# SMART METERING AND DYNAMIC TARIFF: THE WAY TO SMART CONSUMPTION

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**Abstract**— Advanced metering Infrastructure (AMI) involves automatic collection of data from the meters without any human intervention. The smart meter is designed to calculate real-time aspects like accurate meter reading, tariff calculation and alerts in the event of excessive consumption. This data is communicated to the utility as well as the consumer and a graphical analysis of the consumer use pattern as well as the tariff in combined form, is displayed to the consumer via an in-home display.

Smart metering makes the consumer aware of his electricity usage patterns, the different tariffs applicable to him based on his consumption slab, and extrapolating from the data collected, a usage pattern which would help the consumer manage consumption. This management of consumption is 'Demand Response' and it incorporates pricing programs (dynamic pricing), efforts to encourage peak-duration load reduction in order to obtain a flat voltage profile. It is observed that consumers lack the resources to 'know' their bill. An aware consumer can make informed choices of his tariff plans and understands his real-time consumptions rather than paying end-estimated bills.

**Keywords**— AMI, Demand response, dynamic tariff, real-time consumption, peak-duration reduction, end-estimated bills, flat voltage profile

### INTRODUCTION

Demand response (DR) is the development and extension of traditional demand-side management or load management practices and is recognized as a key application of the smart grid. The definition of DR is: "Changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentivize payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized [1]."

The paper discusses demand response, AMI and its importance in demand response and a prototype of a smart meter. The following objectives were defined for the course of the study:

- To conduct a survey in all the houses of a housing society in order to gauge consumer awareness with regards to their electricity bill, i.e., consumption and tariffs
- To build a prototype of a smart meter and a synchronized display, incorporating features such as- real-time consumption and tariff calculation, and graphical analysis of power consumed on monthly basis
- To propose the inclusion of smart meters and dynamic tariff programs to engage and educate the customer and thereby enable 'smart consumption.'

## OBJECTIVES OF DEMAND RESPONSE

The objective of deploying DR has been to go further than simply improving system reliability, and extend towards improving system efficiency and then system flexibility.

*2.1 DR for improving system reliability*

The earliest and most commonly practiced DR focuses on system reliability. A customer, often a large industrial facility, agrees to reduce load to guarantee system reliability under peak demand conditions or other emergency system events, and is paid an incentive for doing so. Since they are designed for emergency use, these DR programs are infrequently called upon.

*2.2 DR for improving system efficiency*

More recently, the focus of DR has been increasingly placed on system efficiency. Many DR programs have begun to focus on non-crisis peak shaving – flattening load curves to improve the efficiency of long-term power system capacity use, since the generation, transmission and distribution capacity of a power system is sized to meet the expected peak demand.

*2.3 DR for improving system flexibility*

This emerging application of DR is very important for supporting Renewable Energy (RE) integration as it provides efficient flexibility to handle variability on the power system. In situations like sudden increase in demand too, demand response resources were able to quickly and efficiently accommodate the unexpected variability [3].

## CONSUMER SURVEY

A survey was conducted in various houses of a housing society. A questionnaire was used to collect the information regarding consumer understanding of their bills, knowledge about peak-load hours, tariffs for different consumption slabs and additional ToU (Time of Use) tariff for commercial and industrial loads, and smart consumption. Analysis of the survey is summarized below:

*3.1 Consumer understanding of bills*

The purpose was to find out how many users read their bills. Due to Electronic Clearing Services, consumers did not really see their bills until the deductions appeared on their credit card statement. Even if the bill was slightly higher than the previous months, consumers hardly tried to understand the cause. Most of them just reduced their use of air-conditioners and washing machines in the next month, expecting a reduction in their bill.

*3.2 Knowledge about peak-load hours and Tariff variation*

Tata Power launched a 'thermal energy storage incentive programme' for consumers to lower peak demand of electricity on its Mumbai distribution network in 2014. According to this, there is a penalty of INR 1 a unit for usage during peak hours and incentive of INR 0.75 for energy used in off-peak hours. Thus, tariffs may vary with time and it is essential for consumers to know about this so that they can plan the use of heavy loads at off-peak hours and save on their bills.

*3.3 Smart consumption*

Setting up alerts and reminders to help manage and track electricity usage and using smart appliances reduce their consumptions at peak-load hours comes under smart consumption.

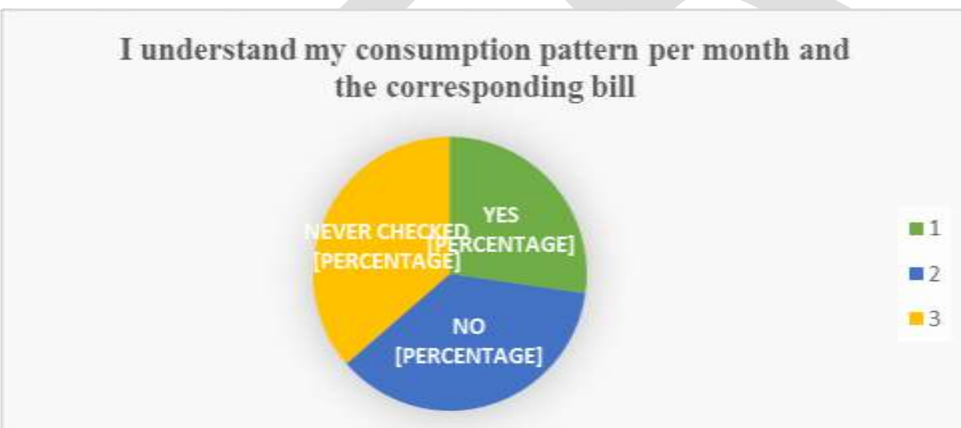


**Fig1. Consumer Awareness Survey**

## TECHNOLOGIES THAT AID DEMAND RESPONSE

Although the success of DR programs depends to a very large extent on effective commercial arrangements (including rate structures and pricing schemes) and on an accurate evaluation of cost-effectiveness, some new technologies are physically essential for DR to function or to function better.

*4.1 Advanced metering infrastructure technology*

Advanced metering infrastructure (AMI) technology, commonly known as "smart metering", permits fine-grained communication of system conditions to customers and fine-grained measurement of customer responses via two-way communications between the customer and the utility. It is the technical foundation for engaging more DR, especially from smaller customers in the future. It allows customers to receive information signals from utilities involving price, environmental impact and other aspects, and utilities to receive time-of-use data that reveals how much energy customers use at any given time.

*4.2 "Behind-the-meter" technologies*

AMI and home area networks also enable the use of a host of consumer-side technologies for building or home energy management, such as controllable appliances, monitoring and analysis of energy use, and price-responsive thermostats. These technologies can enable smaller commercial and residential customers to respond more actively to price or other supply-side signals. However, currently they are relatively immature and costly.

## ROLE OF AMI IN DEMAND RESPONSE

Electricity consumers use a certain amount of power every day, which can be calculated as the base load. Electricity demand varies according to the different hours of the day; it is usually highest in the morning time when appliances such as washing machine, hair dryer are used, and afternoon time when air conditioners in the offices and shops are used continuously. When every customer switches on the load at the same time of the day, it is called as the peak usage time. To meet these demand requirements, we traditionally used to increase the generation of energy. Here is where demand response comes into picture, instead of increasing the generation; we can design programs to adjust energy consumption from on-peak usage time to off-peak usage time depending upon consumer's daily preferences. Thus, demand response is an economical way of reducing peak demand and avoiding energy emergencies.

To achieve the above requirements, we need some form of communication between the utility providers and consumers. Advanced Metering Infrastructure plays a significant role in demand response by engaging consumer response with the utility and enabling them to actively manage energy capacity. With the help of AMI, various demand response programs are designed for e.g. pay according to the consumption program. Using this combination of technology, customers are informed about their real-time usage and even future load curtailing signals are provided such that the customer uses this information to set high-energy use appliances to automatically reduce power demand at high pricing hours.

## HARDWARE SET-UP

After identifying the need for a smart meter, the next step was to build a prototype of the same. The two-way communication between the utility and the consumers provided by the smart meters makes it possible for the consumers to understand information about tariff and the utility to obtain information regarding hourly consumption of the consumer. For AMI (smart metering) to completely serve its cause, the following features need to the incorporated:

a. Two-way communication system

b. End to estimated bills

c. Monitoring and analysis of energy use

d. Control of appliances

e. Fault detection (outage prevention)

f. Real-time usage tracking

g. Remote connect and disconnect

h. In-Home displays

### ➢ OUR PROTOTYPE

We detected the impulses using a digital multi-purpose optical sensor. The output of the sensor is the input to ARM Cortex-M3 microcontroller, where consumption is calculated. Along with consumption, tariff variation as per consumption slabs and plots of consumptions with respect to time were obtained. Now, this data which is calculated and the corresponding plots obtained are communicated to a display. The figure below shows the block diagram of the prototype that we are developing.

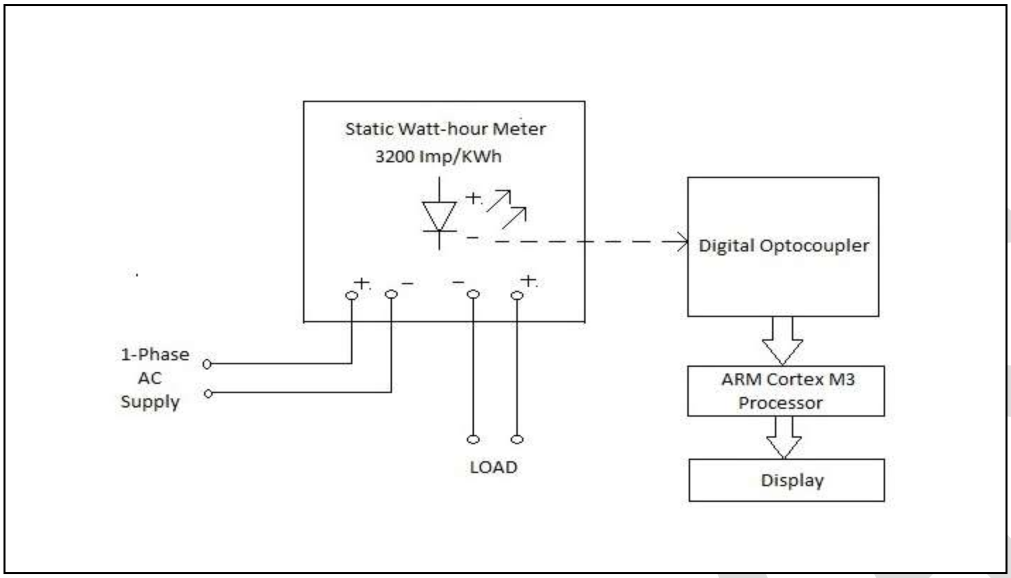


**Fig 2. Block diagram of Smart Meter**

We have used a 32-bit ARM Cortex-M3 processor for highly deterministic real-time applications used to develop high-performance low-cost platforms for a broad range of devices. The ARM processor is used because apart from the incorporated features, future expansion is also easily possible due to its ability to work with devices including microcontrollers, industrial control systems and wireless networking and sensors.

## ALGORITHM FOR ARM PROCESSOR PROGRAMMING

1. START
2. Energy meter constant K as, K= 3200 Impulses/kWh
3. Count number of impulses from optocoupler output
4. Start clock at 00:00 Hours
5. Calculate energy consumption= Number of Impulses/K
6. Reset consumption to 0 kWh at 00:00 Hours everyday
7. Store consumption/hour and consumption/day
8. Multiply with tariff according to consumption slab
9. Plot Consumption v/s Hour of the day
10. Plot tariff for all days of the month
11. Plot consumption for all days of the month
12. Communicate all calculations to display
13. END

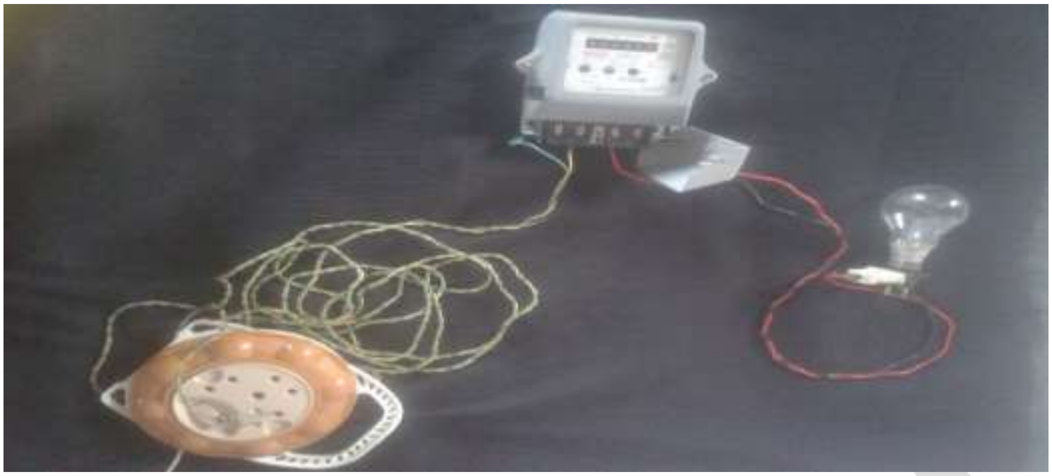

**Fig3. Set-up to detect impulses of meter on test load**

## FLEXIBLE PRICING

One of the objectives of our paper is flexible pricing and tariff calculation. Traditionally electricity tariff rates were of two types- flat rates and tiered rates. Flat rate corresponds to paying according to the energy usage for a given period of time. Tiered rate includes paying according to the blocks of usage, for e.g. for a given period of time, the customer will pay at a certain rate for the first 100 kWh, the rate changes during the next 200 kWh and so on.

- FLAT RATE TARIFF

This is the flat rate tariff plan for one of the surveyed houses (Tariff applicable from 1st April 2014 to 31st March 2015) [5]

| CONSUMPTION SLAB (KWh) | FIXED CHARGE (INR/MONTH) |
|---|---|
| 0-100 units | 40 |
| 101-300 units | 75 |
| 301-501 units | 75 |
| Above 500 units | 100 |

**Table 1. Flat Rate tariff**

The graphs below show consumption and corresponding tariff in the surveyed house.

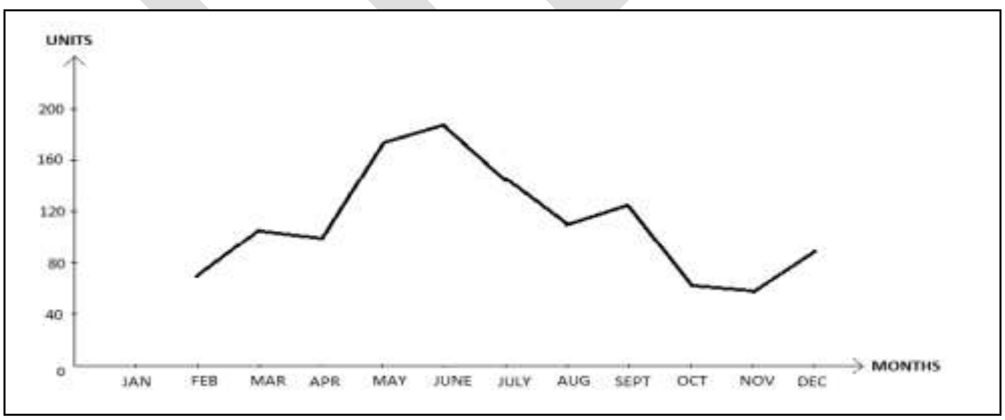


**Fig 4. Graph of consumption for months of the year**

On the graph of fig 4, the numbers on Y-axis represent number of units used (kWh), and X-axis represents months of the year. As it can be observed, maximum consumption is during summer months, and winter months have very light loads.

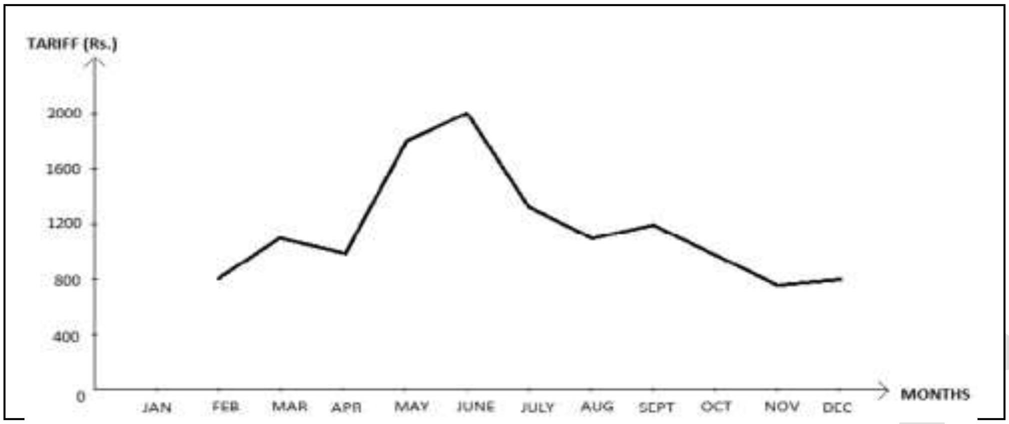


**Fig 5. Graph of tariff per month**

Fig 5 represents Tariff versus Months graph, Y-axis shows tariff in INR and X-axis shows months. As it was seen earlier, tariff during summer days is highest.

## DYNAMIC PRICING PROGRAMS

Dynamic pricing programs use real-time or hourly electricity rates to offer residential customers a choice in how they pay for power consumption [2]

*8.1 Real time pricing (RTP)*

It analyzes the hourly consumption of energy and according to off-peak & on-peak hours, the customer will have to pay

*8.2 Critical peak pricing (CPP)*

During the power emergency conditions where the load demand increases substantially, the price for electricity is increased. There are two sub-types of this rate program. First one is where the rise in the price according to the load demand and its time period is predetermined (For e.g. 2.00 pm-4.00 pm in summer-time) and second type is when duration and time of rise in price is variable according to grid's preferences in the reduction of load.

*8.3 Critical peak rebates (CPR)*

During the power emergency conditions when the increase in load demand and its duration is predetermined, the rate of pricing is kept constant, instead, the consumer gets a certain refund for curtailing loads voluntarily.

*8.4 Variable peak pricing (VPP)*

In this type, the different load hours of the day are predefined. Customer will have one rate for on-peak time period and a different rate for off-peak time period, but the on-peak time period rates are varied according to the market conditions and utility.

All the above programs are referred to as dynamic pricing programs since the rate of pricing is unknown.

*8.5 Time of use (TOU)*

In this type, the rate schedule is predefined, i.e. on-peak periods and off-peak periods are predefined and its pricing rates are kept constant. This is one of the reasons why TOU is not included in dynamic pricing programs since we have determined its parameters in advance.

By using the above-mentioned pricing programs with the help of AMI in demand response, the tariff paid by consumers has been reduced considerably as they can choose the program that is suitable to their usage patterns. These programs allow consumers to save on their bills, understand their energy use in real-time, and reduce strain on the electric grid [4].

## CONCLUSION

Energy is an important resource whose demand is constantly increasing. Hence, it is important to start optimizing the process of load management for sustainable development. DR is the ability of the customer to influence their consumption at peak times and, the improvement in communication systems and smart metering have supported demand response. For a smart meter to be a technological foundation for demand response, all the features mentioned earlier are required to be incorporated. However, the development of AMI largely depends on communication between the utility and consumers, use of smart appliances in homes and cyber-security for building security systems to detect intrusion in the metering infrastructure.

In this paper, we have introduced the concept of demand response, conducted a survey to understand the consumers' attitude towards their bills, explained a prototype for a smart meter that aids demand response, and also highlighted several dynamic pricing programs that would help consumers decide a program suitable to their consumption to save on their bills.

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