Impact on Power Planning due to DSM in Commercial and Government Sectors with Rebound Effect – A Case Study of Northern Grid of Oman

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***Abstract* — This paper presents the results of a study carried out to estimate the DSM energy saving potential in commercial, and government/institutional sectors of Oman and evaluates its impact on generation capacity and energy savings (Northern Grid area). The end-use (lighting and air-conditioning) energy consumption data have been collected in two major segments of the commercial sector for simplicity and to save time and money. The study has found that due to DSM the capacity saving at the horizon year is between 372-596 MW and the overall energy saving for the whole planning horizon is about 29-44 TWh. The total avoided cost in generation and capacity saving is somewhere between 416-597 million dollars.**

***Index Terms* — Power planning, Demand-side management, Energy conservation.**

I. Introduction

The utility planning process which takes into account both the supply- as well as demand-side options to meet the demand forecast is known as integrated resource planning (IRP) [1]. In many IRP processes the resource contribution from DSM programs could be very large because of untapped resources that exist. For screening the large number of DSM options available and identifying the most promising options avoided costs method is used to estimate their value to the utility system [2]. To reduce the large number of DSM options in the resource planning process the individual DSM options are bundled together into larger resource blocks. The economy of aggregated bundles of DSM options is tested by the avoided cost method. The avoided cost has two components of savings the energy costs savings and capacity cost savings. The planning horizon is optimized twice; one with a base case set of loads and another with load shape changed by the expected load impact of DSM. Avoided cost is then calculated by the difference in energy and capacity costs of the two optimized cases [3].

The first DSM study in Oman (1998), ‘‘The Study on Demand Supply Management for Power Sector in Sultanate of Oman’’, was conducted by Japan International Cooperation Agency (JICA). The study identified several strategies for potential load management [4]. However, the recommendations of the study have not been implemented since then.

This paper presents the results of a recent study, undertaken at Sultan Qaboos University, that estimated the DSM energy saving and load management potential in commercial and government/institutional sectors in Oman and evaluated its impact on generation capacity and energy savings [5]. The commercial and government sectors in Oman includes service businesses, retail and wholesale stores, hotels and restaurants, Government Ministries, schools and universities, and hospitals and health clinics. The diversity of the end-uses and the technologies available in these buildings requires a large stratified sample. To do a survey with such a large sample size would be difficult because of the poor availability of statistical data and obtaining financial support for such a project. Therefore, the energy saving potential in only two end-use functions, i.e., lighting and air-conditioning, is looked at because these two end-use functions constitute a major energy consumption (79%-96% of the surveyed samples) in these sectors regardless of the activity in both physical and economic terms. The scope of the study is further limited to find the DSM potential in large customers of commercial and government/ institutional sectors only. The commercial sector represents about 16% and government sector represents about 18.4% of the total consumption in 2003 [6]. The load forecast and generation data was taken from Ministry of Housing, Electricity and Water (MHEW) of Oman and the software used to optimize the generation plan is Wien Automatic System Planning (WASP) [7]. The software has its own modeling limitations; for example the transmission and distribution are not modeled. Because of this limitation the saving in (T&D) capacity cost due to DSM measures is not quantified. However, the reduction in T&D losses is worked out as explained in section two of the paper.

The paper is arranged in six sections. Section one is an introduction. Section two in brief provides a general methodology adopted to carry out the study. Section three provides an overview of electricity tariff structure in Oman. Section four provides generation and load data of interconnected northern grid system. Section five presents the results of generation capacity and energy savings. And the last section concludes the paper.

II. GENERAL METHODOLOGY

The estimate of DSM potential is based on a survey of 6 large commercial (shopping malls) customers and 6 large government/institutional customers. The annual energy consumption of these 12 customers represents about 4.6% (127.6 GWh) of the total consumption (2,775 GWh, year 2003) in these two sectors. The energy saving potential is worked out in only two end-use functions, i.e., lighting and air-conditioning, because these two end-use functions constitute the major energy consumption (79%-96% of the surveyed samples) in these sectors regardless of the size of the activity in both physical and economic terms.

To work out the potential of DSM, in these two sectors, the following procedure is adopted:

1. A survey questionnaire was designed to get the data needed from the commercial and government/institutional sectors. The first section of the survey requests some general information about the building such as floor area, electric end-use penetration rate, and annual power consumption. The second section surveyed on lighting end-use share, percentage efficiency and the lifetime of the lighting system and devices. The last section of the survey requires information about the air-conditioning system in the sector, its end-use share, percentage efficiency and lifetime of the air-conditioning equipment.
2. From the catalogue information available for the efficient cooling and lighting devices [8-9] the cost of efficient cooling and lighting functions were then worked out as 9.4 OR/m2 and 2.1 OR/m2 respectively (1 Omani Rial (OR) = 1000 Baizas (Bz) = 2.58 US$).
3. The estimate of total energy saved in lighting and air-conditioning function for each customer was worked out using the percentage of efficiency save in lighting and air-conditioning, if the existing lighting and air-conditioning systems were replaced with more efficient equipment, and multiplying the annual consumption in lighting and air-conditioning respectively.

After getting the DSM potential the benefit of DSM from the utility point of view is estimated using the following procedure:

1. An aggregate energy saving potential is worked out with the assumption that the reduction in power consumption due to DSM in the sample data is representative of the actual potential in both the sectors. However, standard error analysis (95% confidence interval) is also done from the sample data by normalizing the energy saved in the 12 customers' sample. Sector-wise analysis of variance has shown that the standard error of average reduction in power consumption was not significantly different (8.8% and 8.3% for commercial and government sectors respectively) and the pooled standard error is 8.6%. Moreover, the rebound effect is also studied. Rebound effect suggests that the technical saving potential may not be a correct indicator as consumers may use more energy in other areas. Rebound effect varies across countries even for a particular DSM program. A study done in commercial/household sectors in Norway found that the rebound effect is 10%-40% [10]. Using these two limits the range of DSM benefit from electric utility point of view is estimated.
2. The sectoral energy consumption from 1999-2003 taken from [6] is extrapolated and forecasted till 2024 (end of study period).
3. The energy forecast in commercial and government sectors is then converted to peak demand forecast by using the following expression:

$$Peak\ Demand\ (MW) = \frac{Annual\ Energy\ Consumption\ (MWh)}{LF \times 8760\ hrs} \quad (1)$$

where LF is the system load factor. Here an assumption is made that the load factor of both government and commercial sectors are same as the average system load factor of 53%. The average system load factor was calculated using the past data of average demand divided by the actual system peak demand.

4. To get the contribution of peak demand of both sectors toward the system peak another assumption is made that the peak coincident factor of government sector is 100% of the system peak and commercial sector is 80% of the system peak. This assumption is based on the fact that the system peak occurs between 2:00-4:00 pm in July (actual data) when all the Government offices are working (100% coincidence, assuming it is basically air-conditioning load) and major commercial stores and buildings are open while some of the commercial retailers are closed (about 80% coincidence assumed).
5. The peak losses are calculated from the average system losses from the following expressions [11]:

$$Peak\ \ losses\ = \frac{Average\ \ System\ \ losses}{Peak\ \ loss\ \ factor} \quad (2)$$

The average of system losses of eight years from 1995-2002 is 18.25% [6]. The peak loss factor in (2) is the ratio of the energy loss in the system during a given time period to the energy loss that would result if the system peak loss had persisted throughout that period. The following empirical approximation is used to calculate the peak loss factor [11]:

$$Peak\ loss\ \ factor = 0.3LF + 0.7LF^2 \quad (3)$$

6. The combined commercial and government peak demand to be supplied from the generation end is then calculated by the following formula

$$Combined\ \ Peak\ to\ be\ supplied\ = \frac{Peak}{100\% - Peak\ losses} \quad (4)$$

TABLE I
IMPLEMENTING DSM IN GOVERNMENTAL AND COMMERCIAL SECTORS

	Actual energy consumption (GWh)	Modified energy consumption (GWh)	Energy Saved (GWh)	Estimated Percentage Reduction (0 % rebound effect)	Standard Error in the energy saved (%)	Percentage Reduction with 40% rebound effect	Percentage Reduction with 10% rebound effect
Governmental Sector	78.76	62.12	16.64	21.1%	8.8 %	12.7%	19.0%
Commercial Sector	48.85	30.05	18.8	38.5%	8.3 %	23.1%	34.6%

7. The combined reduction in peak in both sectors is then worked out with the estimated percentage reduction from the sample data and considering the reduction upper and lower limits with 40% and 10% rebound effects respectively. The system peak is then modified accordingly.
8. The utility benefit in terms of avoided cost of generation capacity and energy is then worked out by optimizing the planning horizon thrice; one with a base case set of loads and the other two cases with load shape changed because of DSM that is having 40% rebound effect and 10% rebound effect.

III. ELECTRICITY TARIFF STRUCTURE

The government of Oman provides a large subsidy to the electricity sector, where the domestic sector takes the most of this subsidy because it constitutes the main service receiver among the power consumers. However, the average returns of the electricity sector from the domestic slab constitute 50% of the total subsidy of the government. In addition, the government of Oman provides generous subsidy to other sectors. There are several electricity tariff structures in different sectors. These sectors are: Domestic, Commercial, Industrial, Agriculture and Fisheries, and, Hotels and Tourist Establishments. The domestic tariff increases with the quantity of consumption and starts from 10 Bz/kWh for the first 3000 kWh of consumption and end at 30 Bz/kWh for consumption more than 10,000 kWh. The commercial tariff is 20 Bz/kWh without any maximum unit for consumption. The industrial tariff in summer is 24 Bz/kWh and 12 Bz/kWh in winter season. The summer is taken from May to August for Northern grid system. The other tariff rates can be found in Annual report of MHEW [6].

IV. GENERATION AND LOAD FORECAST DATA

The generation expansion planning is carried out for the Northern grid system from 2005 to 2024. The Northern Grid power system area comprises mainly six interconnected power stations, which are Ghubrah, Rusail, Barka, Wadi Jizzi, Alkamil and Manah stations. The interconnection between these stations is through 132 kV transmission lines. However, recently Barka power station is connected with the Northern grid through 220 kV lines. All the power stations are operating on natural gas as fuel. The total capacity of these stations is about 2517 MW (year 2005). The power transmission and distribution system mainly consists of 132 kV, 33 kV, and 11 kV and 415 V. Until recently 220 kV line from Barka station is constructed to connect the station to the main 132 kV grid. Only few kilometers of 66 kV line also exists. The overall system losses reported in 2003 were 20.83%. The generation data collected from MHEW was manipulated, refined, and made suitable for WASP-IV input. For some of the missing data, typical values found elsewhere were used. The generation data for fixed plants, committed plants and candidate plants can be seen in [5] the load data is presented here.

A. Load Data

The surveyed governmental buildings annual consumption is 78.76 GWh, which represents about 5.31% of the total governmental sector consumption in Oman. Similarly, the surveyed commercial buildings annual consumption is 48.85 GWh, which represents about 3.78% of the total commercial sector consumption in Oman (2003) [6]. An aggregate energy saving potential is worked out with the assumption that the reduction in power consumption due to DSM in the sample data is representative of the actual potential in both the sectors. Table I shows the percentage of energy consumption reduction by implementing DSM in commercial and governmental sectors. Also shown are the standard error and the percentage reduction in peak because of 10% and 40% rebound effect.

Figure 1 shows the energy consumption forecast of government and commercial sectors up to 2024 using linear regression on the 5 year actual energy consumption data. The DSM energy forecast is made, also shown in Fig. 1, using estimated percentage reductions of table I.

TABLE II

RESULTS OF OPTIMAL GENERATION EXPANSION PLAN FROM 2005 TO 2024

Cases	Present worth cost (thousand $) Obj. Fun. B_j (Cumm.)	Average LOLP %	Cumulative Candidate Plants (No. of Units)			Cumulative Capacity (MW)	Cumulative Energy (GWh)
			FRM9	FRM6	BRKA		
Base (Case 1)	3801320	0.797	16	0	6	6217	413752
DSM with40% rebound effect (Case 2)	3385609	0.496	12	0	6	5845	384588
DSM with10% rebound effect (Case 3)	3204479	0.527	5	0	7	5621	369961
Difference (Case 1-Case 2)	415711	0.301	4	0	0	372	29164
Difference (Case1-Case 3)	596841	0.270	11	0	(1)	596	43791

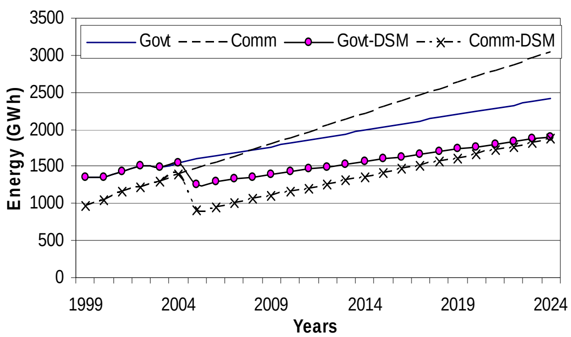

Fig. 1. Forecast of energy consumption in Government and commercial sector with and without DSM.

The energy forecast of government and commercial sectors is then converted to peak demand forecast using (3). The system peak reduction from generation end is worked out as explained in the steps of section two. Figure 2 shows the system peak demand forecast, taken from MHEW, and the modified system peak demand with 40% rebound effect and 10% rebound effect. The annual chronological load data of year 2003 taken from MHEW was used for making normalized load duration curve (LDC) shapes. The year was divided into two seasons and 2 LDC shapes were formed [5].

VI. RESULTS AND DISCUSSION

To investigate the DSM benefit from the utility point of view the avoided cost method is used. The avoided cost of generation capacity and energy is worked out by optimizing the planning horizon thrice; first with a base case set of loads (Case 1), second with load shape changed by the expected load impact of DSM with 40% rebound effect (Case 2) and the third with 10% rebound effect (Case 3). Table II provides the summary of the optimization results. The table shows the present worth of total cost (cumulative objective function in thousands of dollars), the average loss-of-load probability index, and the cumulative candidate plants selected over the planning horizon. The table also provides the cumulative capacity selected in each case and the energy requirement for all the three scenarios. The difference in cost, capacity and energy of Case 1 and Case 2, and Case 1 and Case 3 is also shown. The overall cumulative cost difference over the planning horizon (avoided cost = $B_{j,\ base} - B_{j,\ DSM}$) with 40% and 10% rebound effect is about 416 and 597 million dollars respectively. At the horizon year the capacity and energy difference from the base case is about 372 MW and 29.2 TWh for 40% rebound effect, and 596 MW and 43.8 TWh for 10% rebound effect.

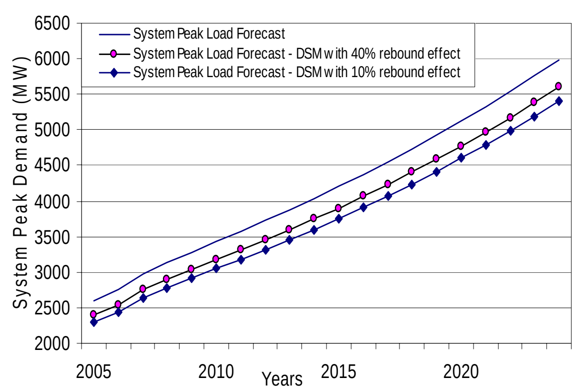

Fig. 2. System peak demand forecast with and without DSM.

VII. Conclusions

The study has shown that by applying DSM programs in the government and commercial sectors the energy consumption can be reduced up to 21% and 38% respectively with 8.6% standard pooled error. From the supplier (MHEW) point of view the capacity saving at the horizon year ranges between 372 MW to 596 MW considering 40% and 10% DSM rebound effect respectively. Likewise, the overall energy saving for the whole planning horizon ranges between 29-44 TWh and the total avoided cost saving from 416-597 million dollars.

One of the problems which faced the countries that applied DSM is motivating costumers to pay for replacing their inefficient devices. Financing DSM remains a significant issue in most places. Many countries have imposed DSM taxes within power tariff schemes. Other governments have opted to fund DSM programs for low-income customers as a social program, and effectively pay the utility to implement the program.

Finally, it can be concluded with confidence that Demand Side Management has positive outcomes for consumers, MHEW, environment and the national income which makes it strongly recommended to start thinking about implementing it in Oman.

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