

Study and Analysis of Dynamic Pricing in India and Proposing for Residential Consumers in Maharashtra

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Abstract

Dynamic pricing is the most important tool in demand side management, that can offer variety of prices at various demand levels. This paper presents the existing electricity tariff structures around the globe with its risk and rewards. Also presents the analysis of availability of Time-of-Day (ToD) structure in different states of India like Maharashtra, Kerala, Karnataka, Gujarat, Chhattisgarh, Uttar Pradesh, Madhya Pradesh, Bihar, Assam, etc. To minimize the electricity bill, TOD model is discussed, which is already implemented in many countries for residential and non-residential sector like USA, Germany, Japan, China, etc. But in India TOD is available only for non-residential sector. Hence, this paper proposes the real time tariff model for residential sector in India to get the maximum benefit in electricity bill. The analysis of TOD model of different states in India is carried out through this paper and is proposed for Indian residential sector. The case study of a middle class family is carried out for understanding the effectiveness and benefits of TOD. Net metering is a rising concept which helps consumers to minimize their electricity bills by consuming self-generated electricity from sustainable vitality resources. It also facilitates consumers to sell the surplus vitality back to utility

Keywords

Dynamic Pricing, Real Time Pricing, Residential Load, Sustainable Vitality, Time - of - Day.

Introduction

Dynamic pricing is the most rising field of exploration in the market of electricity and also an important parameter of demand-side management. It can reduce peak load by levying variety of prices at various levels of time periods as per demand. Normally, the energy markets offer flat rate tariff or block rate tariff. In flat rate tariff, prices remain unaffected irrespective of demand, whereas, in block rate tariff, the per unit cost of electricity is either more or less with the increasing slabs of consumption. The costs of generation during peak hours are high, since most peak hours generating units have higher operating costs than base load units. Thus, above-mentioned electricity tariffs do not reflect the exact costs of generation and distribution. Dynamic pricing not only helps in reducing peak demand, but also provide each consumer with a chance to reduce energy bill at a persistent consumption level. It is possible just by changing the energy consumption pattern by shifting the load from peak hours to off peak hours [1]. Therefore, electricity prices can be roughly divided into two types: 1) static prices which does not change with a change in demand and 2) dynamic prices which changes with the changing demand situation [2]. There are several types of pricing schemes such as flat rate tariff, block rate tariff, seasonal tariff, time of use tariff, super peak ToU, critical peak pricing, variable peak pricing, real time pricing discussed below [2 - 6]:

- 1) *Flat Rate tariffs*: In the flat rate tariff, electricity tariff remains unchanged even though power demand changes. Thus, customer have no monetary encouragement to reschedule their energy utilization pattern. Consumers do not have any risk of higher electricity bills for any unplanned electricity consumption.
- 2) *Block Rate tariffs*: It is a type of tariff which charges customers a different price depending on the quantity of electricity utilization. It consists of several slabs based on the amount of energy consumption. Increase in consumption leads to increase in the tariff and decrease in consumption leads to less tariff.
- 3) *Seasonal tariffs*: In the seasonal tariffs, electricity rate changes with change in seasons. Energy rates are directly proportional to demand i.e. If the demand is high, rates are high and vice versa.
- 4) *Time-of-use (TOU) tariff*: In ToU, the electricity rates are pre declared and are different for a different time interval of day. i.e. high in peak hours and low in off-peak hours.
- 5) *Super peak TOU*: It is similar to TOU, but the peak period is very short in duration and prices are very high during this period.
- 6) *Critical peak pricing (CPP)*: In critical peak pricing, consumers are charged at a higher fixed rate during some peak hours of the day and at a discounted rate during the rest of the day.

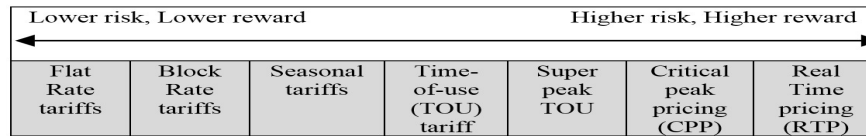


Fig. 1: Risk-Reward in Dynamic Tariff.

Fig. 1, shows the risk and reward relationship in the dynamic tariff. As the prices are fixed in flat (Slab wise), block (quantity of consumption), seasonal tariff (according to season) so risk is less and reward is also less. Whereas, in time of use (pre declared tariffs varying during the different times of the day), super peak (peak window is shorter in duration), critical (high fixed rate during a few peak hours) and real time pricing (based on time intervals), the risk is high and reward is also high. Therefore, as we move from the flat rate tariff towards the real time tariff, the risk is higher and rewards are also higher.

Materials and Methods

A. Time of Use Tariff:

Time-of-Use (ToU) tariff is also called as Time of Day Tariff (ToD). In ToD, tariffs are declared in advance, based on time intervals. It varies in different time intervals of the day, i.e. high in peak hours and low in off-peak hours. Normally this is effective for short or long terms. The different types of real time tariff are as follows:

- 1) Day ahead pricing: In this case, the consumer knows the cost of electricity for the next day in advance for each time period.
- 2) Hourly ahead pricing: In this case, the rates change over an hour and the consumer receives the signal for each interval, reflecting the costs of generating electricity during that time.
- 3) Time of Day (ToD): In ToD, the entire day is distributed into two or three large intervals with different prices like off-peak period (the lowest rate), shoulder period (moderate rate) and peak period (the highest rate); these rates remain fixed day-to-day over the season.

In India, the ToD tariff is most popular amongst the High Voltage (HV) and Extra High Voltage (EHV) customers. In fact, ToD is compulsory for this group of consumers. For example: Large scale Industries, Ice Factories, Ice-cream manufacturing units, Milk Processing Units, Engineering Workshops, Engineering Goods Manufacturing Units, Non-Residential, Commercial and Business premises, including Shopping Malls and Showrooms; etc. comes under this category [7]. The consumer is broadly categorized into three levels viz. Level 1 (L1): Low Voltage (LV), Level 2 (L2): High Voltage (HV) and Level 3 (L3): Extra High Voltage (EHV). The analysis of existing ToD tariff structure in some of the states in India is shown in the Table I and Table II and the time of day are divided into different intervals like: SP- Shoulder period, PP- Peak period, MP-Morning peak, EP-Evening peak, OPP-Off peak period. In many states like Maharashtra, Karnataka, Andhra Pradesh, West Bengal, Goa, Gujrat and Uttar Pradesh, the time of day is at level 2 and level 3. Only in Kerala, ToD is available for all levels; in level 1 if the unit's consumption is above 500 units then ToD is applicable. In some of the states like Telangana, Chhattisgarh, Madhya Pradesh, Bihar and Assam ToD is available for level 3 only [7 - 19].

States in India	12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
Maharashtra (L ₂ ,L ₃)	OPP -1.50 Rs. per unit					SP +0.00 Rs. per unit			MP +0.80 Rs. per unit			SP +0.00 Rs. per unit					EP +1.10 Rs. per unit			OPP -1.50 Rs. per unit				
Kerala (L ₁ ,L ₂ ,L ₃)	OPP 75% of the normal rate					SP Normal rate of energy charges										PP 150% of the normal rate			OPP 75% of the normal rate					
Karnataka (L ₂ ,L ₃)	OPP -100 paise per unit					MP +100 paise per unit			SP +000 paise per unit					EP +100 paise per unit			OPP -100 paise per unit							
Telangana (L ₃)	OPP - 1.00 Rs. per kVAh					PP + 1.00 Rs. per kVAh			SP +0.00 Rs. per kVAh					PP + 1.00 Rs. per kVAh			OPP - 1.00 Rs. per kVAh							
Andhra Pradesh (L ₂ , L ₃)	OPP - 1.00 Rs. per kVAh					PP + 1.05 Rs. per kVAh			SP +0.00 Rs. per kVAh					PP + 1.05 Rs. per kVAh			OPP - 1.00 Rs. per kVAh							
West Bengal (L ₂ ,L ₃)	OPP 494 Paisa per kWh					SP 628 Paisa per kWh										PP 945 Paisa per kWh			SP 628 Paisa per kWh			OPP 494 Paisa per kWh		

Table 1: Time of Day for Different States in India

States in India	12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
Goa (L2,L3)	SP 90 % of the normal rate						OPP Normal rate of energy charges												PP 120% of the normal rate			SP		
Gujarat (L2,L3)	OPP 85 Paise per unit discount						PP ToU Charges 45 Paise per unit			OPP 40 Paise per unit discount						PP ToU charges 85 Paise per unit			OPP 85 Paise per unit					
Chhattisgarh (L3)	SP 75 % of the normal rate				OPP Normal rate of energy charges												PP 120% of the normal rate			SP				
Uttar Pradesh (L2,L3)	SP 0% of the normal rate				OPP -15% of energy rate per unit					SP 0% of the normal rate					PP +15% of the normal rate			SP						
Madhya Pradesh (L3)	OPP - 20% energy rate per unit rebate					SP Normal rate of energy charges												PP Normal rate of energy charges			OPP -20% energy rate per unit rebate			
Bihar (L3)	SP 85% of the normal rate				OPP Normal rate of energy charges												PP 120% of the normal rate			SP				
Assam (L3)	OPP -1.5 Rs. per kWh					SP Normal rate of energy charges												PP +1.5 Rs. per kWh			OPP -1.5 Rs. per kWh			

Table 2: Time of Day for Different States in India

B. Tariff Structure in Maharashtra State:

In Maharashtra, power system is divided into two parts: Mumbai and rest of Maharashtra. Mumbai is served by Reliance power, TATA power, BEST power whereas the rest of Maharashtra is served by MSEDCL. The tariff structure of all utilities are approximately same i.e. slab wise tariff for residential consumers and TOD for non-residential consumers [20]. The MSEDCL tariff structure for residential sector and TOD structure for non- residential is shown in Table III.

LT I (B): LT – Residential (MSEDCL)			
Consumption Slab (kWh)	Fixed/Demand Charge (Rs. / month)	Wheeling Charge (Rs/kWh)	Energy Charge (Rs. /kWh)
0-100 units	1- Phase: Rs.65/ month	1.18	3.07
101 – 300 units	3- Phase: Rs.185/ month	1.18	6.81
301 – 500 units		1.18	9.76
501-1000 units		1.18	11.25
Above 1000 units		1.18	12.53
TOD Tariffs (in addition to base Tariffs) for Non- Residential sector			
2200 Hrs-0600 Hrs	Off Peak Period (OPP)		-1.50 (Rebate)
0600 Hrs-0900 Hrs & 1200 Hrs-1800 Hrs	Shoulder Period (SP)		0.00 (Base rate)
0900 Hrs-1200 Hrs	Morning Peak (MP)		+0.80 (Penalty)
1800 Hrs-2200 Hrs	Evening Peak (EP)		+1.10 (Penalty)

Table 3: Tariff Structure of MSEDCL

The first part of Table III shows the tariff structure of residential sector and the second part shows the ToD rates of non-residential sector. The ToD time slots are labeled as: (2200 Hrs-0600 Hrs): Off peak period (OPP); (0600 Hrs-0900 Hrs & 1200 Hrs-1800 Hrs): Shoulder period; (0900 Hrs-1200 Hrs): Morning Peak (MP); and (1800 Hrs-2200 Hrs): Evening Peak (EP). The ToD rates are mostly applicable to LT - II non - residential load (optional), HV and EHV load compulsorily. The objective behind the ToD tariff is to shift the load from peak to off-peak hours and avoid spikes in the demand pattern [7].

C. Proposed Tariff Structure:

In India, almost all states are having real time pricing for non-residential sector only, hence there is no scope for the reduction in electricity bill of residential consumer. Therefore, the new tariff structure is proposed. The Proposed tariff structure is the combination of slab wise tariff from the residential load and time of day tariff from the non-residential load. For example, for slab 100 - 300 units: wheeling charge is 1.18 Rs. / unit, energy charge is 6.81 Rs. /unit & depending upon supply 1-ph or 3-ph fixed charges will be

decided. Assume that 1-ph supply, so the fixed charge is $65/300 = 0.216$ Rs. /unit. Hence, per unit cost = $(1.18+6.81+0.216) = 8.206$ Rs. /unit (base price). Now depending upon the time slot in which consumer are using energy, the TOD charges will be added. Example:

- 1) Slab 1: 100-300 units; Base price of electricity is 8.206 Rs. /unit; Morning Peak (MP) = $8.2+0.8 = 9$ Rs. /unit; Evening Peak (EP) = $8.2+1.1=9.3$ Rs. / unit; Off Peak (OPP) = $8.2-1.5 = 6.7$ Rs. / unit; Shoulder Period (SP)= $8.2+0=8.2$ Rs. / unit.
- 2) Slab 2: 301 -500 units; Base price of electricity is 11.07 Rs. /unit; Morning Peak (MP) = $11.07+0.8 = 11.87$ Rs. /unit; Evening Peak (EP) = $11.07+1.1=12.17$ Rs. / unit; Off Peak (OPP) = $11.07-1.5=9.57$ Rs. / unit; Shoulder Period (SP) = $11.07+0=11.07$ Rs. / unit.
- 3) Slab 3: 501 – 1000 units; Base price of electricity is 12.49 Rs. /unit; Morning Peak (MP) = $12.49+0.8 = 13.29$ Rs. /unit; Evening Peak (EP) = $12.49+1.1=13.59$ Rs. / unit; Off Peak (OPP) = $12.49-1.5=10.99$ Rs. / unit; Shoulder Period (SP) = $12.49+0=12.49$ Rs. /unit.
- 4) Slab 4: Above 1000 units; Base price of electricity is 13.775 Rs. /unit; Morning Peak (MP) = $13.775+0.8=14.575$ Rs. /unit; Evening Peak (EP) = $13.775+1.1=14.875$ Rs. / unit; Off Peak (OPP) = $13.775-1.5=12.275$ Rs. / unit; Shoulder Period (SP) = $13.775+0=13.775$ Rs. / unit.

Time Period (Slots)	Time	Assumed rate in India INR/kWh
Off Peak Period (OPP)	(10pm-7am)	8 INR/kWh
Shoulder Period (SP)	(7am-2pm & 8pm-10pm)	9 INR/kWh
Peak Period (PP)	(2pm-8pm)	10 INR/kWh

Table 4: Assumed Tariff Structure for Residential Load in India

Based on the above calculations of slab wise tariff in combination with time of day structure the assumed rates of electricity are shown in Table IV. During off peak period, i.e. 10 pm to 7 am approximate electricity price is 8 INR/kWh; during the shoulder period, i.e. 7 am to 2 pm and 8 pm to 10 pm approximate electricity price is 9 INR/kWh; and peak period, i.e. 2 pm to 8 pm approximate price of electricity is 10 INR/kWh. These rates are considered for calculations of the electricity bill of a middle class family. The per unit cost of electricity depends upon the various factors like capital cost, number of consumer connected to utility, unit consumption by all connected consumers, cross subsidy, different types of loans, rent of land, etc. Therefore, these rates will vary from state to state and country to country.

To understand the effectiveness of the proposed method of the reduction of the electricity bill of residential consumers, different cases were considered and electricity bills are calculated for: 1) with slab wise tariff 2) with the proposed real time tariff 3) with real time tariff & load scheduling 4) with real time tariff & load rescheduling. The cases are discussed below:

1) *Case 1: middle class family living in 1 bedroom hall kitchen with slab wise tariff (1 BHK):*

The load connected to the house is light (100W), Fan (100W), Charger (120W), Radio (50W), Television (350W), Washing machine (500W), Refrigerator (800W), Oven (1200W), Geyser (400W), Air conditioner (1000W). The normal load consumption pattern for the middle class family is shown in Table VI. The calculation of electricity bill for a day, month and year for an above load pattern is carried out. The approximate unit consumption in one day is 32.09 Unit/ day. Hence in one month the units consumed is 32.09 units/ day* 30 days = 962.7 units/ month. Therefore, the electric bill for one month is calculated as per tariff structure of MSEDCL LT-I(B): Electric Bill = $[(100*1.18*3.07) + (200*1.18*6.81) + (200*1.18*9.76) + (462.7*1.18*11.25)] + 65 = 10,415.12$ Rs. / month (slab wise tariff). Assuming the same load pattern will be continuing for the entire year then the annual electricity bill = $10,415.12$ Rs. *12 months = 1,25,761.44 Rs. / year.

Household Appliances	12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
Light	√	√	√	√	√	√	√						√	√				√	√	√	√	√	√	√
Fan						√	√								√	√	√	√	√	√				√
Charger											√	√	√	√					√	√		√		
Radio							√	√	√						√		√	√				√		
Television										√	√	√	√	√	√	√	√				√	√		
Washing machine															√	√								
Refrigerator	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Oven															√							√		
Geyser								√	√											√				
Air Conditioner																√								

Table 5: Normal Load Pattern of Middle Class Family with Slabwise Tariff

2) *Case 2: Proposed Real Time Tariff (RTT) structure for the same case study of middle class family:*

The normal load consumption pattern for middle class family is shown in Table VII. The calculation of the electricity bill for a day, month and year is carried out by assuming real time tariff. The total unit's consumption in one day is 32.09 Unit/ day. Hence for one month 32.09 units/ day* 30 days = 962.7 units/ month. According to real time pricing the cost of electricity for one day for a normal load pattern is 293.25 Rs. / day; hence for the entire month, i.e. for 30 days $293.25 * 30 = 8,797.5$ Rs/ month. If the same load consumption pattern is continuing for the entire year then the annual electricity bill is $293.25*30*12 = 1,05,570.0$ Rs. /year. Monthly

saving is 1,682.62 Rs. / month and hence the annual saving is 20,191.44 Rs. / year after implementation of real time tariff as compared slab wise tariff structure.

Household Appliances	12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
	Off Peak Period (Rs. 8 INR)							Shoulder Period (Rs. 9 INR)						Peak Period (Rs.10 INR)						Shoulder Period (Rs. 9 INR)	Off Peak Period (Rs. 8 INR)			
	Light	✓	✓	✓	✓	✓	✓	✓					✓	✓				✓	✓			✓	✓	✓
Fan						✓	✓								✓	✓	✓	✓	✓	✓				✓
Charger											✓	✓	✓	✓					✓	✓		✓		
Radio							✓	✓	✓						✓		✓	✓						
Television										✓	✓	✓	✓	✓	✓	✓	✓				✓	✓		
Washing machine															✓	✓								
Refrigerator	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oven															✓							✓		
Geyser								✓	✓											✓				
Air Conditioner																✓								

Table 6: Normal Load Pattern of Middle Class Family with Real TimeTariff

3) Case 3: Real time tariff with load scheduling:

Load scheduling is carried out based on the consumer preference. i.e. As the rates of electricity are high during the peak period and moderate during shoulder period, so try to shift the load from peak period to shoulder period or off peak period, as per consumer preference as shown in Table VIII. Hence, if the consumer makes the load scheduling (without RE), again the electricity bill will be less as compared to case 1 (slab wise tariff). Total unit consumption in one day is 32.09 Unit/ day; hence in one month it is 962.7 units/ month. The cost of electricity for one day in load scheduling with RTT is 282.12 Rs. / day; hence for 30 days $282.12 * 30 = 8463.6$ Rs/ month. Annual electricity bill = $282.12 * 30 * 12 = 1,01,563.2$ Rs. /year.

Household Appliances	12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
Time Slots	Off Peak Period (Rs. 8 INR)							Shoulder Period (Rs. 9 INR)						Peak Period (Rs.10 INR)						Shoulder Period (Rs. 9 INR)	Off Peak Period (Rs. 8 INR)			
Light	√	√	√	√	√	√	√						√	√				√	√	√	√	√	√	√
Fan						√	√						√	√	√	√	√							√
Charger					√	√					√	√	√	√							√			
Radio	√						√	√	√				√	√								√		
Television	√									√	√	√	√	√				√			√	√	√	√
Washing M/C													√	√										
Refrigerator	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Oven																						√	√	√
Geyser						√	√													√				
Air Conditioner														√										

Table 7: Normal Load Pattern of Middle Class Family with Slabwise Tariff and Load Scheduling

4) Case 4: Real time tariff with load scheduling:

As there is not much difference in the annual electricity bill of a consumer with case 2 (real time tariff) and case 3 (real time tariff with load scheduling) hence, the rescheduling of the load is carried shown in Table XI and it is observed that the total unit consumption in one day is 28.75 Unit / day; hence for one month, 28.75 units/ day* 30 days = 862.5 units/ month; The cost of electricity for one day with load rescheduling and RTT is 253.72 Rs. / day; hence for one month it is 30 days $253.72 * 30 = 7,611.6$ Rs/ month; and the annual electricity bill for one year = $253.72 * 30 * 12 = 91,339.2$ Rs. /year.

Household Appliances	12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
Time Slots	Off Peak Period (Rs. 8 INR)							Shoulder Period (Rs. 9 INR)							Peak Period (Rs.10 INR)							Shoulder Period (Rs. 9 INR)	Off Peak Period (Rs. 8 INR)	
Light	✓					✓	✓						✓	✓				✓	✓	✓	✓	✓	✓	✓
Fan						✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Charger					✓	✓					✓	✓	✓	✓								✓		
Radio	✓						✓	✓	✓	✓				✓										
Television						✓	✓			✓	✓	✓	✓	✓			✓				✓	✓	✓	✓
Washing M/C						✓	✓																	
Refrigerator	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oven																						✓		
Geyser							✓												✓					
Air Conditioner																								

Table 8: Normal Load Pattern of Middle Class Family with Real Time Tariff and Load Scheduling

5) Case 5: Considering slab wise tariff, load scheduling and renewable energy (solar)

The combination of slab wise tariff with load scheduling will reduce electricity bill only if RE sources used. From the survey it is found that effective solar energy is available from approximately 7 am to 4 pm. Hence, effective power generation from solar is from 9 am to 3 pm shown in the Table X. So if during this period load can be run then no charges from utility for this period. If excess energy is generated during this period, then it can be stored and can be utilized at night time also. Hence, whenever the scheduled load will run on solar, no charges from utility, leads to saving in electricity bill.

12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am
							Effective Solar Insolation available for power generation																

Table 9 : Availability of Effective Solar Energy

6) Case 6: Considering real time tariff, load scheduling, and renewable energy (solar):

The combination of real time tariff with load scheduling will reduce electricity bill satisfactorily. But if the consumer wants to save electricity bill above this, then RE must be used. As it is mentioned in section E, solar is available from approximately 7 am to 4 pm. The effective power generation from solar is from 9 am to 3 pm shown in Table XI. So if during this period load can be run then no charges from utility for this period. If excess energy is generated during this period, then it can be stored and can be utilized at night time also. Hence, whenever the scheduled load will run on solar, no charges from utility leads to saving in electricity bill.

OPP								SP								PP								SP		OPP
12 am - 1 am	1 am - 2 am	2 am - 3 am	3 am - 4 am	4 am - 5 am	5 am - 6 am	6 am - 7 am	7 am - 8 am	8 am - 9 am	9 am - 10 am	10 am - 11 am	11 am - 12 pm	12 pm - 1 pm	1 pm - 2 pm	2 pm - 3 pm	3 pm - 4 pm	4 pm - 5 pm	5 pm - 6 pm	6 pm - 7 pm	7 pm - 8 pm	8 pm - 9 pm	9 pm - 10 pm	10 pm - 11 pm	11 pm - 12 am			
							Effective Solar Insolation available for power generation																			

Table 10 : Availability of Effective Solar Energy

7) Case 7: Real time tariff, load scheduling and net metering:

Same as in case 6. Only difference is that due to the net metering energy exchange between consumer and utility will happen and whenever solar is sufficient to run the scheduled load, no energy exchange. Hence, the cost of electricity during that period will be zero (saving in electricity bill). If solar energy is not sufficient to run the scheduled load, then energy will be taken from the grid at real time tariff rate. Depending on the tariff rate, the electricity bill will be generated. The electricity bill will be definitely less than that of the flat rate tariff electricity bill.

Result and Discussion

To save electricity bill above the regular method of slab wise billing, then government policy need to be revised and the dynamic pricing need to be introduced. Hence, based on the assumption that the real time tariff is exist in India, a case study of a middle class family with different combinations of tariff structure is discussed in section III.

Case study 1, 2, 3, 4 shows the effectiveness of the proposed system with reference to Indian residential load. The Table XII shows the results and validation of the proposed scheme. It is observed that, the comparison of slab wise tariff with the real time tariff, the real time tariff with load scheduling and the real time tariff with load rescheduling results in saving in electricity bill i.e. 1) The comparison of case 1 (Slab wise tariff) with case 2 (Real time tariff) results in 16.05% saving in electricity bill, 2) The comparison of case 1 with case 3 (RTT + Scheduling) results in 19.24% saving, 3) The comparison of case 1 with case 4 (RTT + Rescheduling) results in 27.37% saving, 4) The comparison of case 2 (RTT) with case 3 (RTT + Scheduling) results in 3.79% saving, 5) The comparison of case 2 (RTT) with case 4 (RTT + Rescheduling) results in 13.47% saving, 6) The comparison of case 3 with (RTT + Scheduling) case 4 (RTT + Rescheduling) results in 10.06% saving in electricity bill.

Sr. No.	Bill calculations	No. of units/day	No. of units /month	Monthly electricity bill	No. of units / year	Annual Electricity bill
1	Slab wise	32.09 units	962.7 units	10,480.12 Rs. / month	11552.4	1,25,761.44 Rs./ year
2	Real Time Tariff	32.09 units	962.7 units	8,797.5 Rs./ month	11552.4	1,05,570 Rs. / year
3	RTT+ Scheduling	32.09 units	962.7 units	8463.6 Rs./ month	11552.4	1,01,563.2 Rs. / year
4	RTT+ Rescheduling	28.75 units	862.5 units	7611.6 Rs./ month	10350.0	91,339.2 Rs. / year

Table 11 : Comparison of Electricity Bill of Sample Case Study

Conclusion

Case study 1 to 4 in section III proves that the real time tariff is superior over slab wise tariff. The different cases like real time tariff (RTT) in combination with load scheduling i.e. shifting the load from peak period to shoulder period or off peak period is discussed. The combination of RTT with load scheduling gives minor saving in the bill. To obtain major saving in the bill, proper load scheduling is required. So rescheduling of load i.e. shifting the load from peak period to shoulder period or off peak period as per seasonal requirement is discussed (may turn off the least essential devices). Case 5, shows that the combination of slab wise tariff with RE leads to saving in electricity bill whereas in case 6 and 7, combination of real time tariff, load scheduling with RE source leads to major saving in electricity bill.

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