THE BENEFITS OF SMART GRID

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Abstract: *The Smart Grid is the next generation electrical grid that can improve the reliability of the entire electrical energy transport and distribution system and potentially change the way customers think about electricity and its consumption. The Smart Grid differentiates itself from the old-fashioned grid by introducing two-way communication between the customers' appliances and the source of energy. It's basically the conventional grid entering a new, advanced and IT dominated era in which information is everything.*

Key words: *Grid, meter, network, distribution, consumer, digital, Time-of-Use (ToU) tariff.*

Prior to defining the Smart Grid, we would like to provide a description of what the grid in fact is. "The grid," concept, refers to the electrical grid, which is a network of transmission lines, substations, transformers and more, that are delivering electricity from the power plant to our homes and businesses. It's what the customer plugs into when flipping on light switch or powering up the computer. Our current electrical grid was built in the 1890s and improved upon as technology advanced through each decade. Today, it consists of more than 9,200 electric generating units with more than 1 million megawatts of generating capacity connected to more than 300,000 miles of transmission lines. Although the electrical grid is considered an engineering marvel, we are stretching its patchwork nature to its capacity. To move forward, we need a new kind of electrical grid, one that is built from the bottom up to handle the groundswell of digital and computerized equipment and the technology dependent on it and one that can automate and manage the increasing complexity and needs of electricity in the 21st Century [1]. In other words, we need an enhancement of the past century electrical grid. We need a Smart Grid [2,3]. And it seems that we are on the right path. The traditional electrical grids are generally used to carry power one-way: from a few central generators to a large number of customers. In contrast, the new emerging smart grid uses two-way flows of electricity and information to create an automated and distributed advanced energy delivery network.

The idea of a smart grid revolves around the smart meters. The difference between an analog measuring device and a smart one is that the latter allows for two-way communication, whereas the former only allows for the data to be read directly from it, which means that someone has to physically be there to take the readings. As you can imagine that costs time and money, so some energy providers don't bother with that and they simply estimate the consumption based on that particular customer's history and a few weeks/months down the line they slap a big made-up bill, which is rather inconvenient. A smart meter will send information about the customer's consumption of energy automatically and therefore it will eliminate the previously mentioned issue. More so, with a smart meter the customer himself will be able to see how much energy has been consumed at any one time.

Furthermore, the smart meters can reduce the risk of power outages. With the old analog meters, power companies could not know about blackouts until customers would alert them. Smart meters on the other hand are notifying the power source's operators without anyone's intervention. They are able as well to temporarily solve the problem by rerouting the power.

The smart grid can also improve energy efficiency. Experts estimate that less than 50 percent of power generated actually reaches consumers a large portion of it is simply lost on the way to our houses. A smarter electrical grid would use sensors to detect inefficiencies in the system, reducing line loss.

Digital meters are paving the way for creative pricing plans that can help consumers not only lower their bills, but reduce power prices for everyone. Even a small reduction in peak demand electricity we as consumers devour at the busiest part of the day would make a big difference on our power bills. The idea is that smart meters will notify consumers about the prices of electricity at different times of the day and, potentially, even adjust the work of household devices in such a way that they will consume power when it is cheaper. That will encourage customers to consume electricity during non-peak hours, which will lower the load at the power plants and that will reduce the general price of electricity and improve the impact on the environment.

One problem that can be solved trough smart grid implementation is the variation in energy demand. Despite the fact that generating electricity is more expensive during peak hours, the tariff remains the same through the day .With the introduction of Time-of-Use (ToU) tariff the demand will switch ever so slightly which will reduce the load and the consumption of fuel at power plants. The Italian Authority for Electricity and Gas (AEEG) conducted some research on how the introduction of ToU tariffs will influence consumer behavior and consumption of energy.

The Italian Authority for Electricity and Gas (AEEG) approved the implementation of a mandatory Time-of-Use (ToU) tariff based on two time slots for residential customers in Italy, starting July 1, 2010. The introduction of the ToU tariff is the final step of a process that was designed to progressively expose Italian customers to time-variable costs of the electricity supply. The process started several years ago with high- and medium-voltage customers, and was extended to low voltage.

The mandatory ToU tariff provides variable prices of electricity depending on the hour of the day. Prices are higher during "peak hours" (between 08:00 and 19:00 hours during working days) and lower during "off-peak hours" (which comprise the remaining hours). The energy prices during peak and off-peak hours are, respectively, higher and lower than the corresponding value of a hypothetical flat tariff; however, the differences between the flat and the ToU tariff prices are higher at peak time than at off-peak, due to the fact that off-peak hours occur more than twice as often as peak hours during a typical year. The table below shows the price difference between flat and ToU tariff [4].

Table 1

Energy price difference between flat and ToU tariff during the transition period	
Peak hours	-0.592 c€/kWh
Off-peak hours	0.297 c€/kWh

The price difference between peak and off-peak hours (equal to 0.889 c€/kWh, value-added tax [VAT] excluded) corresponds to 10% of the energy price during peak hours; however, the other components of the tariff, which do not depend on the time of day, make the final price variation between peak and off-peak hours much lower than the above mentioned 10%. The percentage decreases as the annual consumption of the customer increases (from 7% for the lowest range of consumption to about 4% for the highest range).

The convenience of the ToU tariff with respect to the flat tariff depends on the distribution of customer consumption between peak and off-peak hours. If more than two-thirds of the consumption is during off-peak hours (i.e., during nights or weekends), the ToU tariff is less expensive than the flat tariff. Otherwise there is a cost increase. Two-thirds of the total consumption (66.67%) is called the indifference threshold. It should be noted that the price difference of the Italian ToU tariff is extremely low in comparison to similar tariffs adopted in other countries.

Flat rate is the most common method to bill electricity consumption because it minimizes the costs of metering and billing. However, it does not induce customers to adjust their consumption according to the abundance or scarcity of electricity. In particular, it does not encourage them to lower it during high demand hours.

Conversely, real-time rates link the price paid by the customers to the real costs of electricity.
This method requires a more complex metering infrastructure because consumption needs to be recorded for each time interval with the specific price, but it allows price signals to reach the customers in the proper way. The drawback is the fact that customers who are unable to move their electricity consumption will face higher costs. ToU tariffs serve as a middle ground. There are a certain number of time slots during the day in which the price paid by the customers is established in advance, based on midterm (e.g., quarterly) predictions. This allows for a less complex metering infrastructure, and, the longer the time slots, the more averaged/smooth the price signals are. Such a mechanism relates, to a degree, the price variability of electricity with the costs of its supply, allowing a collaborative response to the customers' energy demands (the demand response). At the same time, it relatively protects (with regard to real time + rates) those who are not able to modulate their demand according to the price.

The introduction of the ToU tariff for residential customers in Italy was a significant event.
In fact, 20 million families are currently paying their electricity consumptions based on a variable price during the day. This situation represents an unprecedented occasion to analyze the changes in customers' behavior in response to time-variable electricity prices.

In order to assess the impact of the ToU tariff in the short and medium terms on the
Italian consumers, Italian Company RSE started a research project in collaboration with and under the patronage of Italian Authority for Electricity and Gas (AEEG).

To this aim, a group of approximately 28,000 households (the customer panel) was selected to statistically represent the whole Italian population. Their monthly electricity consumption data, as measured by smart meters, was collected starting in July 2009 (i.e., one year before the introduction of the mandatory ToU tariff). This study allowed for an analysis of the change of consumption behavior after the introduction of the transitional ToU tariff.

To improve the significance of the analysis, a restricted customer panel was selected based on several requirements, and a comparison was made between the customers' behavior in two different semesters that were one year apart:

- Flat rate period: January 1, 2010–June 30, 2010
- ToU rate period: January 1, 2011–June 30, 2011

The restricted customer panel includes 9,952 customers (i.e., about one-third of the overall customer panel). Comparisons of the two panels showed that the restricted customer panel had a composition statistically in line with that of the customer panel, as well as of the Italian population.

The monthly average percentage of consumption allocated during off-peak hours was about 66.95% in the period with a flat rate tariff (i.e., slightly above the indifference threshold 5 of 66.67%), even in the absence of any price signal provided by the tariff. This corresponded to about 55% of the customers in the "restricted customer panel." This group would have saved money if they had been billed with the ToU tariff in the period with flat rate.

The percentage of consumers belonging to the restricted customer panel whose consumption is concentrated in off-peak hours (above the indifference threshold) in the period with the ToU tariff is about 59%, an increase of about 4% with respect to the corresponding percentage found in the period with a flat rate. This group had a small average monthly saving equal to about 0.8 c€/month for each customer. During this period, 61.5% of the customers shifted their average monthly

consumption towards off-peak hours. Therefore, most residential customers demonstrated a willingness to modify their habits by adjusting their consumption according to the price signal provided by the ToU tariff. The average shift in consumption for each customer was approximately 0.96 kWh/month.

It is important to keep in mind that the variation of the expense is the result of two different effects for each customer:

- The customer's original consumption allocation between peak and off-peak hours before the application of the ToU tariff (in the period with a flat rate) can, by itself, make the ToU tariff convenient or not.
- The application of the ToU tariff (in the period with the ToU tariff) can have induced the customer to shift his/her consumption from peak to off-peak hours, in accordance with the price signal.

The combination of both the above factors can determine a cost increase or decrease for the customer, with respect to what he/she would have paid with a hypothetical flat tariff in the second period (with the ToU tariff).

The resulting average monthly savings of less than 1 c€ might seem quite low at a first glance, but it must be compared with the maximum achievable monthly savings of a customer hypothetically capable of concentrating all his/her consumption during off-peak hours: in such a case, the savings would be equal to about 29 c€/month. Of course, such a case is unattainable; a more realistic scenario would be achieving a consumption allocation during off-peak hours of 70%, which would yield average savings around 2.8 c€/month.

It should be emphasized that the moderate savings are also due to the low price difference between peak and off-peak hours.

Customer behavior following the ToU tariff was mixed and not classifiable in a single category. There are, in fact, customers who responded consistently to the price signal given by the ToU tariff and customers who did not. However, more customers shifted their consumption from peak to off-peak hours than shifted their consumption in the opposite direction; moreover, the customers who started from a disadvantaged position were more responsive to the price signal given by the ToU tariff than the other customers.

The mandatory ToU tariff in Italy has improved the efficiency of the whole Italian Transmission & Distribution system, moving approximately 1% of the residential consumption from peak hours to off-peak hours. In particular, it has demonstrated the role of the customers in shaping their energy consumption as active users in order to face time-dependent electricitycosts.

In order to maximize the effectiveness of the ToU tariff, it is advisable to systematically provide, in each bill, a report of the cost savings or increase achieved by the customer with the ToU tariff in comparison to a hypothetical flat tariff. There are several aspects that should be improved to make the tariff more effective: the allocation of the hours between peak and off-peak should be revised, a new group of hours intermediate between peak and off-peak ones should be introduced, and the price signal should be increased. These changes will give more flexibility to users and will encourage them to shift their consumption to time slots where the price is lower.

Summary

In conclusion, we would like to mention that obviously adopting Italian concept on the new tariff system would be significantly advantageous for our city. As someone may point out, Gas Natural Fenosa, our largest electrical energy distributor already has a triple tariff system in place. Unfortunately, at this time only a small number of customers have digital meters that are indispensable for the ToU tariff system to actually work. One of the problems is the low consumers' awareness of the ToU tariffs and their profitability. A more widespread implementation of smart meters and ToU tariff would improve the energy consumption of our city and lower the consumption of S.C. Termoelectrica S.A. natural gas with noticeable beneficial results for the entire community.

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