ESTIMATION OF ELECTRICITY DEMAND FOR REMOTE AREA POWER SUPPLY SYSTEMS INCLUDING WATER DESALINATION AND DEMAND SIDE MANAGEMENT MODELS

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ABSTRACT

This paper presents a technique for generation of daily electric load profile for remote areas in the Middle East from first principle. The generated load profile includes energy required to run a small desalination unit to provide necessary fresh water. Demand Side Management (DSM) is used in this study to smooth out the daily peaks and fill valleys in the load curve to make the most efficient use of renewable energy resources. Finally, the load profile is compared with real data for 6 houses collected from Safri area in the Sultanate of Oman; these data may be used as the basis to obtain the load profile in other remote areas of the Middle East since socio-economic and spatial factors are similar.

1. INTRODUCTION

One of the most important problem for the designer of a renewable energy based power system is to know the exact nature of energy consumption and renewable energy resources during a given period. This information is important because it leads to more effective demand side management [1].

The load behaviour affects significantly utility planning and strategic corporate objective (improve earning and cash flow reduce risks etc) [2]. To achieve these business objectives, generic load shape changes are often necessary, such as clipping, valley filling, load shifting, energy conservation, load growth and flexible reliability. So, an investigation of energy consumption is necessary in conjunction with the general shape of its load and the variation of this shape during the year [3]

An electrical daily demand curve for a typical small community in the Middle East is essential for designing a power supply system based on renewable energy resources in order to reduce the capital and operation costs. Although these communities are remote their living standards are comparable to their urban counterparts. One of the major difficulties is the unavailability of data for the electrical demand as typically no measured data for the small communities are available. In this study the load curve is generated using diversified- demand, taking into account, the diversity between similar loads and noncoincidence of the peaks of different types of loads.

The aim of this study is to generate a typical electric load profile for small community in the Middle East from first principle using diversified- demand and demand side management (DSM). This may entail shifting energy use to off-peak hours, scheduling loads when solar irradiation is high reducing energy requirements overall or increasing demand during off peak hours and using more efficient appliances and equipment. Finally, load for water desalination unit will be calculated according to water demand per capita.

2. METHOD OLOGY

The method that is used to generate the daily load profile is maximum diversified demand, which is explained in the following section:
Diversified demand is the demand of the composite group, as a whole, of somewhat unrelated loads over a specified period of time. Here, the maximum diversified demand has an importance. It is the maximum sum of the contribution of the individual demands to the diversified demand over a specific time interval. Nonconcident demand is defined by Manning [2] as the sum of the demands of a group of loads with no restriction on the interval to which each demand is applicable.

Arvidson [5] developed a method of estimating distribution loads in residential areas by the diversified-demand methods, which takes into account the diversity between similar loads and noncoincidence of the peaks of different types of loads.
To take into account the noncoincidence of the peaks of different types of loads, Arvidson introduced the hourly

variation factor. It is the ratio of the demand of particular type of load coincident with the group maximum demand to the maximum demand of the particular type of load [2]. Table 1 gives the hourly variation curves of various types of household appliances.

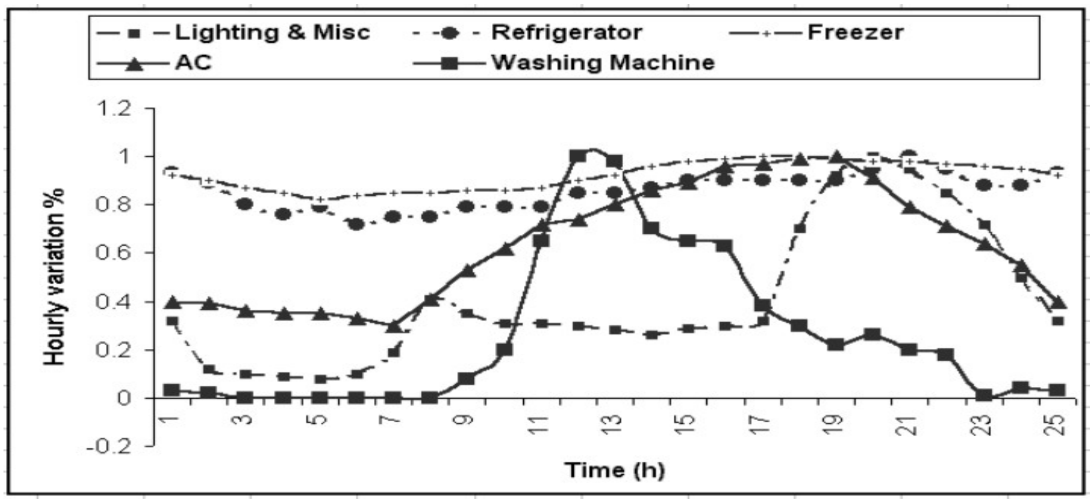

Figure 1: Hourly variation factors [5]

Using above method to determine the maximum diversified demand for a given saturation level and appliance, the following steps are taken in this paper

- Determine the total load of appliances by multiplying the total number of customers by the percent saturation
- Read the corresponding diversified demand per customer from the curve, in [5], for the given number of appliances
- Determine the maximum demand, multiplying the demand by found in step 2 by the total number of appliances
- Finally, determine the contribution of that type of load to the group maximum demand by multiplying the results value from step 3 by corresponding hourly variation factor found from figure 1

Table 1 shows the appliances in a typical Remote Middle Eastern house.

Appliances	Numbers of appliances	Rated power (watt)
AC	03	1500
Freezer	01	160 W
Fan	10	50 W
Refrigerator	01	68 W
TV	01	60 W
Video	01	10 W
Washing machine	01	1000 W
Cassette recorder	01	8 W
Lights	20	18 W
Vent. Fan	03	32 W

Table 1: Appliances in a typical Middle Eastern house

Figure 2 shows the calculated summer daily load curve using above method for small village in Middle East with six houses and with real data for 6 houses collected from Safri area in the Sultanate of Oman.

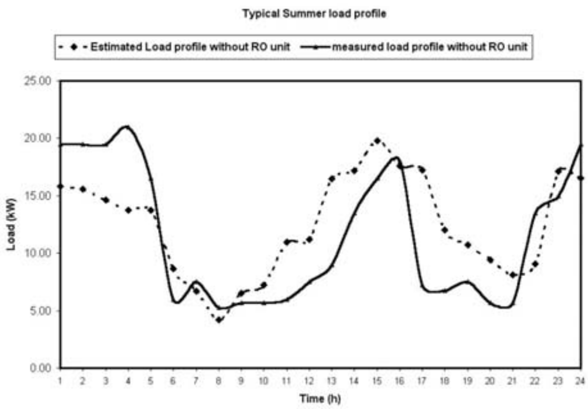

Figure 2: Estimated and measured Load curves of Remote areas In Middle East, without desalination unit

As can be seen in figure 2 the measured and estimated curves are the same in shape with two hops each. The maximum absolute percentage error is 3.56 %, which is acceptable. So the method is very suitable to find load demand for remote areas where there is the lack of real data.

3. WATER DEMAND CALCULATION

It is very important to calculate the water demand per capita per day. The following guidelines were used for these calculations [6]. People uses 40 to 400 litres of water per capita per day, depending on culture and conservation measure.

Since this project is about Middle East, where the people usually consumed more water than other parts of the world despite the shortage of fresh water. So the water average demand per capita per day is set to be 150 litres.

When above guidelines are used the water demand, if the average groups size are taken to be 6 families (the average family size in Middle East is 5 members) with 30 people is 4500 litres or 4.5 m^3 . Taking safety factor of 1.2, the total demand is 5 m^3/day. In this project the fresh water tank should of capacity to store of two days demand.

4. ELECTRICITY DEMAND FOR DESALINATION UNITS

In this study, power requirements for desalination unit. The desalination technology, used, is membrane separation using Reverse Osmosis. Reverse Osmosis (RO) has been chosen because it is the cheapest desalination technology and also it is commercially available in a range of sizes [4]

The RO desalination plant component takes in account of the net power required for seawater or brackish water desalination which is the power that desalination plant consumes minus the power recovered (if present) by recovery turbine plus the power required for lifting water from the sea or well and power required for lifting product water to the drinkable water reservoir. Some power consumption of auxiliary equipments, such as dosing pumps and back flushing pumps, has been also taken into account.

According to Reverse Osmosis manufacturer [7] power required to produce 5 m^3 per day is 1.8 kW. So the total load profile when the RO unit operates whole day is shown in figure 3. This means the daily energy requirement for desalination unit is approximately 45kWh.

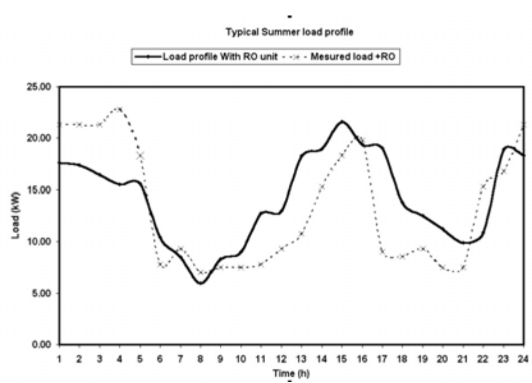

Figure 3: Estimated and measured Load curves of Remote areas In Middle East, with desalination unit running 24 hours a day

5. SOLAR RADIATION

It is very important to analyse the hourly solar radiation for the selected site. The solar radiation used in this study is from Thamrait location in Sultanate of Oman. Figure 4 shows the solar radiation and electric load demand for one day not including power required for desalination unit

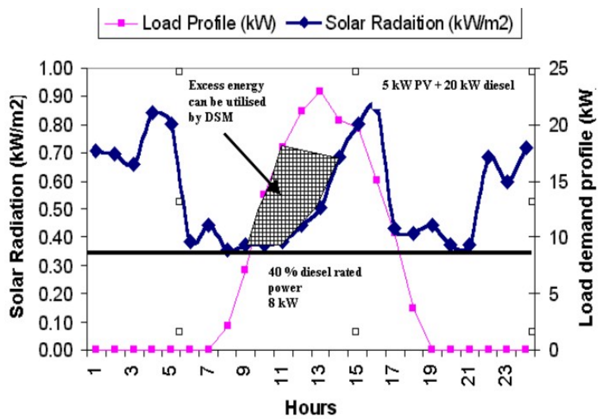

Figure 4: Estimated and measured Load curves of Remote areas In Middle East, with desalination unit

Figure 4 shows the possibilities of using Demand Side Management during the period power from PV is available in the hybrid system, which has 5 kW of PV and 20 kW diesel generator. To use the diesel generator in efficient way, it should not run below 40% of its rated power. In this system, 40% of rated power is 8 kW plus 5 kW from PV generator the desalination unit can be limited to the shaded area in figure 4.

6. DEMAND SIDE MANAGEMENT

In the remote area power supply systems based on renewable energy sources, it is very important to utilise all available power resources especially renewable energy. This can be done by using Demand Side Management (DSM).

In this study DSM can be implemented: (1)-desalination unit scheduled to run during low load demand, that will lead to smooth out the daily peaks and valleys in load curve to make the most efficient use of energy resources. (2)-by use of more efficient appliances to reduce further daily energy demand that reduces the size of the system.

Finally, since the air conditioners are main contributor of energy consumption in the Middle East, they should have very high efficiency and the rooms in the houses are to be insulated with temperature control.

Figure 5 shows load profile when desalination unit runs during off peaks hours and it can be seen very clearly DSM reduced the peaks in the load curve.

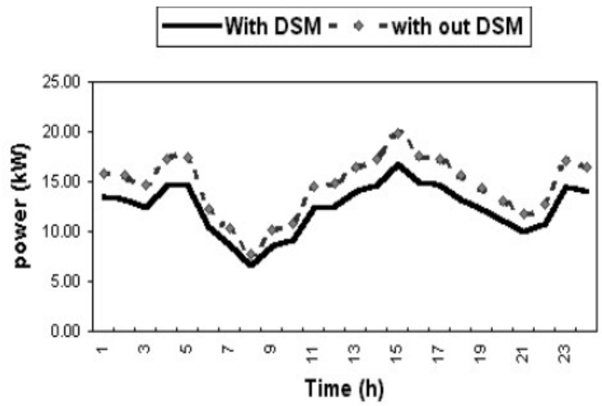

Figure 5: Load curve of Remote areas In Middle East with and without DSM

7. RESULTS

Results of a typical study on a 6-house remote community including Reverse Osmosis desalination unit for water supply are presented

Figure 2 shows the daily load curve as calculated with and without desalination unit and measured data. Measured and calculated values are in close agreement and show the capability of the mathematically computed load curve.

Figure 4 shows how peak clipping and valley filling approach can be used to reduce the peak electricity demand from renewable energy sources and reduce the need for energy storage respectively.

8. CONCLUSION

This paper has shown that it is possible to generate load profile for remote area from first principle using diversified demand with very high accuracy. By using Demand-side management the power supply system components can be reduced in size and the energy available will be utilised in proper way. Which will lead to reduce the capital cost of the system. Further study should investigate the use of solar hot water systems

9. REFERENCES

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