New Rate Design Innovations to Aid Utilities toward Building Sustainable Micro grids

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***Abstract*—The objective of this paper is to present new rate design innovations toward improving or replacing the net energy metering and billing associated with the rooftop solar PV systems. New rate design innovations are helpful in enhancing the sustainability of renewable energy based micro grids and utility's network. The paper is presented in five parts.**

Part I being introductory in nature, summarizes the rate design innovations by utilities in the US with regard to net energy metering. Part-II presents analyses about the applicability of Time of Use (TOU) tariff to net energy metered solar and non-solar customers in the residential sector. In part III, Welfare Economics of the proposed TOU tariff is presented. Part IV discusses results. Finally, conclusions and recommendations have been presented in part V of the paper.

It may be noted that the paper is prepared in the context of the US utilities, but the rate design innovations, conclusions and recommendations that have been discussed in the paper are equally applicable to such utilities in Africa and other parts of the world, that are building renewable energy based micro grids.

***Index Terms*- Net Energy Metering, New Rate Design, Sustainable Micro grids, and Time of Use Pricing**

I. INTRODUCTION

The solar PV's rapid stride has been made possible by several factors, namely, rapidly declining cost of solar PV technology, innovative leasing models, and supportive policies and incentives. According to the International Renewable Energy Agency (IRENA) and others [1, 2], the solar PV module cost fell by four fifth during the 2009-2015 period. In addition, the total global installed cost for utility scale solar PV fell by an average of 62% over the same period.

In the United States, innovative financing models and incentives such as the Investment Tax Credit (ITC), Renewable Portfolio Standards (RPS), and net metering have boosted the spread of solar PV technology in the residential and utility sector.

While the RPS defined the share of renewable energy in the supply mix to be achieved by utilities, the net metering enabled the setting up of micro grids and roof top solar system's integration in the electricity grid. This also enabled owners to purchase electricity from the utility when the solar PV is not functional, and feed excess electricity to the utility's network when the system is fully functional, i.e., during the day. No financial obligation was envisaged on the part of owners to maintain and upgrade the utility's electricity grid.

As asserted by many utilities [3], the non-solar customers were disadvantaged as they were made to subsidize the solar customers. The non-solar customers end up paying a higher price than solar customers for buying electricity from the utility, thus, subsidizing the former, which is termed as "Cost Shifting". On the other hand, the solar companies [4] allege that utilities and regulators don't recognize the positive benefits such as avoidance of Carbon Dioxide release in the environment and postponement of utility's investment in new electricity generation and transmission capacity.

The Utility Dive [5] review indicated that the net metering policy is being revised in several states in the United States. In Arizona [6], the avoided cost expectedly replacing the net metering rate is expected to reduce the solar customer credit by 30%. However, the state regulators support to limit the credit loss to 10% in any given year. The proposal of levying demand charges on the residential customers, based on their peak time usage, is new in its application to domestic consumers.

Illinois new Renewable Portfolio Standard [7] requires minimum additions of 3000 MW solar and 1300 MW of wind capacity by 2030. The roof top solar market is expected to take-off in 2017. However, adjustable block program, which is designed to procure renewable credits from the Distributed Energy Resources (DER), is up for debate. Each block is defined in terms of a net metering rate and a block of capacity (MW) to be procured.

As an alternative to net metering, customers will be given a choice to pick out of three options in New Hampshire [8]: (i) A Time of Use option for net metering customers, (ii) Fixed

Solar Credit Rate scheme, and (iii) Community solar option. The proposal to levy demand charges to residential customers is considered impractical.

Massachusetts [9] is rich in off-shore wind resources and energy storage technology. Regulators have been asked to develop a successor tariff to net metering to create new 1600 MW solar capacity. The Department of Energy Resources is also proposing a declining block incentive.

The Act 236 of South Carolina [10] requires regulators to approve a Value of Solar methodology and Third Party Ownership of Rooftop Solar. The Act further requires utilities to undertake the installment of renewable energy capacity equivalent to 2% of the past five year peak demand average of the system.

Utah's Rocky Mountain Power Utility (RMPU) [11] found that the roof top solar customers underpay their actual cost of service by US$400 annually, equivalent to an annual cost shifting of US$6.5 million. To remediate this, RMPU proposed to reduce payments to solar customers and impose a fixed fee of US$15 per month.

Hawaii [12] has achieved significant penetration of roof top solar PV residential systems in efforts toward building clean energy future. According to Hawaiian Electric Company (HEC), Oahu, Hawaii, and Maui residents together added 487 MW new solar PV generation capacity and signed 60600 roof top solar PV system net metering contracts. However, the HEC [12] scrapped the net metering policy in October 2015 and replaced it with new Distributed Resource Program, which is comprised of (i) Customer Grid Supply (CGS) and (ii) Customer Self Supply Program (CSS). Under the former, the customers receive credit at the rate approved by the Hawaiian Public Utilities Commission and are billed at the retail rate of utility. The Customers on Self Supply Program (CSS) produce energy for their own use and also store excess energy. Such customers are not allowed to export electricity to grid.

In summary, utilities are contemplating new rate design innovations for improving or replacing the net energy metering and billing in the context of roof top solar PV system. Such factors as the "cost shifting" to non-solar customers, declining block incentives, new leasing schemes, and equity to all stakeholders are influential in the new rate design. In addition, the Time of Use Rate application to net energy metering customers is a very innovative and interesting concept for analytics.

The Time of Use Rate also deserves adoption by electric utilities in developing countries [13] to reduce peak-time demand, which is caused mainly by residential loads in such utilities, and save investments in new capacities to meet that demand.

II. THE TIME OF USE PRICING APPLICATION TO RESIDENTIAL CUSTOMERS

Traditionally, the Time of Use pricing concepts have been utilized by utilities to manage customer loads during peak time. The utilities provide transparent pricing signals to customers to increase off-peak period electricity consumption and decrease peak period electricity use by varying the price of electricity with the cost of electricity supply, which in-turn, varies with the time of day/week/season in a year. The customers then implement the load management decisions in a decentralized manner [14, 15,16] and save money, while allowing utilities to minimize investments in expanding the capacities of electricity generation and transmission assets to meet the peak demand of utility.

As "a new way to save energy", the HEC offers a pilot program based on "Optional Time of Use Plan" under which residential customers are offered the following rates during peak period, mid peak period, and off-peak period:

On-Peak 5p.m. to 10 p.m.: 39.6 cents/kWh

Mid Peak 9 a.m. to 5 p.m.: 17.3 cents/kWh

Off- Peak 10 p.m. to 9 a.m.: 26.0 cents/kWh

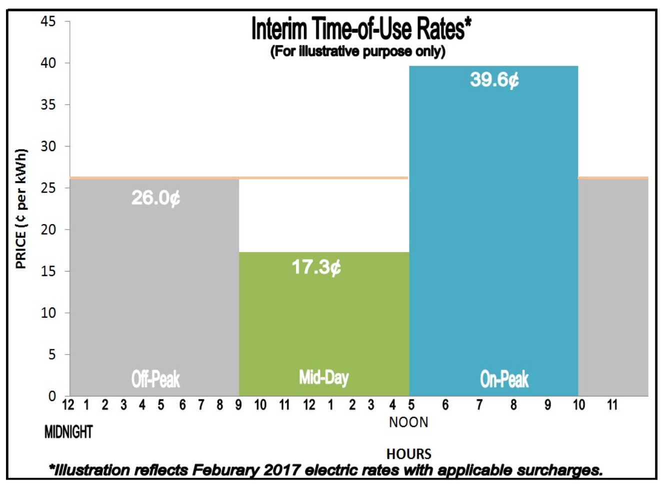

Fig.1 Interim Time of Use Rates for Residential Customers (Courtesy: Hawaiian Electric)

The analysis of the Time of Use rates reveals the following:

a) The HEC supply capacity is under stress during the peak time from 5 PM to 10 PM due to Heating, Ventilating, and Air Conditioning (HVAC) loads;

b) The rates are transparent and provide signals to residential customers to shift certain end uses such as dish washer, vacuum cleaning, and laundry to mid peak period from 9 AM to 5 PM from peak time. The ratio between peak to mid peak rate is 2.28, which is sufficient to motivate residential customers to change their behavior and reduce cost;

c) The ratio between the off-peak period to mid peak periods is 1.5, which is still quite high. It discourages residential customers to conduct energy intensive activities even during off-peak period. However, it encourages consumers to shift energy intensive chores to mid-peak period; and

d) The ratio between the mid peak rate to net metering rate incentivizes the roof top solar home owners to using solar electricity produced during mid peak period. However, consumers would likely benefit more from using grid electricity for very energy intensive applications during the mid peak period.

III. THE WELFARE ECONOMICS OF THE PROPOSED TIME OF USE RATES

Fig.2 below shows mid-peak period and peak period demand curves of a typical residential customer who has signed-off the Time of Use Rate pilot program. Before the sign-off, she is operating at an average electricity price (P_{av}). The Pilot program offers her three prices on: (i) peak price (P_P), (ii) mid peak price (P_m), and off-peak price (P_{op}). Under the influence of new prices, she reduces her electricity consumptions from Q_p to Q_{p1} during peak period, but increases electricity use during mid-peak period from Q_m to Q_{m1}.

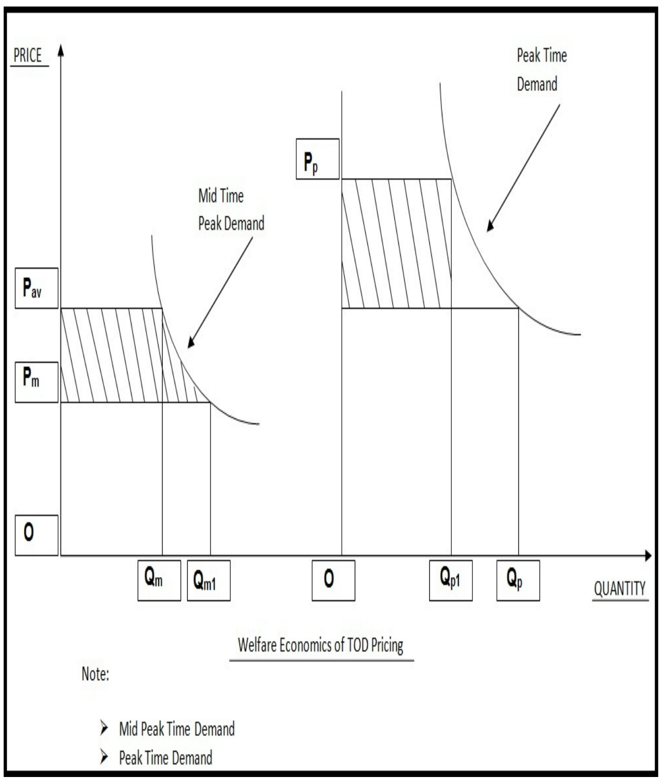

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Fig.2 Welfare Economics of Time of Use (TOU) Pricing

The increased consumer surplus during mid–peak period (CSM) is given below:

$$CSM= [Q_{m}*(P_{av}-P_m)+1/2(P_{av}-P_m)*(Q_{m1}-Q_m)] \quad (1)$$

The decreased consumer surplus during peak period (CSP) is given below:

$$CSP= - [(P_{av}-P_P)^{*}Q_{p1}] \quad (2)$$

$$\text{Net Consumer Surplus}=CSM+CSP \quad (3)$$

The Net Consumer Surplus should be positive in order for a residential consumer to hold on to the Time of Use Tariff plan.

IV. DISCUSSION OF RESULTS

Let us consider a typical residential customer, which receives a monthly supply of 400 kWh from the utility. However, her rooftop solar system produces and feeds 650 kWh to the grid. According to the HEC, the customer credit is restricted to 400 kWh, thus de-motivating the customer from installing an oversize roof top solar PV system.

Now we assume the same customer is participating in the TOU rate pilot program and is offered an electricity rate, as indicated in Fig.1. Given this rate, a typical customer can be expected to reduce her peak- time electricity consumption. However, the exact amount of energy saved will still remain unclear, given the lack of data on, peak-time and mid–peak time demand functions.

One way to understand customer behavior in the specified conditions, is to use the estimates of the elasticity of electricity demand for residential consumers in Hawaii. According to the State of Hawaii-Department of Business, Economic Development and Tourism (Research and Economic Analysis Division), the long-term price elasticity of electricity for residential customer is (-) 0.57 [17], which implies that this customer has a propensity to reduce electricity consumption by 0.57% for every 1 % increase in price.

The price elasticity of electricity demand and the ratio between the proposed peak time price and the average price indicate that the consumption for this residential customer should be reduced by 33%, which can be achieved by shifting the energy intensive activities to mid-peak period.

Similarly, a typical customer will increase consumption during mid peak period at least by 17% on a normative basis, given a price drop in mid peak period of about 30%.

The customer will conserve electricity during off-peak period at least by 2.28% for every percentage increase in price similar to his peak time behavior.

The net customer surplus for residential customers is expected to be positive, based on the normative analysis as explained above. The cut-off point is that the net customer surplus should be greater than the cost of Time of Use meters, which also includes the expenses involved in information dissemination and education and training of the consumers.

V. CONCLUSIONS AND RECOMMENDATIONS

This paper presents an analysis of the net energy metering policy which is under review by the utilities in the United States, as well as about successor tariff such as the Time of Use Rate to net metering customers.

The application of Time of Use Rate for residential customers, which signed–off TOU rate plan, has been analyzed, and inferences drawn may be used in improving the TOU rate design and building sustainable systems.

In the absence of findings of pilot, the results have been discussed by extending the concept of price elasticity of electricity demand to residential customers estimated by the State of Hawaii's agency. The customer behavior has been analyzed and it is expected that customers will shift consumption to mid –peak period from peak and off-peak periods, but exactitude needs to be verified by analyzing the results of the pilot program, when available.

It is expected that the Time of Use Rate Pilot Program initiated by the HEC, in consultation with the Public Utilities Commission of the State, should be successful.

The recommendations for future work include: intensify campaign to sign-off more customers to the TOU pilot and carry out load research and estimate peak time, mid-peak and off-peak period demand functions as well as price elasticities of demand during different periods for calibrating the TOU rates. It will be interesting to estimate cross-price elasticity of demand between solar and grid electricity consumption during mid-peak period.

It should be noted that the paper is prepared in the context of the US utilities, but the rate design innovations and conclusions and recommendations to carry out load research toward understanding customer behavior and building sustainable micro grid systems are equally applicable to electric utilities in Africa and other parts of the world.

VI. REFRENCES

[1] IRENA Quarterly Progress Report, 3rd Quarter 2016, "summer of Solar"

[2] A. Poullikkas, et al, 'A Review of Net Metering Mechanism for Electricity Renewable Energy Sources', International Journal of Energy and Development, Volume4, Issue6, pp975-1002, 2013.

[3]Edison Electric Institute on Distributed Generation and Net Metering available on http://www.eei.org/issuesandpolicy/generation/NetMetering/Pages/default.aspx

[4] Solar Energy Industries Association, USA (http://www.seia.org/policy/distributed-solar/net-metering)

[5]. K. Shallenberger, '10 Rooftop Solar Debates in 2017 and Beyond', Utility Dive, February 9, 2017

[6] Arizona Regulators Vote to Stop Net Metering for Solar available on http://www.azcentral.com/story/money/business/energy/2016/12/20/arizona-regulators-vote-stop-net-metering-solar/956533500

[7] Illinois's Attorney General –Net Metering and Interconnection-Lisa Madigan-Available onhttp://www.illinoisattorneygeneral.gov/environment/netmetering.html#how

[8] New Hampshire Rooftop Solar PV Permitting, Zoning and Interconnection Guide, January 2015.

[9] T.Griset, 'Massachusetts Develops Next Solar Incentive' available on http://www.jdsupra.com/legalnews/massachusetts-develops-next-solar-11271/

[10]H.K.Trabish, 'is South Caroline Solar about to Explode?', Utility Dive, Newsletter Available on http://www.utilitydive.com/news/is-south-carolina-solar-about-to-explode/334164/

[11]Rocky Mountain Power Study supports New Rate for Rooftop Solar Customer, November 6, 2016. (See https://www.rockymountainpower.net/about/nr/nr2016/proposed-net-metering-changes.html)

[12] The Hawaii Electric Company-Time of Use Program, available on https://www.hawaiianelectric.com/save-energy-and-money/time-of-use-program

[13] B. Ram, 'Time of Day Pricing Schemes for Electric Utilities in Developing Countries', Surrey Energy Economics Center Discussion Paper, ISBN-1852370688, June 1991.

[14]B. Ram, 'Tariffs and Load Management: A Post Privatization Study of the U.K. Electricity Supply Industry', IEEE Transactions on Power Systems, Volume 10, No.2, pp1111-1117, May 1995.

[15] B. Gook, et al, 'Bidirectional Energy Trading and Residential Load Scheduling with Electric Vehicles in the Smart Grid', *IEEE J. Selected Areas Comm*. 2013, *31*, 1219–1234.

[16] R.D. Tabors, F.C. Schweppes, and M.C. Caramanis,' Utility Experience with Real Time Rates', IEEE Transactions on Power Systems, Vol.4, No.2,pp463-471, 1989.

[17] State of Hawaii, Department of Business, Economic Development and Tourism, "Study on Income and Price Elasticity of Hawaii Energy Demand, Economic Issues-, May 2011."