supply electricity to the end users, so loads and their characteristics are important. Load data is crucial for planning electricity distribution networks and optimal production capacity [1]. The load types can be divided into five categories: residential, agricultural, industrial, commercial, and public [1]. The identification of the pattern of energy uses for a house and the prediction of the domestic load profile are essential in order to match the load shape to the power generated.

The domestic energy-consumption can be divided into three categories: cooling and space heating, domestic hot water, lighting and appliances [2]. The used pattern varies depending on many determinants, such as weather, household composition, income, behaviour patterns of occupants… etc. Occupants influence the use of electricity of the houses by the number of electrical appliances they own and throughout their use of the appliances [2]. The number of occupants and their age influences energy consumption, for example, households where there are no children or where couples work consumes less energy than a household with children or older people [3].

The estimated population of Libya according to the Bureau of Statistics and Census of Libya is approximately 6.2 million [4]. The city of Tripoli, the capital, is the largest city in Libya with a population of just over a million. In addition, it is the country's principal sea port and the commercial and manufacturing centre. The energy consumption per person in this city has increased by 2.6% between 2008 and 2009 [6]. The demand on the energy is increasing every year and there is a shortage in the studies that addressing the load profiles and the energy consumption of the different load types mentioned before.

In November 2009, the Cadmus Group (Cadmus), Navigant Consulting (Navigant), and Global Energy and Technology Consulting (GETCON) has been contracted by the General Electricity Company of Libya (GECOL) to provide an assessment of the demand side management (DSM) potential in Libya. These services were provided throughout 2010 and include winter load (end-use metering), estimating DSM potential, and designing appropriate pilot programs.

End-use and load metering were conducted between December 2009 and March 2010 for the following six sectors: residential (housing), street lighting, commercial, governmental, agricultural and light industrial [6]. They provided their data without explaining how they conducted their measurements and obtained their results.

This paper is a complementary study to the study conducted in [6] to generating a realistic electricity load profile data for the pure flats complex residential. Direct measurements were taken over a month period for flats in housing complex located in a district named (Zawiyat al-Dahmani) 600m far from seashore near to what is well known as eyes hospital. A sample of 18 flats in bloke number 2 was chosen to be subjected to the load measurements. The total flats in the housing complex were 108 divided between 6 blocks. Measurements were taken at each flat and at the main feeder supply power to the building using reliable measuring equipment every 5 minutes for all the study period. A supporting detailed survey using a questionnaire of the householders sought to obtain an understanding of the appliances used and energy-related behaviour.

II. METHODOLOGY

In order to come-up with close-to real end-uses load curve for housing complex, the research consider the following steps:

1. Load measurement inside selected flats in the housing complex.
2. Supporting detailed survey using a questionnaire of householders sought to obtain an understanding of the occupant behaviour toward their use of electricity and generally their habits toward the use of energy.
3. Mathematical and statistical analysis for data and measurement analysis.

A. Electricity Measurement

Electricity measurements were made using a five-minute load meter installed in series using three different types of meters. The measurements of individual consumers load curves were performed in periods of approximately 20 days (February-March). The meter is the conventional digital type, where each meter rotation produces an electric pulse. These pulses are counted by the electronic equipment that accumulates them in programmed intervals by the user (1, 5 or 15 min). Thus the power (demand) at the interval is determined. In order to achieve a good accuracy, curves were defined at intervals of 5 minutes i.e. 288 points on a daily curve were measured. A meter was located at the feeder of each of the selected flats in the building. The type of the measuring equipment used was a Multichannel meter. Measurements were also carried out close at the main feeder of the building and at the main feeder of the housing complexes. Based on a collection of measurements, the average electricity consumption was calculated by averaging consumption for each day of the month.

B. The Region under Study

Zawiyat al-Dahmani included village, homes were detached dwellings, bungalows, and terraced houses; the remaining 40% of homes flats in the blokes. 20% of the homes were less than 15 years old, 30% between 15 and 30 years old, 30% between 30 and 60 years old and 20% of houses were over 60 years old, the weather in this suburb is Mediterranean sea climate. The choice of this district because it contains many of the communities represented in vertical format identical buildings (the 108 flats form the housing complex of 6 blocks) in terms of space and the number of flats. Each block has nine floors; the floor has two flats with area of 180 m^2 each. In each flat there are three bedrooms, living room, dining room, two toilets and kitchen, and each bloke contain two lifts and two three phase pumps. This pattern of buildings can be seen throughout the city of Tripoli and even the entire country.

C. Questionnaire Output

A questionnaire was distributed to consumers of block number 2, nine consumers back it. The 18 flats selected for load measurements were less than 7 years old. 19% of flats had four occupants, 22% had two occupants, 23% had five occupants, 12% had six occupants and 24% had eight occupants. The income of the occupant of these flats, as reflected from the questionnaire, classified as an average. 75% of the occupants between 18 to 45 years old and the remaining are between 1 to 17 years old.

In all the surveyed flats, heating was provided by means of Electrical heaters. The other installations in the surveyed flats which consume electricity are divided broadly into three categories: lighting, kitchen and entertainment. The lighting installations are as follows: 90% of flats have halogen bulbs, 10% fluorescent tubes. The kitchens are as follows: most flats use microwave ovens. Each household has at least one fridge or fridge-freezer and 10% of the households have also separated freezers.

Eighty percent of the flats under test have different air condition, 80% have washing machine, and 90% have Irons. In terms of entertainment, each flat may have on the average 2.7 TV sets, 1.5 video recorders, 1.4 DVD players, 1 stereo system, 0.8 games consoles and 1 computer.

D. Household Types

There are two types of flats in the housing complex under study:

Type1: Single adult household, the occupier is a full time employee and the unoccupied period is considered from 9:00am to 6:00pm. The number of the flats represents a 54% of total flats covered by load measurements.

Type 2: Two adults with children, one occupant have a full time job and the other adult may have a part time job in the morning. The unoccupied period is considered from 9:00am to 1:00pm. The number of the flats represents a 46% of total flats covered by load measurements.

III. DISCUSSIONS

Daily load curves are obtained from the measured values of consumed energy for each flat during each day of the measurement period for all types of flats, where measuring equipment were installed. Mathematical and statistical analysis has been done using Excel and Minitab programs in order to generate domestic load profile for different consumption types, which can be found in details in [7] (as this paper cannot fit for the equations and the tables of measured data). Curves were classified for two measure types according to flats occupancy; i.e. working days and off days, and occupant style; i.e. single or family.

A. *Type1: Single Adult Household*

There are 7 flats for a single adult household (1, 4, 5, 10, 11, 17, and 18).

A.1. *Average Load Curve for Week Days*

Figure 1 shows the average daily load curve for one flat of the type one (single adult) on week days.

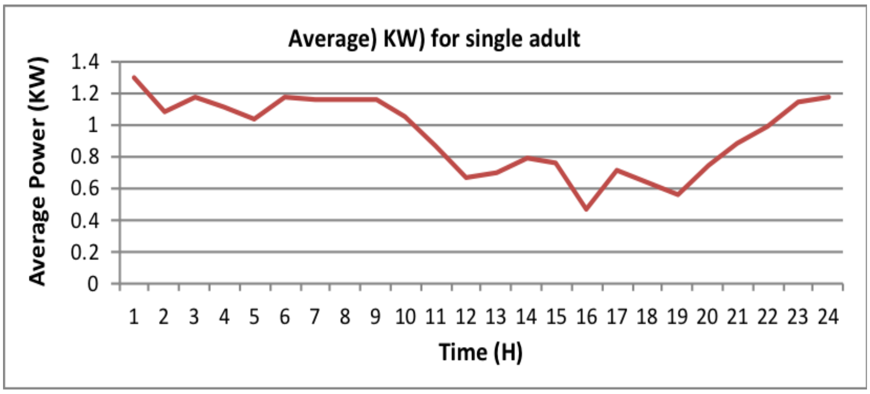

Fig. 1 The average daily load curve for single adult flats during week days

It can be noticed that a gradual increase in the electrical power consumption starting from 05:00 a.m. This is the wake up of some consumers at the dawn time where they began their daily activity and use of different electrical equipment for the preparation of their breakfast and taking shower. Such activities continue disproportionately among the flats which their occupants are ready for going out to work. The load consumption is then declining gradually, as a result of being out of the flats at different times. This slop continues until approximately mid-day where activities start to pick up, when some starts coming back from work. Such coming back reflects the demanding on power needs for preparing lunch, also using heaters due to the drop of temperature, this continues until 14.00 afternoons. One of Libyan habits is to relax after 14:00; as a result, power demand declines during that period, i.e. (14:00 till 16:00). However, as activity is resumed at 16:00, load starts to go up and down for a small period depending upon social activities as some visits and so on. Some of the occupants stay at their flats, but others leave. Power demand increases gradually around 18:30, as shown in the curve. It can be noticed thereafter through the curve starts gradually declining due to the gradual decrease of power demand, as most of the occupants reach sleeping time.

A.2. *Average Load Curve for Week Ends*

Figure 1 shows the average daily load curve for one flat of the type one (single adult) on week days. In weekends, occupants usually do not wake up early, as they do not go to work. The life style of a single adult leaving in a flat is different than that of a family. This can be seen quite obvious from the details of load curve. From 05:00 to 16:00, it can be noticed that the curve does not change much from flat line at 0.8 KW reading. The little increase and decrees reflects a minor change in the occupants habits as some still wake up early. This is due to the wake up of some consumers at the dawn time when they begin their daily activity and use of different electrical utilities such as utensils for preparation of the breakfast, taking shower and washing clothes with automatic washing machine, cleaning with vacuum, preparation of lunch and accompanying use of electrical devices inside the kitchen, such as electrical heaters, electrical ovens and watching T.V. After that the curve starts gradually declining due to the gradual decrease of power demand, due to the siesta of most consumers.

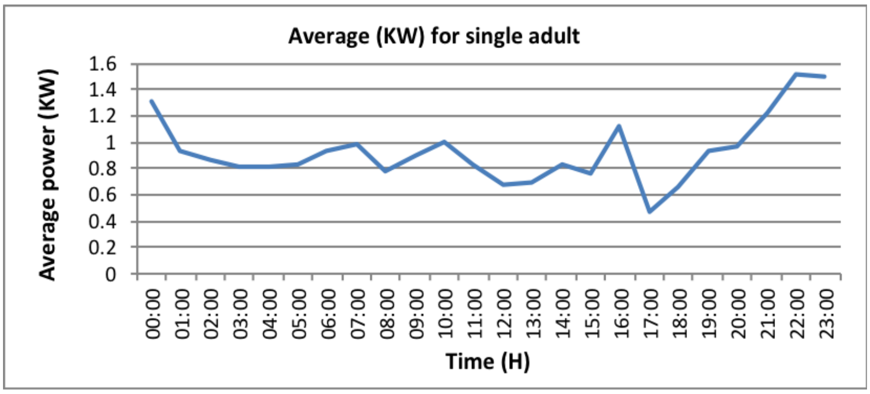

Fig. 2 The average daily load curve for single adult flats during week ends

At 18:00, the curve increases gradually due to the increase of power demand. This may be explained be returning back of some consumers who were out to stay at the flats until the next day. Another reason could be the severe decrease in temperatures, particularly in evening, increase of heating demand until 22:30. At this time the curve starts gradually declining due to the gradual decrease of power demand. Then the curve takes approximately constant shape, increases or decreases slightly, due to some equipment working automatically during sleeping time, such as heaters, water heaters and refrigerators, thus it continues until 5:00. For single adult occupant flats, the maximum consumption recorded between 20:00 to 24:00 is 1.5 KW. This is understood since the occupant usually stays in their flats at these times and uses the electrical equipment. From 14:00 to 17:00, another peak is recorded since this time is common for preparing the lunch and using the washing machines. The minimum average power is around 17.00 because most occupants are outside their flats either to visit friends, families or to go shopping.

B. Type 2: Two Adults with Children Household

There are 6 flats for two adults with children households (3, 6, 7, 8, 9, and 12).

B.1. Average Load Curve for Week Days

Figure 3 shows the average daily load curve for one flat of type two (two adult with children) on week days. At 06:00, a gradual increase of the demand on electrical power can be noticed. This is due to the wake up of some of occupants living at this type of flats at dawn time when they begin their daily activity as mentioned before. Such activity continues disproportionately among the people who are ready for going out to work until 8:30, when consumers start leaving to work and children to schools. The curve gradually decreases, and continues in such decrease until 11:00, thereafter starts to increase due to the increase of demand on power by the housewives, starting the activities that can increase the consumption of electrical power, such as washing clothes with automatic washing machine, cleaning with vacuum, preparation of lunch and accompanying use of electrical devices inside the kitchen. The curve continues increasing until 18:00. After that, the load curve fluctuates between increase and decrease for short periods. Until 23:00. Then the curve starts gradually declining due to decrease on power demand and consumers go to bed. The curve afterwards takes stable shape and the base load is only on automatic equipment during sleeping time, such as heaters and refrigerators, it continues until 06:00.

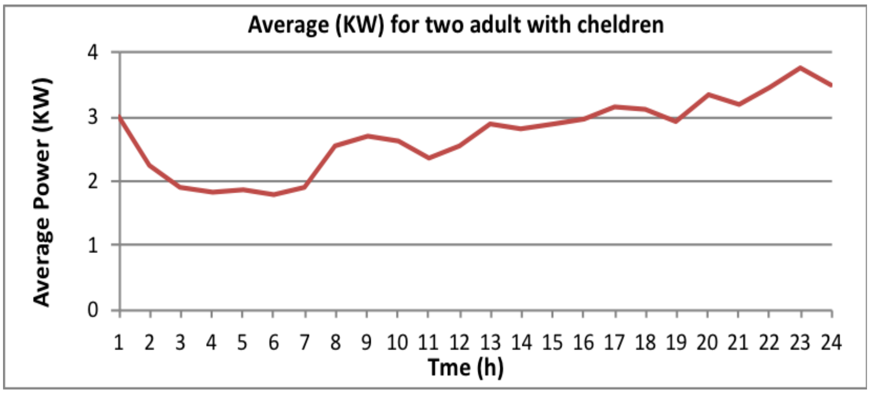

Fig. 3 The average daily load curve for two adults with children during week days

B.2. Average Load Curve for Week Ends

Figure 4 shows the average daily load curve for one flat of type two on weekends. From 06:00 to 16:00, a gradual increase and decrease on the electrical power consumption can be noticed due to the different daily activity of the families as mentioned before, after that the curve starts gradually declining due to the gradual decrease on power demand. Then at 17:00, the curve increases gradually due to the coming back of other consumers who were out, also due to the severe decrease in temperatures, particularly in evening. After 23:00, it can be seen that the curve starts gradually declining due to the gradual decrease on power demand, since most of consumers go to sleep. Then the curve takes approximately constant shape, increases or decreases slightly until 06:00. For two adults with children occupant flats, the maximum consumption recorded between 18:00 and 24:00 was 3.73 KW.

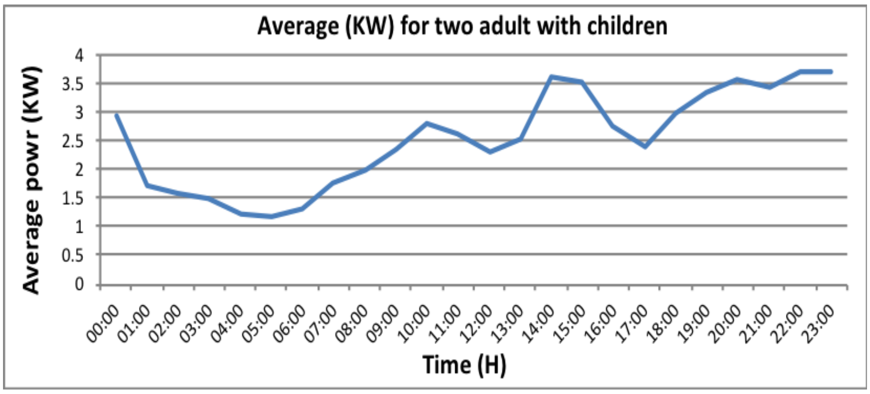

Fig. 4 The average daily load curve for two adults with children during week days

C. All Flats with Two Types Household

C.1. Average Load Curve for Week Days

Figure 5 shows the average daily loads curve for all flats with two types on week days. The curve shows similarities in the behavior with the one presented in Figure 3 which is average daily load curve of flats with two adults with their children. The similarity of the two curves is due to consumers living in this type of flats. It also may be attributed to the fact that the average always biased to the dominant values, which is in this case the consumption of the flats with bigger family members. The key factors of the behavior of this carve is the same as mentioned in the commentary on Figure 3.

As the power consumption depends on the size of the family and the available facilities at home, electrical power consumption in modern house increases after sunset, since this time people usually stay at homes and relax having meals and watching T.V. This was notable since the demand of power goes to minimum and load curve start declining since midnight the use of electrical power is limited to heating or a little light.

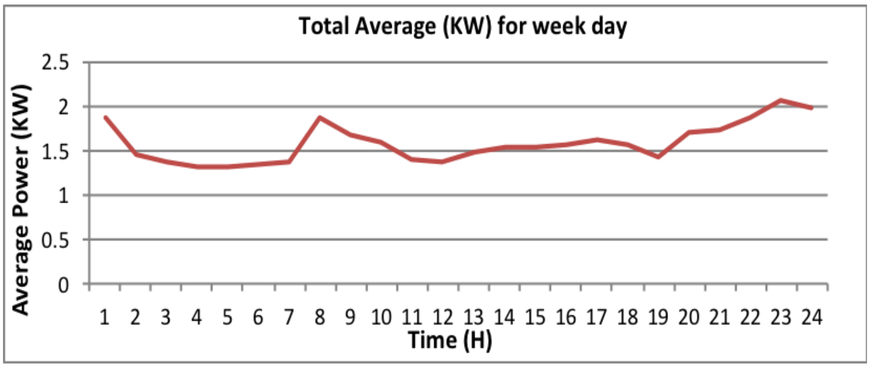

Fig. 5 The average daily loads curve for all flats with two types on week days

C.2. Average Load Curve for Week Ends

Figure 6 shows the average daily loads curve for all flats with two types on weekends. It can be seen that the behavior of the curve is not more different than the curve of total average (KW) for weekends illustrated in Figure 4. The similarity of the two curves is due the same reasons that mentioned in the previous section.

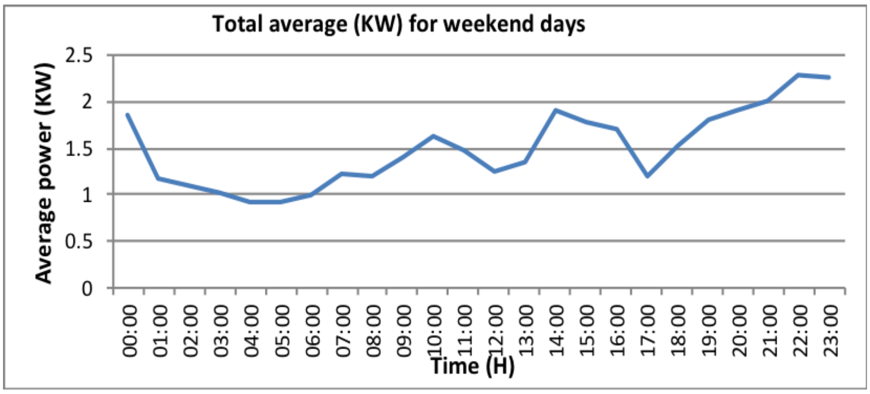

Fig. 6 The average daily loads carve for all flats with two types during weekends

D. Daily and Average Load Curves As Measured On the Main Cable

Figure 7 shows the average daily electricity load profiling for the main distribution box (DB). The average load curve records its minimum values between 01:00 and 05:00. At this time the main load is lighting, fridges and freezer (which usually stay on all the time. The maximum consumption was recorded between 23:00 and 24:00 was 34 KW. From 05:00 to 08:00, another peak is recorded since this time is common for preparing the breakfast and taking shower. And the minimum average power is15 KW around 05.00 because the most occupants are sleeping.

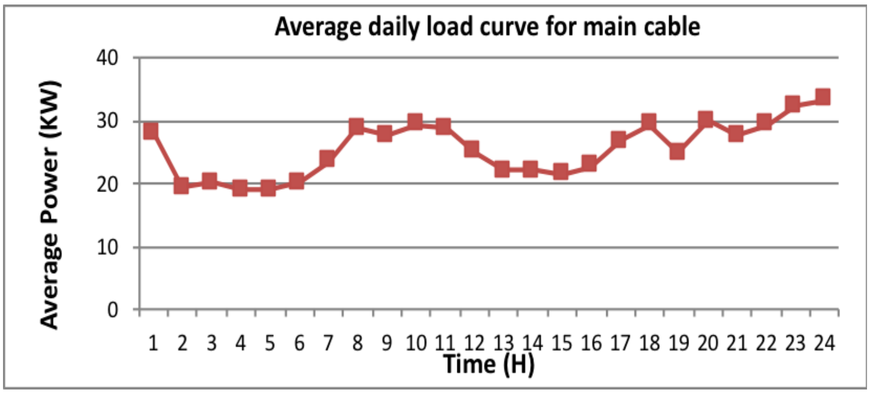

Fig. 7 The average daily Power (KW) for the main distribution box during week days

IV. COMPARATIVE ANALYSIS

A. Comparison between Main Cable Load Curve and Average Load Curve of the Flats

The plots of actual load curve for the flats as resulted from individual load of each flat (Total average KW for (13) flats in block 2 = Max. Average power per flat * No. of Flats in Block 2 (which is 13)) and the load curve as measured at the main feeder are shown in Figure 8. In normal cases, these two curves should be very close to each other and never coincides. This curve represents the sum of average electrical load for all flats of the two previous types of consumers, and the average electrical load measured at the main cable to all flats. The main difference between the two curves is the power consumed in lifts and water pumps. However, four flats (flat13, flat14, flat15, flat16) were not included in the measurements due to social and technical impairments. The common area lights for all block (2) are also not included.

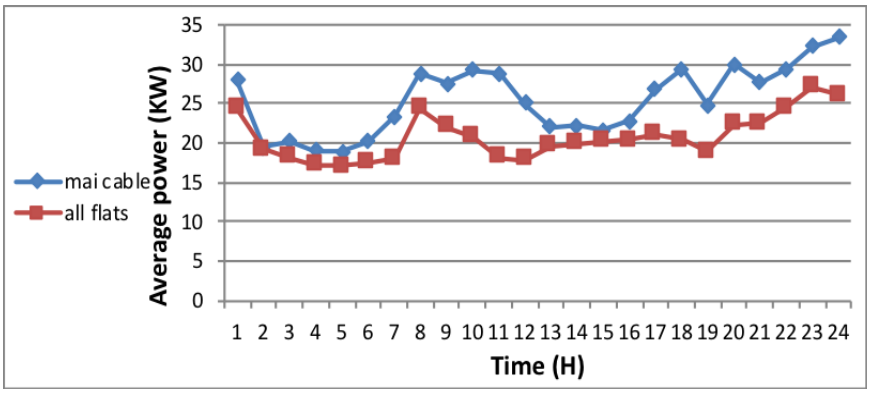

Fig. 8 The average daily load curves for the main cable and all flats in building No. 2.

B. Average Daily Flat Load Shape

Figure 9 shows the average Daily Flat Load Shape in one day. The fluctuation in the power consumption is from 2.2 KW max to 1.33 KW min. This means the power consumption by consumers are nearly the same during each day of the week (including weekends), which reflects the power consumption behavior of the residents using different appliances in different times.

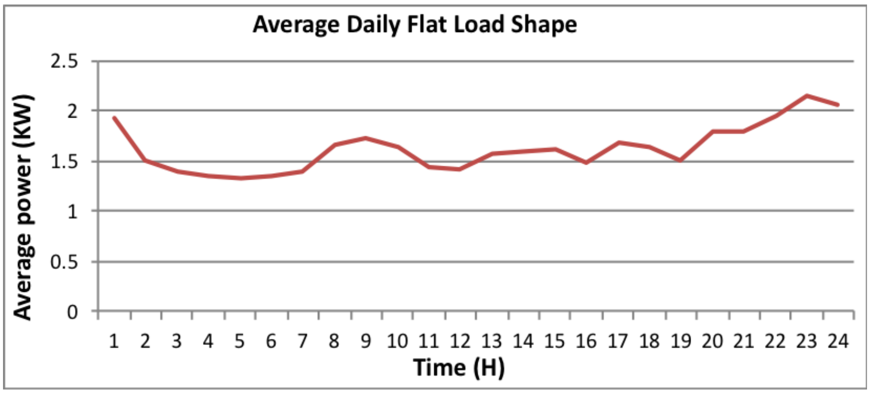

Fig. 9 The average Daily Flat Load Shape.

C. Comparison between the Outcomes Obtained from this Study and the Outcomes of the American Consultant Cadmus Study

As mentioned before, the Cadmus Group (Cadmus) with other corporations were contracted by the General Electricity Company of Libya (GECOL) to provide an assessment of the demand side management (DSM) potential in Libya in 2009. Table 1 shows the comparisons of the main outcomes which demonstrate that the outcomes in terms of the average power may differ based on the accuracy and the parameters, such as a pure residential feeder or mixed one, included in the measurements and calculations.

TABLE 1 A comparison between this study and the Cadmus 2010 study

Study	Flat Area (m^2)	Measurement Areas	Time of Measurement	Duration between each reading	Measurement Period	Daily demand in (KW)		
						Avg	Max	MIN
This study	180	Zaweet Eddahmani	All the day long for 20 days	5 minutes	All the daylong for 20 days in February and March	2.72	3.77 at 10 P.M	1.77 at 5 A.M
Cadmus 2010 study	200	Airport road – Azzuhur quarter - Enjila	All the daylong for 15 days	15 minutes	All the daylong for 15 days from 12/2010 to 01/2010	1.8	2.4 at 7 A.M	1.4 at 5 A.M

V. CONCLUSION

This paper presents a method of generating realistic electricity load profile data for the city of Tripoli domestic buildings. This method is based on the information and results of previous investigations and works that is available in the public reports and statistics. Two household types, which present the behavioural characteristics and common occupancy pattern in the city of Tripoli, have been proposed to regenerate the diversity in electricity consumption between households. The five minutes daily load profiles for proposed community of 108 flats have been generated for the various types and then the average electricity consumption for individual flat has been calculated. The generated load profiles show a good agreement in flats load profiles compared with the other residential types of the city.

This method has allowed the creation of typical seasonal and lifestyle activity profiles from statistical data. These profiles play an important role in predicting the future electricity demand and in designing and distributing the loads. The daily load profile from individual dwelling to community can be predicted using this method. The measurements reflected the consumption behaviours of different size of families during working and weekend days. The measurements conducted under this study may be considered as of high accuracy. That is because the measuring units measure at (5) minutes intervals and the selected area is 100% residential, i.e. no other type of loads are fed by the main feeder to the complex.

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