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An Arduino Based Smart Meter for Demand Side Management of Electrical Load Using Real-Time Pricing.

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ABSTRACT: Real time pricing(RTP) is financially more effective when compared to conventional flat rate pricing, to facilitate RTP smart meters with communication system is required. This paper is about smart meter which supports RTP with other features. In this prototype we have built a smart meter using Arduino – UNO with 16x2 LCD display, current and voltage sensors and used MATLAB to simulate rest of the system, and a Bluetooth module is used for communication between Arduino and MATLAB, which can be replaced with other convenient device to communicate with supply side and real time smart meters. The paper focuses on the features and design of the proposed system. The primary point of the system development is to be low cost and facilitating RTP requirements.

KEYWORDS: Real time pricing; Smart meter; Load curve optimisation; Reduced mean cost per unit

I. INTRODUCTION

Electricity fluctuates every fraction of second and the demand increases during midday business hours when the weather is hot and industrial loads come into action. Hence to match supply with demand, the supply side needs to generate more electricity, it may lead to increased load on generators or synchronizing more generators to the grid. Traditionally, we need enough generation capacity to meet the peak load. Usually peak load generators are less economic as they run on gas or oil. Few peaking units are idle for all but a few hours a year. Recently, demand response has been proposed to control the load instead of providing enough generation capacity. Where, energy providers can adjust the load by flexible pricing, such as real-time pricing (RTP).Time-shifting rates such as RTP, have assumed an imperative part in supporting interest in smart metering [1]. With the development of smart meter, which supports the collection of meter readings and the announcement of electricity price, this can be achieved. As electrical load increases, cost per unit generation increases due to various factors, such as British thermal unit for steam generators, synchronization of lesser efficient generators and generators which run on natural gas. Hence by shifting load from peak hours to off peak hours, we can reduce the mean cost per unit generation. A pricing-based energy control strategy,such as RTP, can be used to remove the peak load from the grid. Where load is shifted from peak hours to off peak hours. The RTP technique can likewise raise the income of the supply-side and lessen the power costs of buyers to accomplish a win-win circumstance [2].Also, numerous examinations have demonstrated that uncovering end-use consumers to hourly RTP is known as the most productive apparatus that can ask consumers to expend all the more admirably and effectively [3]. And by successful implementation of RTP, we can reduce on current spent on infrastructure development and maintenances for power generation, as number of required peaking units will be comparatively lesser.As the entrance of discontinuousgeneration increasesvery much composedfurthermore, used

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demand responcecould prompt great system wide advantages as far as enhancing power system security and financial efficiency [4].

II. LITERATURE SURVEY

As per the (CIA World Factbook) Cia.gov (30 November 2016) [5] 308.8 million kW is installed generating capacity in India. If we assume 5% of the installed capacity taking into account just peakdemand, at that point 15.44 million kW in India is the peak load capacity. If we consider (U.S. Energy Information Administration) Eia.gov [6] capital expenses data fornatural gas driven power plant, we locate that enormous speculations of about USD 14.16 billion are caught in introducing such peak load capacities. Peaks in load curve are due to unregulated demand, and to meet peak load additional power generators are required. These peak load generators stay idle during off-peak periods, hence a loss of opportunity cost and system efficiency. According to Hung-po Chao [7],Price-responsive demand is fundamental for the accomplishment of a brilliant framework of a smart grid, similarly dynamic pricing can move the request from peak to off-peak and help stay away from expansive capital speculations of any grid.For the demand side management,analysts have presentedreal-time pricingplans that lessen the ratio of peakto average through urging clients to move their utilization to off-peak hours [8]– [10]. By Applying Game theory on RTP profit for both supply side and consumer side is assured [11].A smart metering framework has been proposed in the past but it only looked at consumer characterization and not holistic view of the complete smart metering process and environment [12].

III. PROPOSED SYSTEM

This project is primarily concerned with the RTP, which uses Smart meter for interaction between the supply side and the consumer under the control of the system. The paper will shed light on the features & design of the system.

A. *Features:*

- *Displays power components:*The smart meter is designed to show power components to user, viz. voltage, current, power factor etc.
- *Displays current rate per unit load (tariff):* This can be considered as the major feature of the smart meter, where tariff will be calculated at supply side according to the current load, and generators active at that time. And this tariff will be displayed on the smart meter, according to which consumer will be charged.
- *Notification during peak loads:*Smart meter will notify consumer when the tariff is higher and also when tariff is lower than usual. This helps consumer to reduce electric charges easily.
- *Displays due amount to pay:*No human force is required to provide bills to consumer, smart meter will calculate the due charges according to the power consumed and the tariff when it was consumed.

B. *Design:*

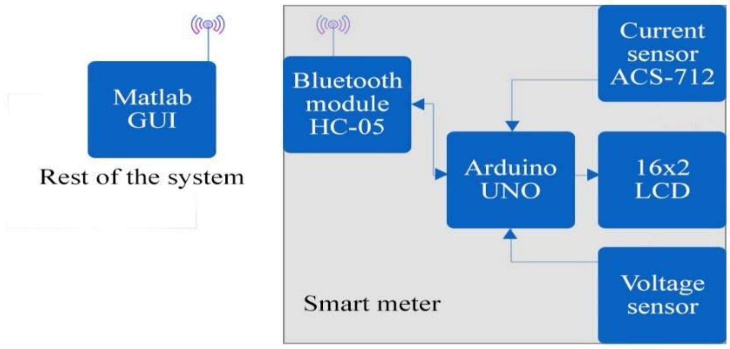

Figure 1: Block Diagram.

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The block diagram shown above represents the work-flow of the prototype built (system). The MATLAB is used to simulate the rest of the system. The Arduino will get the current and voltage readings with the help of current and voltage sensor. And the RMS values of voltage & current, power factor, energy consumed and all other power components will be calculated using emon library for Arduino.The tariff will be calculated in MATLAB by using equations for incremental cost curve and other factors such as amount of power available from renewable sources, and according to the load and the generating capacities set on the GUI. And the tariff calculated will be sent to the smart meter via Bluetooth. And the charges for using electricity will be calculated according to the updated tariff and will be displayed with the tariff on the LCD. User is supposed to reduce his charges by checking the current tariff and scheduling the load according to the tariff. Hence this will lead to flattening of load curve. Tariff can be updated every minute or even in few seconds depending on the communication system used and processing time.

IV. ADVANTAGES

- Saves a lot of money to the nation, as it increases revenue to supply side, and consumers will be charged less.
- Reduces the percentage of the installed capacity taking into account just peak demand. i.e. No extra infrastructure required which stays idle except few hours a year.
- Electricity billing will be easier as the smart meters will show the amount to pay.
- We can reduce load shedding to a greater extent if the response degree of customers to real-time prices is high enough.
- Upholds a step on conserving expensive fossil fuels which were used to generate electricity at the peaking hours.

V. DISADVANTAGES

- Uninterrupted communication system is required for smart meters which is quite hard to establish at remote areas.
- Replacement of conventional meters with new smart meters consumes money and time.

VI. SIMULATION RESULTS

For simulation purpose we have taken load curve of date 4/2/2018 of Karnataka from KPCTL [13]. And the generation capacity from renewable sources, thermal power plants were considered as limitation in incremental cost curves.

Assumed incremental cost curve of generation in thermal power plants in Karnataka

*lambda1 = 1*P1 + 15₹/MWh3420MW Max.*

Assumed incremental cost curve of charges for imported power.

*lambda2 = 1.3*P2 + 8₹/MWh5500MW Max (Assumed).*

Assumed incremental cost curve of generation from diesel power plants in Karnataka.

*Lambda3 = 6*P3 + 6₹/MWh*

Power from diesel is not generated because the load demand was not high enough.

We have obtained the following results from MATLAB, for savings of fuel cost at generation side for the date 4/2/2018. Excluding the savings by reduced infrastructure and maintenance. If people respond to tariff displayed on smart meter. According to game theory[3]. At Nash equilibrium (i.e. Completely flattened curve) savings in fuel are 2.2761e+05₹. Reaching Nash equilibrium is practically not possible, so we've calculated the savings in fuel cost for economic dispatch using assumed incremental cost curve and by assuming the percentage of curve flattened, and the results are shown below in the Table-1.

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Table – 1:Fuel cost saved for percentage of curve flattened.

Assumed percentage of curve flattened (i.e. percentage of people responding positively to the tariff displayed on smart meter)	Savings in fuel cost In Rupees. On 4/2/2018.
20%	8.1941e+04
40%	1.4567e+05
60%	1.9119e+05
80%	2.1851e+05

VII. CONCLUSION

In this paper, we have shown the design and features of the smart meter developed, and how this technique can be used to shift load from peak hours to off peak hours. profit for both the utility and the buyers & shorter-duration peak periods can be achieved assuming consumers responding to the real time pricing in a positive way.

VIII. FUTURE SCOPE

In future, with the addition of few more sensors at few nodes State estimation of power system can be done. And thus, possible region and time of power theft can be suspected.

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