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Load scheduling of residential load for optimum cost

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Abstract
This paper develops a GUI based on a simulation model to simulate the load for a day, a week or a month through which load rescheduling can be organized to reduce the cost of electricity consumption throughout the day which in turn will reduce the electricity consumption bill for the consumer. The GUI provides an easy and convenient way to schedule the load for the consumer.

Keywords: smart grid, load shading, market models, smart meter

1. Introduction
Load Scheduling is the method of scheduling the load at the consumer side to reduce consumption of electrical energy in order to reduce the expenses and to save electricity. Scheduling of the load helps in determining the actual load requirement for a consumer also it can be used to study the usage patterns or behavior of consumers which helps understand the electricity scenario of the power system better [3]. Load scheduling of residential load is possible in any smart grid thus increasing the overall efficiency of the grid.
In 1980s Demand-side management (DSM) developed that helps to maintain the balance the consumer's load demand & maximum generation capacity of a power system according to time-varying demand [2]. To reshape consumer’s consumption behaviors DSM provide two approaches i) Direct Control Strategies ii) Pricing Mechanism. With the help of these two approaches, consumer’s encouragement to shift their load peak hours to Non-peak/off-peak hours is possible. Different -2 tariffs apply for the different-2 time interval of the day.

2. System Models
A. Smart Grid
Smart grid means to increase the efficiency of the grid. It also helps in determining faults & preventing those faults which can be prevented by shutting down certain parts of the grid whenever required. The smart grid also supports the notion of load scheduling as well as flexible and day ahead bidding forms of electricity pricing. The smart grid can be thought of as an ideal grid which is free of errors and is capable of self-maintenance and correction faults that might occur during the operation of the power system [6].

B. Smart House
In a smart grid, a smart house plays the most important role since residential consumers form the basic part of the smart power grid system [1]. The smart house model follows the ideology of the smart grid in which the control is digital in nature and the efficiency which in the case of a smart house is hugely related to the electricity bill needs to be controlled. Smart usage of electricity to minimize load and maximize efficiency is the main purpose of a smart house which again is an ideal concept and requires lots of implementation equipment for implementation in a practical grid. Residential load scheduling is the method of achieving optimum cost efficiency in a smart house having a smart meter to control the load. Load scheduling for the residential load can be done in various ways in various consumption scenarios.

C. Scheduling of loads
Estimation of instantaneous loading of consumers called scheduling of loads. This scheduling helps to provide the following information of particular installation active, reactive & apparent power (kW, kVAR & kVA) [3].
Load scheduling requires a smart meter which can be used to operate and manage the different load appliances in the house. An algorithm is developed based on behavior patterns of the consumer which works to minimize load and maximize efficiency. A GUI can also be created which helps the user to input the operating hours of the different appliances and the same can be implemented by the smart meter according to the electricity pricing mechanism.

1) **Need for load scheduling:** Preparing an electrical load schedule eases the work of designing the system in terms of equipment sizing as well as in power system studies. The process requires an understanding of the installation, all the equipment that will be installed, frequency of using the equipment and their importance or criticality.

The load schedule should ideally be started as early as is practically possible in the design process. One requires an idea of the main voltage levels required in the installation as well as all other details of the function of the facility or building, and the nature of process and non-process loads.

2) **Methodology and information used in load schedule:** No standard methodology & varying method used for the type of installation. Some basic steps help us for load schedule. This involves collection of a list of equipment, their design load ratings, expected operating & peak power consumption. Also required are some typical electrical load characteristics such as rated power, absorbed power, power factor, and efficiency. The loads are then classified according to some specific criteria which may differ from one installation to the other.

The loads are mostly classified using three parameters, the first criteria are according to voltage, the other one according to the load duty to show whether loads are standby, continuous, or intermittent. And lastly according to load criticality based on whether they are normal loads, essential loads or critical loads. The collected information is then used to calculate the individual and overall operating, design and peak power at continuous, intermittent, and standby load duty.

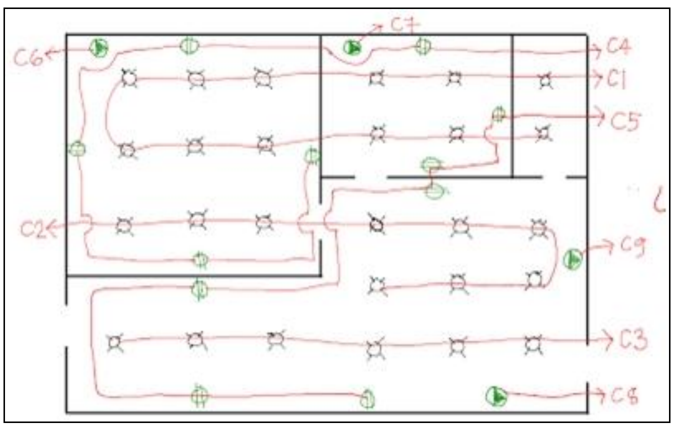

Fig 1: Sample electric plan

D. Cost Efficiency

Modern society development requires resources saving as well as the environment-friendly operation of the smart grid. People always in the habit of getting full satisfaction for consumptions [15], there is a need of a tool to measure the consumption efficiency of electricity. The tool helps to manage the power consumption behaviors of the consumers [7, 19]. Output and production cost ratio is maximum and then best production efficiency is possible. Maximization of production output is possible only and only by optimal utilization of the resources, therefore as a result production cost will decrease & saving in resources will be achieved. Unnecessary expenses control and resources saving is possible if a similar approach is applied to a household consumer. Cost efficiency concept points out the ratio of consumer's utility function & cost to measure effectiveness consumption, also called as utility cost.
The consumption behaviors of consumers [10, 11, 16] are effectively captured by cost efficiency approach. After employing successfully this metric we are able to know following information of a customer's load.

1. Analysis of consumption patterns behavior of different-2 household.
2. Study the efficiency analysis of appliance cost efficiency behaviors during different operating modes and different periods.
3. Analysis of household consumption management based on cost efficiency.
4. Optimal scheduling of household loads.

Consumption cost consists of service fee existing algorithms for load scheduling not taken into account. The service fee is treated as constant therefore; these algorithms have no effect on scheduled output. While in real life users get affected by services fees. The considerable effect takes place on the behavior of consumer.

E. Residential Load

Residential load bears the same meaning as the general cost efficiency but only the formula and the calculation method changes according to the present scenario. The cost efficiency of the residential load is calculated by the electricity bill generated by the power supplier for the residential consumer for a number of days to the utility of electricity by the consumer [12-14, 18, 20].

F. Smart residential consumption model

Residential consumption pricing mechanisms and smart consumption for the residential user are described here. A smart house must have a smart energy meter for monitoring the overall electrical appliances activity of household & reschedule the automatically electricity consumption activity. After applying this proposed model an exchanging information protocol established that helps to bidirectional communication between Distribution Company and end user of electricity. The proposed algorithm ensures that there is no missing data and incomplete information.

G. DER (Distributed Energy Resources)

A renewable generator of a smart house is the non-dispatch type, generator output depends on many factors like wind condition for the wind turbine, weather condition (sunny, rainy, summer, winter) for a photovoltaic system, so designing of proper schedule by specific strategies is not possible.
End-user faces storage device problems & additional burden in term of high investment on devices. Currently, more work is under progress to increase the storage capacity, to reduce the size and to improve the overall efficiency of storage devices. The government also supports DERs activity. Future storage devices will play a boom role to use renewable energy source in residential consumer life. The distributed energy resources model is an additional clause in the minimization of the electricity bill and may or may not be considered for the present scenario.

1) **Pricing Mechanisms:** Current scenario adopt the real-time tariffs changing & ahead bidding mechanisms of electricity market model for the household consumer. Day-ahead bidding system helps us to find out the scheduling of major energy consumption for next day but uncertainty takes place if we adopt real-time charging in real life consumption.
2) **Real-Time Tariff:** The RTT charging pricing mechanism involves a dynamic change of the unit price for electrical

consumption with the changing load demand. The electricity provider charges different rates according to the load demand which may be the peak at some point and low at other. This type of pricing requires instant communication with the smart meter and change in the algorithm in order to schedule the load which is inconvenient and invalid.

3) **Day-ahead bidding:** The day ahead bidding pricing mechanism involves advance setting up of consumption costs at different time slots in the day. The energy provider provides the rate card or the rate tariff and the load can be scheduled accordingly to minimize the cost of consumption by load shifting of the different loads present in the smart house [1].

The whole world leading to develop power market, as a result, competition in power sector industries. Allocation of power to the de-regulated environment is possible is using a day-ahead medium. This technique provides us power requirement of a user in advance for a day before actual power delivery. Bids will be submitted by Selling & buying agents before actual power delivery [8, 9, 17] to end user. Independent system operator or agents responsible for clearing prices of the bid, all subsequent are settled at the bid price.

H. Producer Models

The aim of this model is constructing optimal offer curves in the day-ahead market. This model produces an optimal curve & the curve is submitted to the ISO market coordinator [6].

I. Real Time Markets

The physical market is also called as a real-time market. It serves as a platform to match demand & supply of electricity.
A market clearing price (MCP) is set at 5 minutes of interval. The price of wholesale market is set based on offers settled & bids [2]. Dispatch instructions for every interval are specified the required energy injected by sellers or withdrawn from the IESO-controlled grid based on their offers & bids [5].

J. Role of dispatchable generators

Dispatchable generators submit offers of electricity in specific quantities & at specific prices for the whole day. A generator is able to adjust the output & generate in response to dispatch instructions by minutes to minutes by Independent Electricity System Operator. Most of the resources participating in the real-time market obligations to submit bids & offers day-ahead.

1) **Role of dispatchable loads:** Large energy consumers, also known as loads, submit bids for purchase electricity. Dispatchable loads are able to adjust their consumption in response to instructions from the IESO.
2) **Role of importers and exporters:** Market participants can import energy from another jurisdiction into Ontario, as well as export energy from Ontario. Participants can also move energy through Ontario from one jurisdiction to another in a type of transaction called a linked wheel.

To complete an import transaction, a participant will simultaneously make an offer in the IESO-administered market to import and bid in another jurisdiction to export. In order to export energy, a participant will simultaneously make a bid in the IESO-administered market to purchase energy and offer to import into another jurisdiction.

K. Non-Dispatchable Participants

Non-dispatch able generators submit forecasts of energy production. A non-dispatch able generator is one that typically has little control over its fuel source such as a small hydro generator on a river. Non-dispatch able loads or consumers draw electricity from the IESO grid to meet their needs, regardless of the price. A local distribution company is an example of a non-dispatch able load.

L. Tariffs

Utility apply different-2 tariffs to charge for electricity used by end user. Tariffs charges for electricity will be based on:

1. Standing charge, it based on the total kilo wattage of the installed load.
2. On the bases of units consumed.
3. When an agreed maximum level is exceeded then extra charge- referred as the maximum demand charge.

Standing charge used irrespective to electricity consumed or how often the load is used. The total unit consumed for a particular time period like a month.

M. Generators

If power failure or blackout occurs, alternative supply is achieved using generator set, the different-2 capacity generator is available, few kVA capacity can be obtained for petrol driven, diesel engine driven used for normal kVA [22, 24]. Output depends on the size of generator & starting mechanism of various types of equipment installed in the generators. Both above-said engines will require regular maintenance for satisfactory operation [4].

3. Matlab Model/Simulations

3.1 System Models

A. GUI Model for Electricity Bill Predictor

The GUI model for the Electricity Bill Predictor is prepared in two forms namely:

• Fixed Tariff Bill Predictor
• Day Ahead Bidding Bill Predictor

1) **Fixed tariff bill predictor:** The Fixed Tariff bill predictor simulates and provides the data for energy consumption based on a fixed tariff which is the per unit cost. The cost of electricity per-unit provides us the information about our appliance is how much power spending. This GUI has a simple design and provides the user to input the number of hours of operation for the whole day and predicts the bill according to the pre-set unit cost.

A toolbox to design sample copy of electricity bill for end-user in various states of India. This sample copy carries all the necessary information like latest tariff rate, daily consumption data of a user through our contacts.

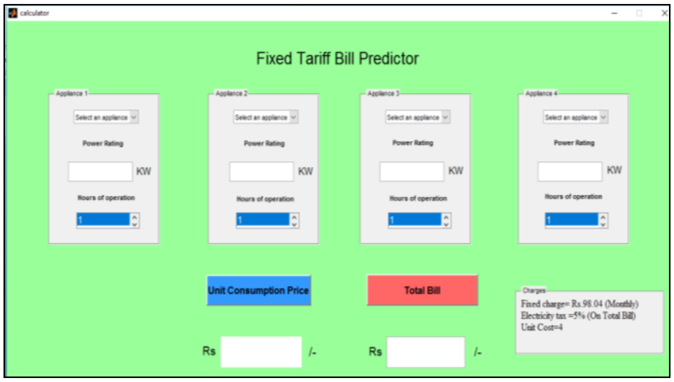

Fig 2: Fixed Tariff Bill Predictor

2) **Day ahead bidding bill predictor:** The Day Ahead Bidding bill predictor divides the GUI into four slots for the 24 hours of the day. Each slot in this predictor has a different or flexible energy price which follows the concept of flexible electricity prices. The bill is calculated for each slot and a total bill prediction is based on the values input by the consumer for each slot and thus the bill is predicted.

Fig 3: Day Ahead Bidding Electricity Bill Predictor

B. Base formula for Calculation

% total power ratings ------------------p = a+b+c+d;
% total operational hours ------------ q = x+y+z+t;
% total bill--------------------------Bill = p*q*4

C. Simulation Model Screen Caps

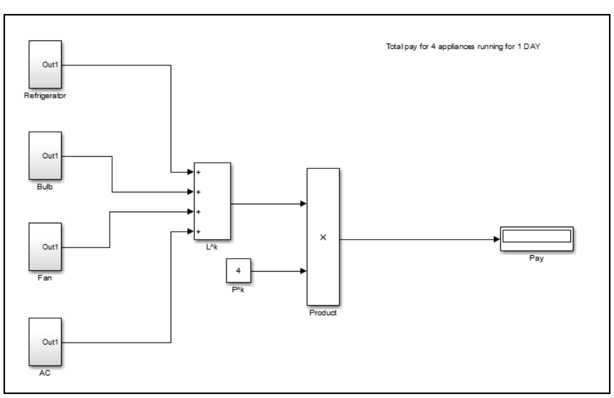

Fig 4: Total Pay for 1 Day

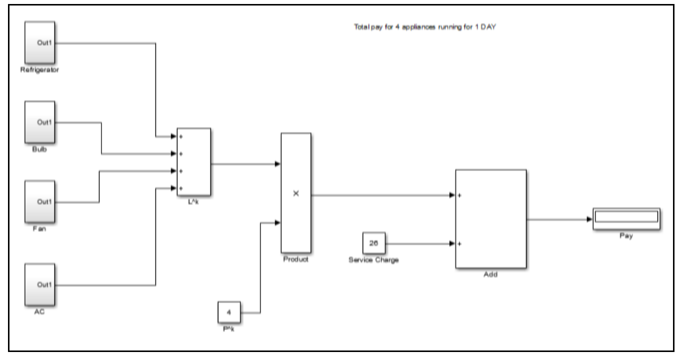

Fig 5: Total Pay for 1 day with Service Charge

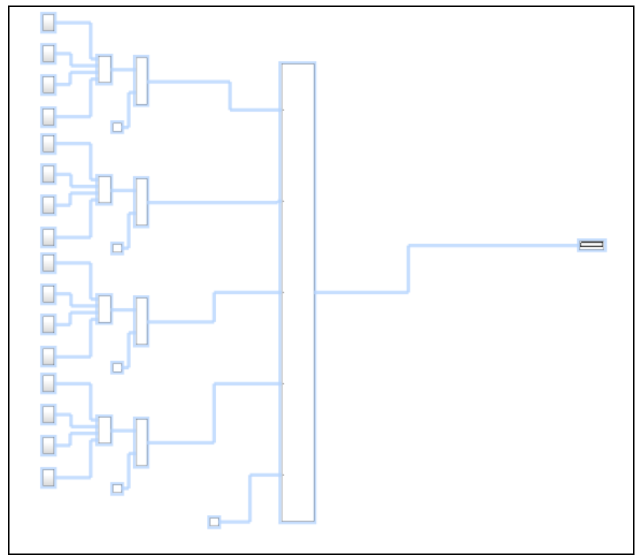

Fig 6: Day Ahead Bidding Simulation Model

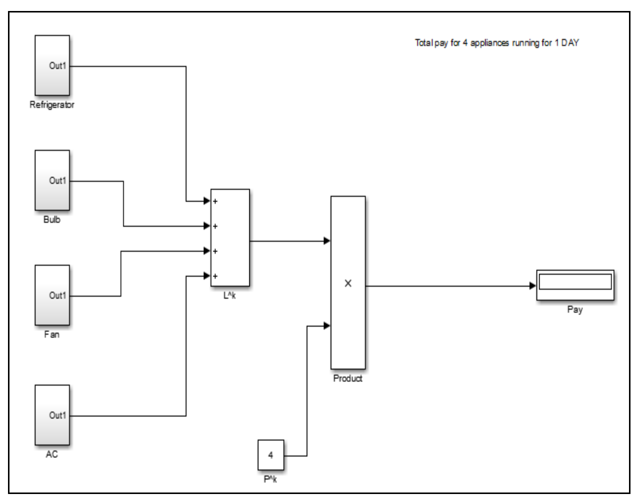

Fig 7: Total Pay for 1 Hour

4. Results & Discussion

Load scheduling is one of the most crucial and beneficial phenomena while considering the electrical energy cost and efficiency. By applying it at the residential level and considering the results, it could be adopted in much more diversified and broader fields. Various data of energy and cost were collected at residential level at different times with constant unit price with different appliances operating in

different regions of the slots. The graphs of the survey were plotted for cost and efficiency with reference to time and the calculations were done through MATLAB simulation.
To overcome the high cost incurred through normal procedures and low efficiency, two new methods were studied and analyzed which were:-

1. Day ahead bidding
2. Real time

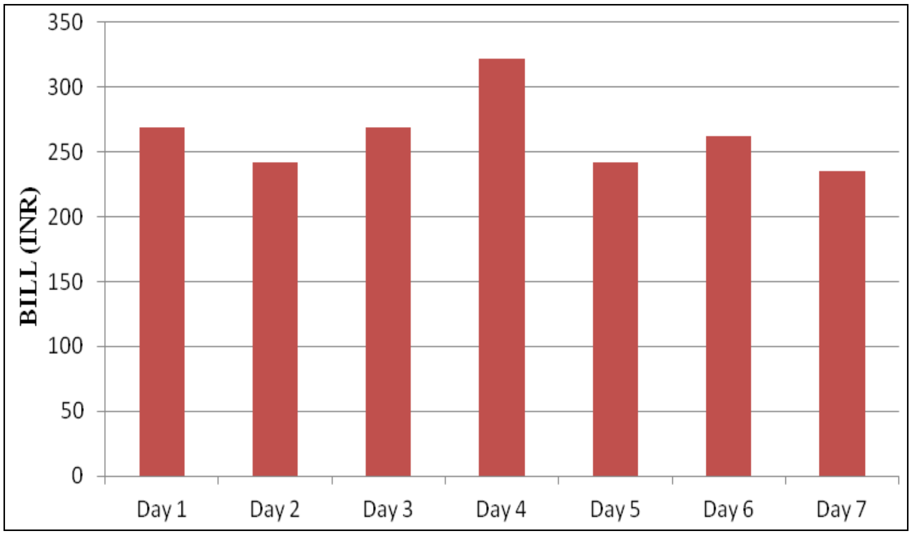

Fig 8: Cost Variation day by day

Out of the two, the day ahead bidding was adopted for driving out the desired results and meanwhile it eventually did. Through the studies of consumer and producers consumption and production a graph, a normalized unit price was generated which through simulation developed various graphs.

Table 1: Difference in bill on application of day ahead bidding

Appliance	Rating(KW)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Refrigerator	0.25	24	22	23	20	24	21	20
AC	1.4	10	12	11	13	10	11	15
Fan	0.04	20	18	19	17	15	16	10
Bulb	0.1	10	11	10	13	12	13	14
BILL (INR)		268.80	241.92	269.19	321.77	241.92	262.08	235.20
Appliance	Rating(KW)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Refrigerator	0.25	24	22	23	20	24	21	20
AC	1.4	10	12	11	13	10	11	15
Fan	0.04	20	18	19	17	15	16	10
Bulb	0.1	10	11	10	13	12	13	14
BILL (INR)		88.43	103.43	98.34	107.88	93.51	85.07	107.54
Appliance	Rating(KW)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Refrigerator	0.25	24	22	23	20	24	21	20
AC	1.4	10	12	11	13	10	11	15
Fan	0.04	20	18	19	17	15	16	10
Bulb	0.1	10	11	10	13	12	13	14
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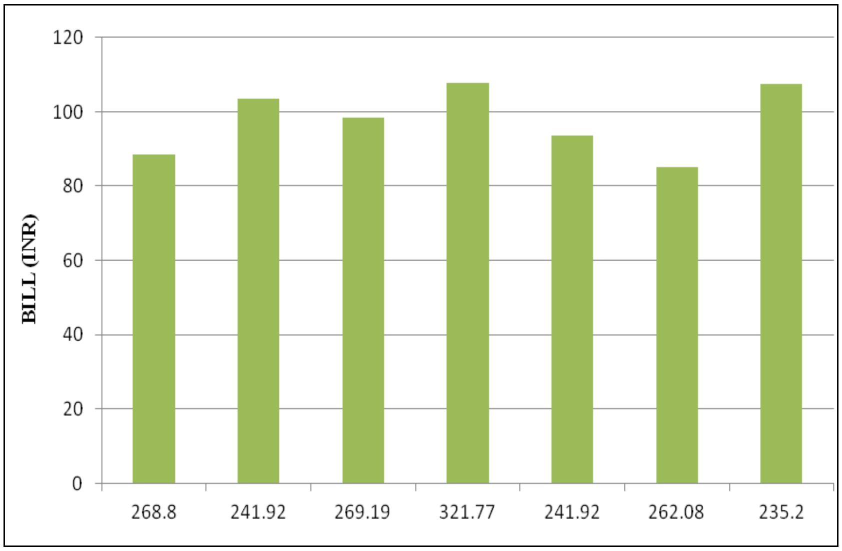

Fig 9: Cost Variation day by day

To A comparative study of the above generated graphs completely reveals the fact that the day ahead bidding is much more economical and efficient method wherever the cost is to be minimized.

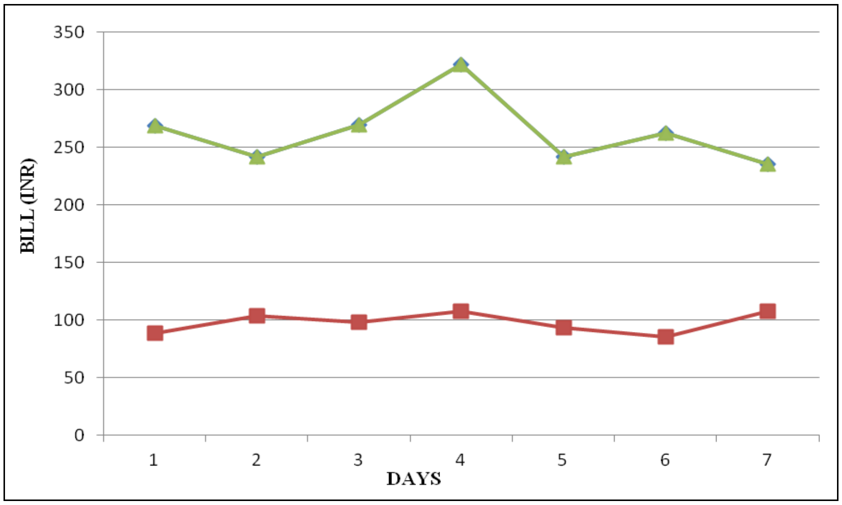

Fig 9: Cost Variation day by day

For the more wide area, this technique could also be adopted with the use of the Dinklebach algorithm and various non-linear programming approaches for calculating cost efficiency. With more advancement in technology, this technique will soon become available and has got much more areas that need to be explored so that generation could be enhanced.

5. Conclusions

This paper presents a cost efficient concept of electricity consumption in such a manner to have optimized consumption benefits for per unit use. Different-2 consumption patterns for getting maximum efficiency & cost efficiency can vary with load shifting effect also explained. The use of distributed energy resource & services fee helps to reduce the burden of generators and decrease the end user consumption. Two GUI model for tariff bill predictor are purposed i) Fixed Tariff Bill Predictor. ii) Day Ahead Bidding Bill Predictor. The end user & utility company improve the cost efficiency after successful implementation of these models.

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