A COST ANALYSIS OF DEMAND SIDE MANAGEMENT FOR DIFFERENT PRICING STRATEGIES

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Abstract: As the world is moving towards the era of smart scenario, conventional grid is also transforming into smart grid worldwide. One of the major issue in the smart grid technology is the Demand side management where the consumers are given priority to change their load pattern according to their level of comfort with respect to the pricing strategy imposed by the utility side. Various pricing strategies are being followed in different countries based on the availability of the generating capacity to meet the load demand. The pricing strategies also vary based on the type of consumers such as industrial, commercial and domestic purposes, since their demand levels are different. This paperprovides clarity to various pricingstrategies and its cost analysis to a domestic consumption.

Keywords:*Demand Side Management, Time of use (TOU), Critical Peak Pricing (CPP)*

I. INTRODUCTION

The lifestyle across the globe is drastically changed and is moving towards the era of smart living environmentwhich makes the life ease and comfort. Smart phones for communication, smart board for the class rooms, smart vehicles for transport,smart cards (id) smart kitchen etc., have been in practice in most of the developing and developed countries. Many countries are developing their cities into "smart city" to enhance and improve the quality of life of their citizens.

The term "Smart" evolved in the field of power industry a decade ago as " Smart Grid" (SG), which is equipped with information and communication technology infrastructure (ICTI) and can assure (provide) a more secure,more reliable, more sustainable and more flexible energy services. Apart from this SG also ensures the following benefits viz; Reduced peak demand, reduced tariff for the consumers, distributed generation through Renewable Energy Systems (RES), consumer owned power generation,and flexible or dynamic (real time pricing) energy prices. As power industry is a large scale industry which connects billion or trillions of people, SG is still in the emerging stage and need to go a long way ahead.

One of the major concern or development part in the SG is the demand side management (DSM) which emphasizes peak load management, real time pricing and demand response (DR). Demand side management is a method of shaping the load profile with an objective of reducing the cost of energy price, benefitting the consumers without comprising their comfort level and also reducing the burden of utility from generating new plants to meet out the demand [1]. Many countries across the world namely, USA, UK, Norway, Italy, Spain and China are reported to use Demand Response Programs. Various methods such as Time of Use (ToU), Interruptible Programs, Load shedding programs, directload control,Real Time Pricing (RTP), Critical PeakPricing (CPP) programs have been found in the literature [2].

Priyaesther et al [3] presented a thorough survey on residential DSM including architecture, conventional and existing techniques using optimization algorithms and its mathematical modeling. A systematic literature review and state of the art on various load reduction techniques for the peak load managementis studied byBenetti et al [4]. A comprehensive methodology for implementing DSM programme in India through action plans, policies and regulations and the barriers and challenges to overcome the realization of DSM in India is outlined by Harish et al [5].

Muralitharan et al proposed a multi-objective optimization technique for demand side management with load balancing approach in smart grid wherein the scheduled running electrical appliances temporarily stops when it exceeds the threshold limit and resumes later. Also this mechanism claims in minimizing the overall electricity bill of the consumers. [6].

Another multi - objective demand side management solution for utilities with peak demand deficit is proposed by Kinhekaretal. In their approach various commercial (1700devices) and industrial (160 devices) controllable loads are shifted using load shifting demand side management program with GA tool in MATLAB environment which helps in considerable reduction in peak load [7].Challenges in load uncertainty for efficient energy scheduling in smart grid is proposed by Samadi et al where the peak to average ratio (PAV) is reduced by introducing IBR and RTP pricing models [8].

Mahmood et al proposed a new autonomous and distributed optimal energy scheduling scheme for household appliances. In this study, it is assumed that every house is equipped with a smart meter embedded with an energy consumption controlling unit and is connected through a local area network for sharing the information, which reduces both the cost of energy consumption and peak demand. [9]

Amin and Rasheed etal proposed a real time load shedding method for the emerging smart cities using priority based appliance scheduling. Two controlling schemes such as Central load manager (CLM) and Local load manager (LLM) is being proposed which sheds the loads on priority basis using stepwise and micro stepwise procedure by classifying loads into different categories [10].

Various researchers [11,12,13,14] proposed solutions for demand side management using cloud computing approach under smart grid environment.

The present work gives a detailed study of the Demand side management implementation for a specific class of consumers and their benefits using different pricing strategies.

II. PROPOSED WORK& CASE STUDIES

This proposed work is attempted to explain the implementation of DSM on the basis of a case study carried out in the state of Pondicherry, The details of the house hold appliances for a middle class consumers are taken into account and also, the consumers considered under study are assumed to be working and they won’t be available during the day time, i.e from 9am to 5pm.

Two case studies are presented, evolving the benefits of DSM for two different pricing strategies such as Time of Use and Critical Peak Pricing.

Time-of-Use (TOU) pricing tariff differentiates the price in peak hours and non-peakhours. Hence, the users are encouraged to use some of their appliances when energy isless expensive. The main purpose for dynamic pricing is to smoothen the energy demand curve by shaving the peaksand filling the valleys.

In Critical Peak Pricing (CPP), utilities communicate the changes in pricing to consumers at spikes in high peakdemand time blocks. Critical peak prices are assessed for certain hours on event days, and prices canbe 3-10 times as much during these few critical high demand hours.Peak Time Rebate (PTR), and Peak Time Penalty (PTP) are the variants of CPP in which the standard rate applies at all hoursbut customers can earn a rebate/incentive by reducing /non reducing usage during the critical peak hours.
These dynamic pricing would be communicated via a smart grid communication network which permits automatic meter readingat scheduled intervals, but in the present study it is assumed that the consumers receives the pricing via smart meter

Table 2.1 gives the details of the type of electrical appliances and their consumptions which would be mostly used by the middle class consumers.

Table 2.1 Electrical Appliances and their rating

SL. NO	APPLIANCE	CONSUMPTION (WATTS)
1	Toaster	800
2	Television	100
3	Microwave oven	600
4	DVD player	30
5	Electric Iron	1000
6	Stereo	20
7	AM/FM auto cassette player	8
8	Dishwasher	1200
9	Sink waste disposal	450
10	Washing machine	500
11	Electric clock	3
12	Sewing machine	100
13	GLS lamp	100
14	Tube light	40
15	PL lamp	20
16	Ceiling fan	100
17	Table fan	50
18	Exhaust fan	100
19	Refrigerator	200
20	Air conditioner	1000
21	Charger: mobile phone charger	1
22	Laptop	50
23	DeskTop	150
24	Grinder	200
25	Mixer	200
26	Pump motor	740
27	Electric cooker	1000
28	Room heater	1500
29	Printer	50
30	Hair dryer	1000
31	Vacuum cleaner	700
32	Water purifier	25
33	Chimney	25
34	Scanner	35
35	Water Heater	4000
36	Coffee maker	1350
37	Kettle	2000
38	Electric Shaver	20
39	LapTop	50
40	Clothes Dryer	4000

Case 2.1: Time of Use (ToU)

In this case the consumers are charged for their consumption based on their time of use irrespective of the type and the quantity of load. The Time of use rates for the consumption of the consumers is given in table 2.2.

Table 2.2 Time of Use Tariffs for a day

TIME OF USE (HRS)	RATE/UNIT (RS)
5am to 9am	2
9am to 5pm	1.5
5pm to 9pm	3
9pm to 5am	1

Table 2.3 Consumers choice of appliances usage in the morning time block(5am to 9 am)

APPLIANCES	CAPACITY (WATTS)	TIME OF USE	UNITS CONSUMED
Coffee Maker	1350	1/4	.3375
Electric Stove	1500	2	3
Mixer	200	1/3	0.066
Toaster	800	1/2	0.4
TV	70	2	0.14
Celling Fan	100*3	3	0.9
Tube light	40*4	2	.320
Water Heater	4000	1/2	2
Refrigerator	200	24	4.8
MicroWave oven	600	1/2	0.3
Electric Cooker	1000	1/2	0.5
Water Purifier	25	1/2	0.0125
Audio Casette player	8	3	0.024
Electric Clock	3	24	0.072
Dish Washer	1200	1	1.2
Total charges for the morning block			14.072@2 =Rs.28.144/-

Table 2.4 Consumers choice of appliances usage in the evening time block (5pm to 9 pm)

APPLIANCES	CAPACITY (WATTS)	TIME OF USE	UNITS CONSUMED
Coffee Maker	1350	1/4	.337
Electric Stove	1500	2	3
Mixer	200	1/3	0.066
Toaster	800	1/2	0.4
TV	70	2	0.14
Iron Box	1000	1/2	0.5
Celling Fan	100*3	3	0.9
Tube light	40*4	2	.320
Water Heater	4000	1/2	2
Refrigerator	200	24	4.8
MicroWave oven	600	1/2	0.3
Electric Cooker	1000	1/2	0.5
Water Purifier	25	1/2	0.0125
Audio Casette player	8	3	0.024
Electric Clock	3	24	0.072
Washing Machine	500	2	0.25
Dish Washer	1200	1	1.2
Cloth dryer	4000	1	4
Mobile Charger	1	1/2	0.005
Laptop	60	2	0.120
Desktop	150	2	0.3
Water Pump	746	1	0.746
Air Conditioner	1000	2	2
Total charges for the evening block			21.9925@3 =Rs.65.9775 /-

Table 2.3 &2.4, provides the details of the appliances used during morning 5am to 9am and evening 5pm to 9pm time blocks. It is observed that the units consumed on each day 14 units in the morning period and 22 units in the evening period. The total cost of electricity for a day for their consumption is as follows, then the total charges/day =Rs. 28.144 +Rs. 65.9775 =Rs. 94.1215. If the consumers choices of use remains the same for the entire month, then the monthly electricity bill will be 94 *30 = Rs. 2820/-. Suppose if the consumers wish to change/shift some of his/her appliances for cost effectiveness as given below in table 2.5, then his/her monthly electricity bill would be Rs. 1976.52/-

Table 2.5 Consumers choice of appliances usage from 9pm to 5am

TYPE OF APPLIANCES	UNITS CONSUMED	CHARGES (RS) BEFORE SHIFTING	CHARGES (RS) AFTER SHIFTING	SAVINGS BY SHIFTING (RS)
Washing machine = 0.25	0.25	0.25*3 =0.75	0.25*1=0.25	0.5
Cloth Dryer = 4	4	4*3 =12	4*1=4	8.0
Pump Motor = 0.746	0.746	0.746*3 =2.138	0.746*1=0.746	1.392
Dish washer = 1.2	1.2	1.2*2+1.2*3 =6	2.4*1=2.4	4.6
Iron Box = 0.5	0.5	0.5*3 =1.5	0.5*1=0.5	1.0
DeskTop = 0.3	0.3	0.3*3 =0.9	0.3*1=0.3	0.6
LapTop =0.12	0.12	0.12*3=0.36	0.12*1=0.12	0.24
Total savings : 16.332				

Total savings/day due to shifting in the off peak hour = Rs.16.322/-

Charges after shifting /day=Rs.94.0 – Rs.16.332=Rs. 77.668/-

Total charges after shifting /month= 78*30 =Rs. 2340/-

Total savings after shifting for a month =2820 – 2340 = Rs.480/-

Case 2.2: Critical Peak Pricing

Table 2.6 depicts the time of use and their rates based on the real time maximum demand. In this case the consumption are charged based on the maximum demand of individual consumers and their time of use.

Table 2.6 Time of Use Tariff - Based on Real Time Pricing

TIME BLOCK	MAXIMUM DEMAND (UNITS)	CHARGES/UNIT (RS)	TIME BLOCK	MAXIMUM DEMAND	CHARGES/UNIT(RS)
5am- 9am	16 units -& above s	3.5/unit	4pm - 10pm	11units -& above	4/unit
	8- 15 units	3/unit		7 - 10 units	3.5/unit
	0 - 7 units	2.5 unit		0- 6 units	3/unit

For the same load pattern the charge variation due to real time pricing is as follows

- Morning Peak =14.072 @2.5 = 35.18/-
- Evening Peak =21.9925@4 = 87.98/-

- Total Amount/day =35.18+87.98 =Rs.123.16/-
- Total Amount/month =123.16*30 =Rs.3694.8/-
- Difference in amount =3697.8 – 2340 = Rs. 1354.8/- is loss to the individual

Table 2.7Incentive charges/unit for peak reduction - PTR

TIME BLOCK	MAXIMUM DEMAND	CHARGE S/UNIT	TIME BLOCK	MAXIMU M DEMAND	CHARGE S/UNIT
5am to 9am	7 units & above	2/unit	4pm to 10pm	5 units & above	2/unit
	5-7 units	1.5/unit		3-5 units	1.5/unit
	0-4 units	1 /unit		0-2 units	1 /unit

Table 2.8Penalties charges/unit for Non Peak Reduction –PTP

TIME BLOCK	MAXIMUM DEMAND	CHARGES/UNIT		MAXIMUM DEMAND	CHARGES/UNIT
5am to 9am	≤10 units	0.3/unit	4pm to 10pm	≤6 units	0.3/unit
	≤7 units	0.2/unit		≤4 units	0.2/unit
	≤5 units	0.1 /unit		≤2 units	0.1/unit

Charges variation Due to Incentives and penalties are calculated as follows:

- Morning Peak =14.072 @3 = 42.216/-
- Non Reduction in peak demand 14.072-10.0 =4.07units
- Penaltypaid for non reduction in morning peak 4.07@0.3= Rs. 1.221/-
- Evening peak = 21.9925 – 7.116 =14.8765/-
- Evening Peak =14.8765@4 = 59.506/-
- Incentive received for reduction in evening peak 7.116@2= Rs. 14.232/-
- Total Amount/day =42.216+59.506 =Rs.101.722/-
- Total Amount/month =101.722*30 =Rs.3051.66/-
- Incentive received for the month = 14.232@ 30 = Rs. 426.96/-
- Difference in amount =3051.66 – 426.96 =Rs. 2624.7/-
- Penalty for 4.07@0.3 =Rs. 1.221*30 =36.63/-
- Therefore total amount =2624.7+36.63 =Rs.2661.33/-

III. CONCLUSION

In this work, implementation of demand side management for domestic middle class consumer is addressed using various pricing strategies. It is observed that the consumers are beneficial if they change their load pattern daily based on the pricing strategy without comprising their level of comfort. Both the methods are described in detail with consumer appliances and it is observed that the both the methods have their own merits and demerits and hence it is left to the consumer choice to choose the pricing strategy based on their comfort. But this would be possible only with help of smart meters which is not addressed in this present work and left to the scope for the future work.

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