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Renewable Generation – Tariff mechanism for enabling DSM and DR at consumer level

by

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SUMMARY

Globally there is an increasing concern for energy conservation and generation of clean energy through renewable sources which are abundantly available as against fossil fuel sources which are depleting fast. In India also there is a realisation that for energy security and sustainability there is need to efficiently harness the renewable potential.

Present share of renewable in India is around 10% (20 GW) and National Action Plan for Climate Change of Government of India aims for 15 per cent of the national generation to be based on renewable sources by 2020. Initiatives of GOI like JNNSM (Jawahar Lal Nehru National Solar Mission) which envisages deployment of 20,000 MW of solar power by 2022 are directed to facilitate above and around 10000MW of this is planned in 12th five year plan period ending in March 2017. Capacity addition thru grid connected wind and small hydro generation is envisaged to be around 15000MW and 2100MW respectively in 12th plan. Besides this, CERC has envisaged an RPO (Renewable Purchase Obligation) mandate for utilities of 10% by 2015 and thereafter increasing @ 1% per year till 2020. These targets are very much in reach considering that officially estimated wind potential in India is around 49GW, some studies have quoted figures which are way above this estimation. Solar Potential in India is abundant and 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day.

However, compared to Conventional generating resources which are relatively stable, controllable and schedulable the renewable energy sources are intermittent and variable in nature and hence pose challenges to system operators and designers. Renewable Energy sources are influenced by factors such as weather and geographic location that lead to challenges in forecasting their generation and system management. Besides there may also be some errors in load forecast that may alleviate or aggravate the net impact on system operations. Large deployments of solar generation capacity is also saddled by the requirement of expansiveness of deployment of panels over large land areas for generation of a decent quantum of solar energy but which is still a fraction of what we get from conventional generation methods. Hence there is need to look for roof top deployment of solar PV to enable its proliferation. To compensate for the aberrations associated with their efficient integration in

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the power system efforts are required not only at design and technology level but also at the regulatory level for development of revenue generation and compensation mechanism and also devising innovative execution models for streamlining their integration. **Demand Side Management and Demand Response** coupled with proficient integration of Distributed solar PV over roof tops could help to buffer variability in supply right from the LT voltage end.

This paper presents an approach to facilitate integration of Distributed roof top solar PV and DSM and DR through an aggregator so as to provide utility with a substantial quantum of controllable generation rather than having to deal with numerous controllable loads/generation of miniscule capacity and what are the communication needs to facilitate such integration. A dynamic tariff mechanism for DR alongwith feed in tariff for solar DER will incentivise and provide a revenue generating option for the consumers and help utilities by way of easing out the load on the system and peak period purchase cost savings.

KEYWORDS

Demand Side Management (DSM), Demand Response (DR), Advanced Metering Infrastructure (AMI), Distributed Energy Resources (DER), Roof top Solar PV generation Communication Infrastructure, Dynamic Tariff, Frequency-based ToU pricing, Feed in tariff, Aggregator.

1. INTRODUCTION

Indian electricity generation capacity has grown at a rapid pace--from 1.3 GW in 1947 to around 225 GW today. Even with the dramatic growth, the deficit in power supply in the country, in terms of peak availability and of total energy availability, is around 11% and 10%, respectively (Central Electricity Authority, 2012-13). In addition, there remains enormous unmet demand of upwards of 200 million people. Per capita consumption is only about 870 kWh per annum against the world average of about 2500 kWh. But this is set to change. India plans to expand generating capacity by almost 50% by the end of the Twelfth Plan period (2012-2017). Moreover, at the current trends of 8-10% economic growth, the installed capacity requirement of the country should be around 575 GW by the year 2027, which is nearly triple today's capacity.

In order to meet the enormous power needs in the coming decades, the Government of India (GoI) has launched various initiatives such as the Ultra Mega Power Projects (UMPPs), facilitating increased private sector participation via IPP in power generation by allotting projects under tariff-based competitive bidding routes. UMPPs are very large projects, approximately 4000 MW each, using super-critical coal technology and involving an estimated investment of about US$ 4 billion. As a result, the share of private sector in generation installed capacity is set to increase from 19% in the Eleventh Plan to around 57% in the Twelfth Plan. Transmission needs of the power sector are catered to by POWERGRID, and from January 2011 onward, the transmission sector has also been opened up for competitive bidding for private participation in the sector. But the critical link of distribution is turning out to be the 'Achilles' Heel' of the Indian power sector. As per the 13th Finance Commission Report of the Government of India (Finance Commission, 2009), the net losses of the State Transmission and Distribution (T&D) Utilities at 2008 tariffs, considering increase in power purchase costs, etc., are estimated to increase from over INR 68000 Crore (€9.7 billion/$12.83 billion USD) in FY 2010-11 to over INR 116000 Cr (€16.57 billion/$21.89 billion USD) in FY 2014-15. These financial losses are expected even after considering reasonable improvements based on historical performance of some of the better performing utilities. The distribution sector is plagued with problems such as:

- **High Aggregate Technical and Commercial (AT&C) losses.** The national average stands at 28.44 % as of 2008-09 according to the Power Finance Corporation Report on Performance of State Power Utilities, which is about 4-6 times higher than levels seen in OECD countries on average.
- **Tariff inadequacy or the absence of cost-reflective tariffs.** Tariff increase requirements aim to meet the burgeoning financial losses even in the better performing states, and considering subsidy at the 2007-08 levels, they are as much as 7% per annum on average while in the case of some of the poorly performing states the increase requirement is as much as 19% per annum (Finance Commission, 2009). The cross subsidies built into tariff structures further stretch the economic viability of the sector. Agricultural consumer is mostly getting free unmetered supply for which utility gets grant from state government. Also, industrial consumers in India pay higher tariffs to subsidise lower tariffs for domestic consumers. Direct subsidies provided to a specific category of consumers is often a better method of providing subsidies--rather than asking one category of consumers to cross-subsidize another set of consumers.
- **High cost of short term power purchases.** Several utilities have not planned capacity addition in time and are relying on short term purchases at high rates, averaging INR 5.19 per kWh (€0.075/ $USD 0.1 per kWh in 2009-10). The inability to reduce T&D losses has further increased the purchase levels and supply costs.
- **Inept energy accounting and auditing.** Accounting and audit errors have led to large gaps in billing and realization. Billing and collection efficiencies are in the range of 71% and 94%, respectively.
- **Unmetered (free) power to certain categories of consumers.** Consumers in the agricultural sector, which has a large load, receive free and unmetered power on the order of up to 40% of total load in some states.
- **Poor infrastructure.** The distribution system infrastructure is very old and has inadequate reactive power managing resources. Proper distribution network planning and periodic distribution system capacity augmentation is generally missing. During the summer of 2012 the power supply for end consumers was below 130 Volts as compared to nominal supply voltage of 220 Volts in some areas.
- **Poor demand side management**. Utilities regularly resort to complete load shedding in certain areas to meet supply shortages. In many areas this expectation of load shedding has led to widespread use of customer-owned backup generation.
- **Customer dissatisfaction**. Utilities' poor financial health has resulted in underinvestment in the distribution network, causing poor upkeep and maintenance. Consequently, the quality of supply is hampered, leading to customer dissatisfaction and poor recovery. This, in turn, leads to further deterioration of financial health of utilities.

Together, the above list of problems represents a vicious cycle that needs to be broken. Appropriate tariff design with the aid of smart grid technologies promises to help in many regards, creating more transparent and orderly demand-side management, improving utility financial health, and establishing a sound basis for revenue collection.

GOI has stressed that it is absolutely vital that the distribution system is made financially viable during the Twelfth Plan. Accordingly, the key focus of the Twelfth Plan is to strengthen the performance of the distribution system to achieve improved financial viability of distribution companies (discoms) and to expand access to power in rural areas. Introduction of smart grid to allow effective demand side management (DSM) is to be taken up earnestly. (Planning Commission, 2012)

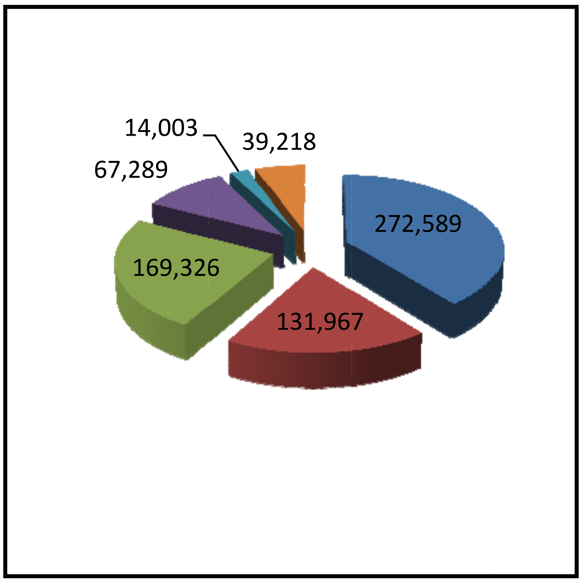
To improve performance of distribution companies, the smart grid in India will aim at:

- Reducing aggregate AT&C losses and bringing them to around 5-7% matching with the benchmark losses across the best utilities around the globe
- Ensuring minimum lifeline supply for all, ensuring there are no power cuts
- Managing and reducing peak power demand
- Utilizing the abundant potential of renewable power by integration of renewables/ distributed generation to the Grid efficiently
- Enabling proliferation of prosumers using rooftop solar PV generation.

In India, the industry, domestic, and agriculture sectors contribute 39%, 24%, and 19% respectively to the total electricity consumption (CEA 2010-11). Further, the compounded annual growth rate of consumption for the domestic sector is set at a maximum of 9.6% over a period from 1970-71 to 2010-11; this can be attributed to improved access of power in the rural sector and an increase in per capita consumption in the urban sector because of changes in lifestyle and a rise in income. The charts below show the consumption pattern and compound annual growth rate.

Whereas attempts are being made for DSM for industrial and bulk consumers in the commercial sector by introducing ToD (Time of Day) tariffs based on some utilities' predetermined peak load charges, there is ample scope for DSM in the domestic sector and the rest of the commercial sector as well. This DSM administered through ToU or Real time pricing can help in peak load management as well as reduction in load shedding.

Roof top Solar PV proliferation in a big way is also required to support the ever increasing capacity requirement of India and their integration into the LT voltage side in conjunction with Demand Side Management and Demand Response could help in containing the problems load management, especially during peak hours, right at the consumption end. Efforts are required at the regulatory level for lucrative compensation mechanism for DSM and DR and for development of revenue generation and compensation mechanism as well as devising innovative execution models for streamlining the integration of DER especially the Roof top Solar PV.



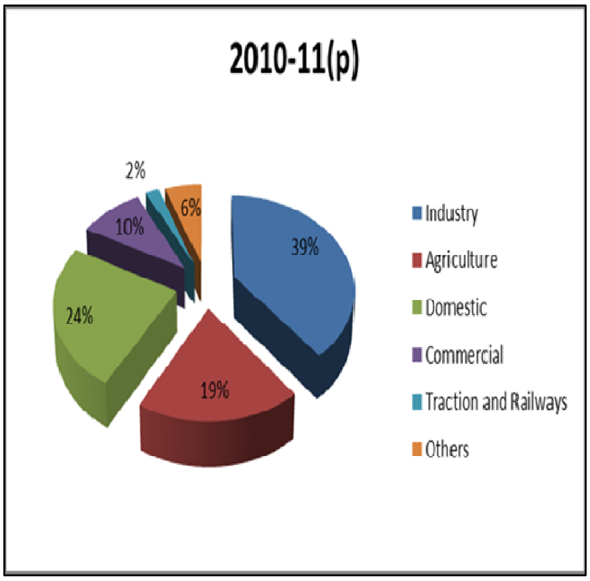


Figure 1-Consumption of electricity (from utilities) by sectors in India (Provisional data) (Gigawatt-hour) = (106 x kilowatt-hour)

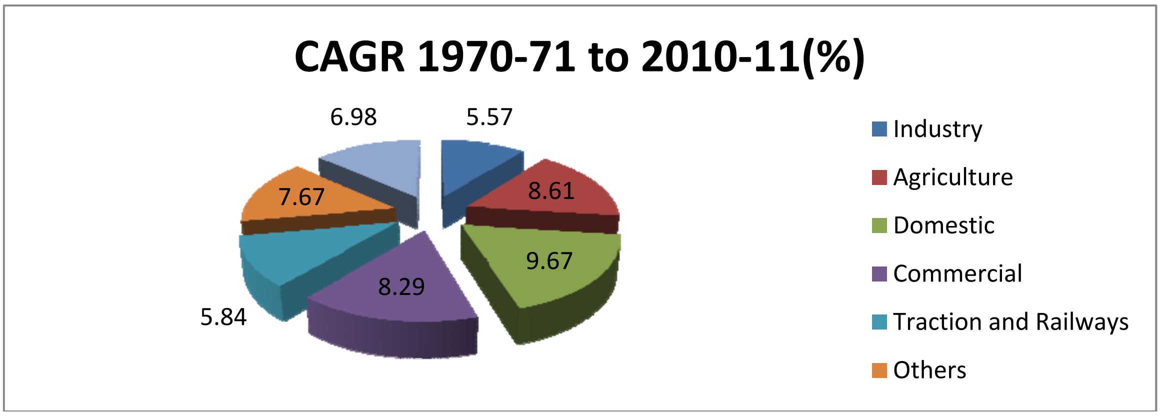


Figure 2- Load growth pattern 1970-71 to 2010-11(%)

2. TECHNOLOGY

ADVANCED METERING INFRASTRUCTURE

AMI is not a single technology, but rather an integration of many technologies that provides an intelligent connection between consumers and system operators. AMI gives consumers the information they need to make intelligent decisions on energy usage, the ability to execute those decisions and a variety of choices leading to substantial benefits they do not currently enjoy while system operators are able to greatly improve consumer service by refining utility operating and asset management processes based on AMI data.

Through the integration of multiple smart grid technologies such as smart metering, home area networks, integrated communications, data management applications, and standardized software interfaces etc. with existing utility operations and asset management processes, AMI provides an essential link between the grid, consumers and their loads, and generation and storage resources.

AMI infrastructure includes home network systems, including communicating thermostats and other in-home controls, smart meters, communication networks from the meters to local data concentrators, back-haul communications networks to corporate data centers, meter data management systems (MDMS) and, finally, data integration into existing and new software application platforms. Figure 3 below graphically describes the AMI technologies and how they interface:

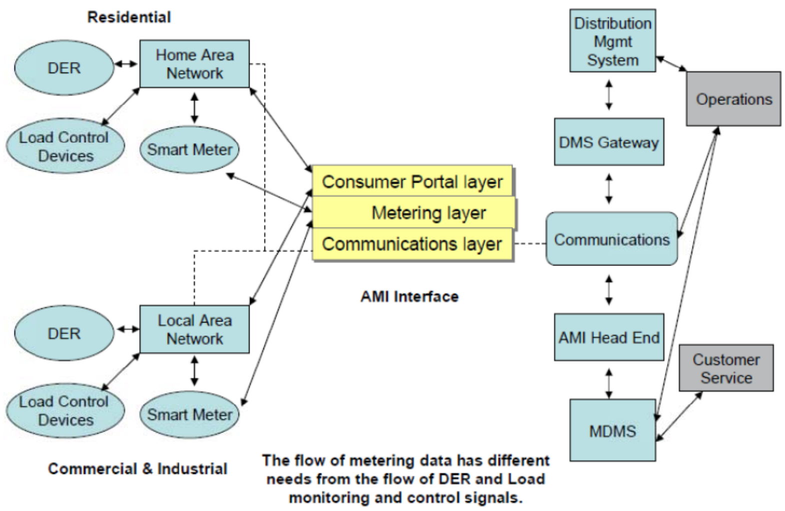


Figure 3- Overview of AMI

At the consumer level, smart meters communicate consumption data to both the user and the service provider. Smart meters communicate with in home displays to inform consumers about their energy usage and assist to modulate electric demand based on dynamic pricing. Consumer portals process the AMI data in ways that enable more intelligent energy consumption decisions.

The service provider (utility) employs existing, enhanced or new back office systems that collect and analyze AMI data to help optimize operations, economics and consumer service. For example, AMI provides immediate feedback on consumer outages and power quality, enabling the service provider to rapidly address grid deficiencies. And AMI's bidirectional communications infrastructure also supports grid automation at the station and circuit level. The vast amount of new data flowing from AMI allows improved management of utility assets as well as better planning of asset maintenance, additions and replacements. The resulting more efficient and reliable grid is one of AMI's many benefits.

COMMUNICATIONS INFRASTRUCTURE

The AMI communications infrastructure supports continuous interaction between the utility, the consumer and the controllable electrical load. It must employ open bi-directional communication standards, yet be highly secure. It has the potential to also serve as the foundation for a multitude of modern grid functions beyond AMI. Various architectures can be employed, with one of the most common being local concentrators that collect data from groups of meters and transmit that data to a central server via a backhaul channel. Various media can be considered to provide part or all of this architecture:

- Power Line Carrier (PLC)
- Broadband over power lines (BPL)
- Optical fiber
- Wireless (Radio frequency), either centralized or a distributed mesh
- Internet
- Combinations of the above

ROOFTOP SOLAR PV SYSTEM

A simple Solar PV system generates electric power by converting solar radiation into Electrical energy. This consists of solar panels installed on roof top made out of crystalline silicon. When sun hits the panels, radiation gets converted to direct current electricity. An inverter that is connected to the panels converts the direct current electricity into alternate current. The electric power generated is fed into the conventional distribution grid. An energy meter is incorporated for metering the energy generated through the system before flowing into the LV grid (Schematic shown in figure 4)

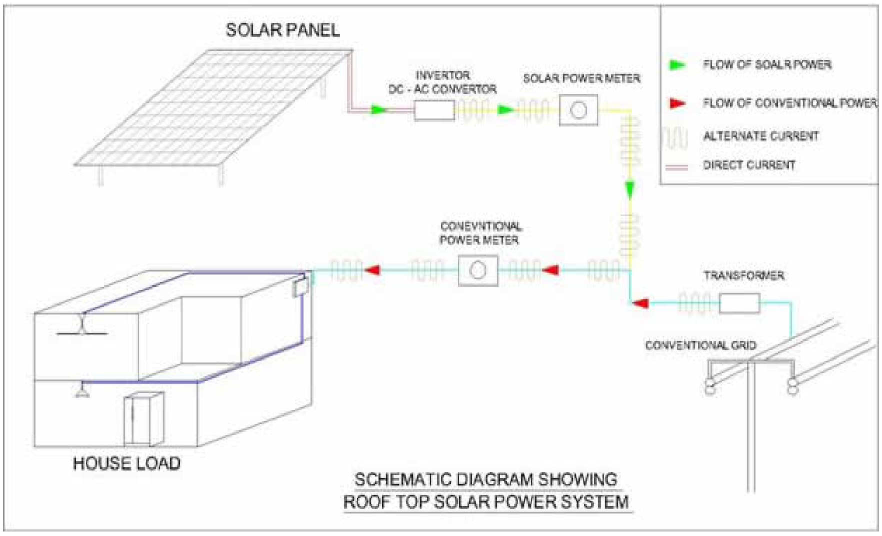


Figure 4- Working of Solar rooftop

3. DYNAMIC TARIFF DESIGN

The current pricing mechanism for Indian consumers is primarily focused on recovery of cost of generation and service cost and as it is highly cross subsidized it does not provide appropriate signal to end consumer for judicious use of electricity. If we add some price component to existing tariff that could reflect the real time imbalances, the end consumers may shift their load to get some incentive or to avoid disincentives. This necessitates design of Dynamic tariff that will not always remain same to encourage participation of end consumers in DR/DSM programs. Further, in order to motivate consumers to install Roof top solar panels, they need to be incentivized thru Feed-in-tariffs so as to make the investment in distribute generative more attractive for end consumers.

The components that may be considered for dynamic tariff design include:

i. Cost of generation and transmission
ii. Service cost of discom
iii. Reactive power consumption
iv. Voltage level
v. Sanctioned/contracted load
vi. Subsidy
vii. Unscheduled Interchange (UI) charges for deviation from agreed drawal and generation schedule
viii. ToD or pre-announced prices based on a forecast for peak load hours
ix. ToU/CPP (Critical Peak Pricing) that can be linked to frequency or to an average of daily maximum demand
x. Power supply quality- based on voltage fluctuations, reliability and harmonics.
xi. Feed-in-tariffs for renewable generation(for LT connected generation)

The ideal case scenario would be to offer a predetermined mix of aforementioned components in order to suit the requirements of different consumer segments. The conventional tariff design (to a certain extent) covers elements i. to vi. as mentioned above. UI charges can be partially recovered through incorporating a frequency-based price component in the consumer tariff as in Real time pricing mechanism (RTP). Some Consumers would prefer some prior notice of price variations in a day which might help them plan consumption for the day as incorporated in ToD pricing wherein higher charges are applicable for peak load times announced by Utility beforehand based on historical data. It is proposed by authors that Dynamic pricing mechanism for DSM can be designed by including both ToD tariff in the form of peak load surcharge and ToU/RTP (i.e. frequency-based price component) in addition to the tariff determined as per ARR (Annual Revenue Requirement). As per the grid code for transmission sector issued by CERC (Central Electricity Regulatory Commission), SLDC/STU, discoms shall initiate restriction of the amount withdrawn from its control area from the grid whenever the system frequency falls to 49.7 Hz. This frequency can be the trigger for upward revision of the ARR tariff by some amount .Same amount of discount can be offered on ARR tariff for consumption at frequency above 49.95Hz. For frequencies between 49.7Hz and 49.95Hz ARR tariff rates can be set.

ToD can be announced by SERC (State Electricity Regulatory Commission) weekly or fortnightly based on the utility's forecasted/projected peak load time periods. Consumers can be informed through portal, SMS, and email about ToD prices in advance.

For effecting DSM for peak load management in this context, the possible Dynamic tariff components could be:

a. **Frequency-based, ToU pricing**: Availability-based tariff (ABT) and UI charges are already deployed for Transmission sector. Indian version of Availability Tariff comprises of three components: (a) capacity charge, towards reimbursement of the fixed cost of the plant, linked to the plant's declared capacity to supply MWs, (b) energy charge, to reimburse the fuel cost for scheduled generation, and (c) a payment (UI charge) for deviations from schedule, at a rate dependent on frequency. ABT could bring discipline in transmission sector in abiding to agreed-upon schedules worked per the Indian Electricity Grid Code (IEGC) by the constituents of Indian Power grid. The same can be tweaked for Distribution sector and accordingly this ToU tariff is proposed to be +/- 20% of tariff calculated on the basis of ARR to be levied in case frequency falls below 49.7Hz and rises above 49.95Hz.
   ToU will aim for near real-time load-supply balancing. As suggested above, three rates can be administered:
   i. ARR rate for frequency in acceptable band (e.g., Rs 4.5 per kWh)
   ii. ARR x 1.2 for frequency below lower limit of acceptable band (i.e., Rs 5.4 per kWh)
   iii. ARR x 0.8 for frequency above upper limit of acceptable band (i.e. Rs 3.6 per kWh).

   Smart meters can communicate with simple LED based display units that may be provided in multiple rooms to show the above three rates as RED/YELLOW/GREEN colors to the end consumer, and this can also be published on a utility's portal. Consumers can also be notified about a change in rates through a small beep sound from the meter.

b. Pre-determined ToD pricing for the utility-specific peak load time zones, to be announced weekly by the Regulatory Commission based on forecast peak load time/ past data from Regional load dispatch centres RLDCs. This can be 10% of the tariff calculated as per existing ARR petition.

c. A reliability surcharge-Utility may consider levying a surcharge of 10% over total bill amount in the areas that have rugged distribution infrastructure so as to provide reliable power supply based on service level agreement (SLA) with consumers of that area. In case SLA is violated no surcharge will be admissible for that month.

Reliability can be maintained by switching to load curtailment (with commitment to supply lifeline supply for that premises) in place of load shedding in those areas. In order to increase available power, installation of roof top solar panels can be promoted by utilities' floating suitable incentive schemes. Smart consumers can also store solar energy during the day time and use it during evening peak times to avoid purchase of costly power during peak load time.

d. Discount of 2% to 5% on pre–paid bills depending on AT&C losses for that area. The higher the losses, the lower the discount for pre-paid bills that may encourage people of that area to identify theft.

e. **Tariff for rooftop solar power:**

   To facilitate penetration of roof top solar panels over houses or in apartments a 'Feed in tariff' can be fixed which could be 1.5 times the amount of tariff to be paid by the consumer for buying electricity from the grid at that time. Utility wiil not get additional financial burden as the supply losses will be minimal due to consumption at source.

4. MECHANISM FOR INTEGRATION OF ROOF TOP SOLAR PV AT LT END

Implementation of frequency based ToU pricing through individual customers for DSM and effecting of feed-in tariff mechanism for roof top solar power generation could be done by creating an entity of '**Aggregator'** for a particular control area, say, smart consumer meters reporting to a Data Concentrator unit or on a larger scale few DCUs reporting to a Control centre of aggregator through the utilization of advanced computer and communications technologies.

This aggregator's role could be enhanced and is suggested to include monitoring, accounting and control of the Solar PV generation being deployed over roof tops of the concerned set of consumers. For effecting such a mechanism AMI system that has smart meter with bi-directional metering units instead of a normal energy meter would have to be installed for solar power meter shown in fig 4. This control of aggregated solar generation and individual consumer loads for Demand Side Management could help in more effective load management at the utility level for better management of day time peak period rather than utility requiring to coordinate efforts of small quantum's of DR and solar PV generation. Communications and networking technology with suitable speed, reliability, and security will be a prerequisite for above.

This model, as is evident, suggests shifting from a centralized control model to a distributed control model wherein distribution networks are divided into "control areas' under the management of an aggregator and in this control area micro grid is formed by interconnection of solar roof top generators. Sensors are required to be deployed in large numbers in order to efficiently monitor power network conditions such as faults at the transformers, breaker status, power flow magnitude and directions etc. The aggregators perform operations locally in their control area and are receptors of the sensor data rather than the centralized control room of utility. Such aggregators operating on a distribution system shall need to operate in a collaborative manner and exchange control information among themselves and control centre regularly for grid management at broader level. Such a system shall curtail the communication requirement for the control room of the utility but it will add new communication requirements as implementation shall require horizontal communication links and more bandwidth.

5. CONCLUSION

In India with the deregulation of diesel prices the consumers located in ever mushrooming housing complexes in an urban city in India are left in a lurch. They are facing a double whammy wherein firstly paying on their own for arranging power backup, which is mostly on DG sets, and secondly paying exorbitant costs for this power which at even regulated diesel cost is as much as 2-4 times the grid supply. With diesel prices to increase by as much as 25% over the next year the plight of major chunk of this middle and upper middle class population is not very hard fathom. In this situation it becomes even more relevant to facilitate penetration of roof top solar panels over houses or in apartments with integration at LT voltage end and also to effect DSM measures so as to provide for optimal load management and reliability of supply right from the consumption end. For this interventions at policy level, regulatory level for feed in tariff to start with and also for innovative implementation mechanisms such as that of ‘aggregator’ suggested here could be devised using the innovative smart grid technologies that utilize advancements in Information, Communication and Automation technology. The cost of deploying roof top solar has been going downwards over last few years and as it reaches grid parity mechanism of Net-metering could be evolved.

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