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Development of Electricity Pricing Criteria at Residential Community Level

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Abstract In the UK there is no real time retail market, and hence no real time retail electricity pricing. Therefore domestic electricity consumers in the UK pay electricity prices that do not vary from hour to hour, but are rather some kind of average price. Real time pricing information was identified as a barrier to understanding the effectiveness of various incentives and interventions. The key question is whether we can evaluate energy management and renewable energy intervention in the behaviour of customers in real market terms. Currently only behaviour changes with respect to total consumption can be evaluated. Interventions cannot be defined for peak load behaviour. The effectiveness of the introduction of renewable energy is also hard to assess. Therefore, it is hard to justify introducing of renewable and demand side management at local community level, apart from when following government approved schemes, subsidies, and other initiatives. In this paper, a new criteria has been developed to help developers and planners of local residential communities to understand the cost of intervention, in order to evaluate where the load is when the prices are high.

Keywords Real Time Pricing, Renewable Energy Intervention, Demand Side Management, Local Community

1. Introduction

The restructuring of power markets has been ongoing in various countries around the world, including the UK, over the last two decades. Since the early 1990's the UK's electricity industry has changed from a government controlled monopoly to a competitive market in order to deliver a lower cost to the consumers, giving consumers the choice to select their energy supplier. In the process a commodity market for wholesale electricity transactions was established. Here electricity is traded in large volumes, mostly between electricity producers (selling the output of their power stations) and electricity suppliers (buying what their customers need).

There are four components to the electricity industry. These components are generation, transmission, distribution and retailers. The generation sector is the production process of electricity in power stations. Transmission refers to the transportation of electricity through high voltage cables. Distribution is the transportation of electricity at lower voltages and facilities to the final customers. Retailers are the people who make the sales of electricity to the final customers. Electricity markets can also be divided into wholesale, retail and balancing markets.

The wholesale market in the UK is the market for the sale and purchase of electricity between retailers and generators of electricity. The current trading arrangements in the wholesale market allow suppliers to buy the electricity they need to meet their customer's needs from the generating company of their choice, i.e. this is a competitive market.

The retail market is the market for the sale and purchase of electricity between consumers of electricity (customers) and retailers of electricity (suppliers). Retailers and generators try to match their demand and generation, respectively, to their contract levels so that they do not have a surplus or deficit of electricity. This is one of the key objectives of the trading arrangements in encouraging all participants to have contracts covering all of their generation and/or demand.

The generators may generate more or less energy than they have sold through bilateral contracts during the process of electricity production and trading. Retailers may purchase more or less power through bilateral contracts than their customers' actual consumption, and traders may buy more or less energy than they have sold. Such circumstances are regarded as being in imbalance. This energy imbalance is also bought or sold.

The balancing mechanism market is through the National Grid Company (NGC). The National Grid Company (NGC) will accept offers and bids for electricity close to real time to maintain energy balance, and also to deal with other operational constraints of the transmission system. The balancing mechanism allows electricity companies and traders to submit offers to sell energy (by increasing

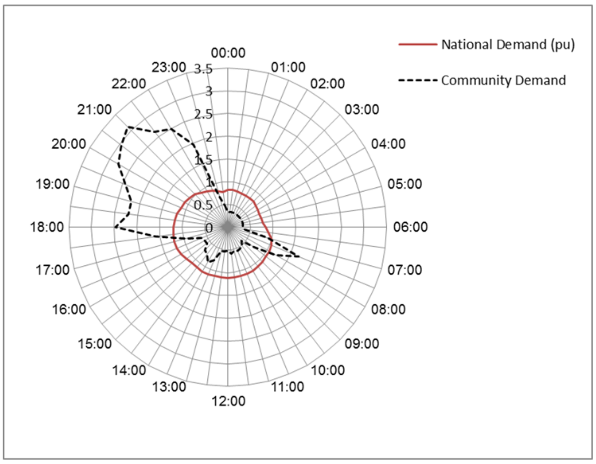

Figure 8. Community Demand vs. National Demand

Figure 8 shows the local demand plotted against national demand. From the figure, it can be seen that the national demand is more stable across the day and has a peak around 16:30 to 18:30. The local residential demand would naturally have peaks at different times of the day. As a result of that, investments to reduce bills under standard tariffs would therefore not have a significant impact on natural peak load (between 16:30 - 18:30). Therefore it is difficult to understand what intervention in behaviour is required using purely load behaviour.

In order to model further, three possibilities of electricity measure of system price are developed in the next section.

5. Price Model

When overlaid the system buy prices data for January, February and March (as shown in Figure 9 [1]), the whole data sets are not visually discernible. It can be seen that the supply capacity is in the range of about 55 to 58 GW, and that there is a considerable knee in the curve at around the 52GW, £100/MWh region. Also, there is a spread in price points for demand between 40 and 58 GW.

Figure 9. System Buy Price Vs. Demand (Data Combined)

Figure 9 is not useful in this form; therefore it was decided to use the quartiles as an indicator of range of prices.

In order to create three quartiles, the sample of 4318 of half-hourly national demand representing three months' data has been arranged in numerical order from smallest *to* largest. The national demand data is divided into 15 groups with equal intervals of 2250. Each demand group is associated with system buy price data and treated as a separate data. For each group the three quartiles of system buy price (SBP) are calculated. Each quartile is treated as a separate data. The first or bottom quartile represents the lowest price data, the second quartile or median represents the median price, and the third or upper quartile represents the highest price. Each quartile of SBP associated with demand data are treated as a dependent variable and an independent variable respectively, which means we have three dependent variables (bottom, median and upper). Each dependent variable has a single value for each demand data interval. The three fitted price equations for each scenario (quartile) were estimated using regression analysis. The computer statistical package software MINITAB has been used to get the fitted regression equation. The electricity price curves are of the form:

$$price = a + be^{cd} \tag{6}$$

Where price is the fitted quartile electricity price in p.u and d is the instantaneous national demand in p.u at that day. The resultant electricity price curves, shown as a function of demand, can be seen in Figure 10.

The resultant fitted equations for high, medium and low electricity price curves are shown in Equations 7, 8 and 9 respectively. The determination coefficients for the three quartiles are 0.96, 0.96 and 0.93 respectively.

$$P_{high} = 0.3365 + 1.565 \times 10^{-3} e^{5.502d} \tag{7}$$

$$P_{medium} = 0.3282 + 1.4523 \times 10^{-4} e^{7.175d} \tag{8}$$

$$P_{low} = 0.108 e^{1.47d} \tag{9}$$

These equations are only valid for the demand data ranging from about 0.6 pu to 1.3 pu. The constant (a) could probably represent the minimum cost of electricity produced, b is a scaling factor and c represents the rate of change of pricing.

Figure 10. System Buy Price Vs. Demand (Data Combined)

The gap between the curves at high demand shows the potential for the market. The curve also shows that at high demand the cost is a significant; up to 2 pu, whereas it can possibly be as good as 0.8 pu. The median curve also indicates that at peak level of demand the price is about 1.5 pu. Structurally, this indicates that for generators it would cost more to invest in additional generation, as this indicates infrastructure costs in future. For planners, this indicates opportunities via understanding of peak load pricing which is based on real data. Moreover, the margin of cost benefit to a local planner can be quantified in financial terms. The base value may change but as the comparison in pu the analysis will still be the same. Updated curves can always be obtained for planners.

The fitted price curves are used in the following section to forecast the half-hourly SBP which were considered as a measure of system price in order to investigate its effect on daily electricity demand.

6. Community Electricity Cost under the New Pricing Criteria

In this section we are looking at the community electricity cost using the three price curves. The cost of one day (Tuesday) under the three price curves is shown in Figure 11. It can be seen that the community demand is higher at 21:00 but the cost is higher at 18:00. The cost variation at peak is ranging from 1.5 pu to 3.5 pu.

It can be seen that the cost was about 1.5 pu at 18:00 for the low model, 2.4 pu at 18:00 for the medium model, and about 3.5 pu at 18:00 for the high model**.** From the Figure, it can be seen that the load pattern is not correlated with the price pattern, where maximum consumption periods do not coincide with periods of high price. The electricity cost at 18:00 is about 3.5 pu with demand of about 2.5 pu. This is higher than it is at 21:00 where the cost is about 2.5 pu with demand of 3.1pu.

The issue is that the peak is costing more so we are looking at an idea of costing. The price models are based on national demand where the local community demand has a very different pattern. Attributable to that, the cost curves do not follow the demand pattern. Therefore, the storage batteries could be used as an alternative for peak shaving and load levelling solutions; if we can shift the load a bit we will save a lot more. The planners can now think where they need to make a big effort to evaluate where the load is when the prices are high. An example, to show how we can actually use these curves in evaluating the possibility of using storage elements at community level, will be provided in the future work.

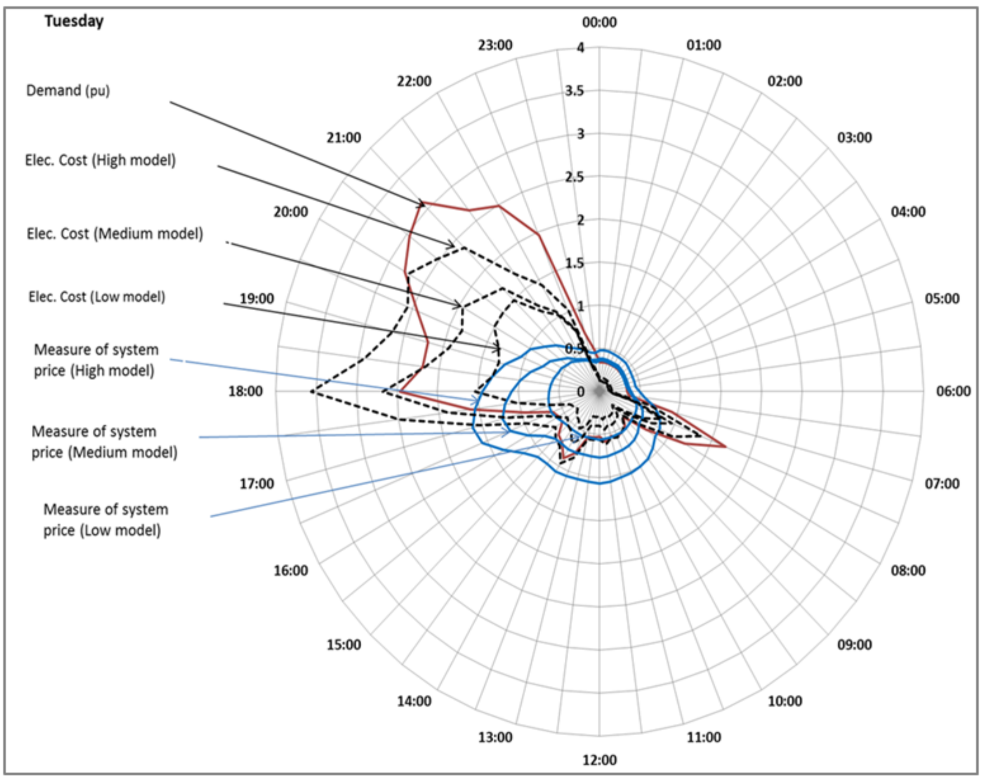

Figure 11. Electricity Cost under Three Price Model Options

7. Discussion

In the UK there is no real-time retail market, and hence no real-time retail electricity pricing. Therefore, consumers do not pay based on the real-time price but rather some kind of average price, and hence have no sufficient incentives to reduce load at times of high prices or to shift their demand to other periods.

A criterion has been developed to help developers and planners of local communities to understand the cost of intervention in order to evaluate where the load is when the prices are high. The SBP was suggested to be used as an indicator of electricity real time price.

To better capture the price fluctuations that can occur in real markets, this work took into consideration the diversification in prices the market might have by developing three price curves in Figure 10 using the quartiles of SBP versus national demand. Each quartile presents a possible pricing case. There are a number of alternatives which could be used as an indicator of range of prices such as minimum, maximum or quartiles. The quartiles have been used rather than the maximum and minimum values because there is a need for an indicator that considers all the values, and not just the minimum and the maximum. The minimum value to the maximum is the range. The difficulty in assessing by range is that an extreme change in just one value drastically changes the range. So, it is not reasonable to use the maximum or minimum; they could be abnormal. The three curves are estimated based on the daily national demand data, because the national demand data is predictable and has low variations. These curves are used as an indicator of electricity real time price and demand, and are presented in pu. These curves can help planners to look at the cost of peak shaving, which is essential for developing a financial case for investment in this market.

Presenting the data in per unit value allows underlying characteristics of the data sets on different scales to be compared by bringing them to a common scale and makes the analysis easier.

The radar chart is proposed as the standard chart to compare the per unit values of demand, price and cost for the local community over the full day, at the nationally accepted half-hourly interval. The chart shows the data around the clock, which is often a good way of comparing several sets of performance indicators. The 24 hours of the day are in a continuous cycle. The day does not end at any arbitrary time. Visualizing data in hourly trends gives people something they can relate to in the context of their daily schedules and enables them to see the consequence of this behaviour. Although the line chart makes graphs easier to read it does not give a good indication of time and behaviour. Therefore it is not easy to conclude where problems are. Moreover, the base value is not as important as the peak value. The radar chart by definition will emphasise the peak and not the common dominator. This is critical when looking at peak prices and infrastructure costs. The radar chart provides a useful set of information and picture of performance to help consumers reduce their electricity costs in order to manage their consumption by taking advantage of lower priced hours and conserving electricity during hours when prices are higher.

The developed three curves would be used as a tool to evaluate the possibility of using storage batteries at community level as an example. PV cells or other embedded could also be studied in a similar way.

8. Conclusion

The conclusions drawn are presented below.

- Presenting the data in per unit value allows underlying characteristics of the data sets to be compared.
- The radar (spider) chart has been proposed as a standard chart to compare the per unit values of demand, price and cost for the local community for load shaving aspect.
- As no real time retail price exists in the UK, the System Buy Price (SBP) has been used as a measure of the real price based on per unit values. In order to better capture the price fluctuations that can occur in real markets, the three curves of Figure 10 have been developed using the quartiles of SBP versus demand.
- The tool developed in [4,5] can now be used alongside SBP to help planners to look at an idea of the cost of peak shaving which is essential for developing a financial case for investment in this market.
- As an example of using the tool developed in [4] and system buy pricing, the possibility of using battery storage at residential community level could be evaluated.
- The introduction of such an independent retail market at local level to enable electricity transactions between communities with embedded generation capabilities requires further research.

REFERENCES

[1] J. Palmer and I. Cooper, "Great Britain's housing energy fact file," Department of Energy and Climate change, 2011.

[2] A. M. Ihbal, H. S. Rajamani, R. A. Abd-Alhameed, and M. K. Jalboub, " Investigation of Tariff Initiatives for Peak Load Balancing at the Domestic Level," in Transactions on Systems, Signals & Devices, Vol. 7, No. 2, pp.19-17.

[3] Paras Mandal, Naomitsu Urasaki, Anurag K. Srivastava, "A Novel Approach to Forecast Electricity Price for PJM Using Neural Network and Similar Days Method," IEEE Trans on Power Systems, vol. 22(4), pp.1058-1065, 2007.

[4] Jianhua Zhang; Jian Han; Rui Wang; Guolian Hou

"Day-ahead electricity price forecasting based on rolling time series and least square-support vector machine model", Control and Decision Conference (CCDC), 2011 Chinese, On page(s): 1065 – 1070

[5] Vuppala, S.K.; Padmanabh, K.; Bose, S.K.; Paul, S., "Incorporating fairness within Demand response programs in smart grid," Innovative Smart Grid Technologies (ISGT), 2011 IEEE PES , vol., no., pp.1,9, 17-19 Jan. 2011.

[6] Areekul, P.; Senjyu, T.; Toyama, H.; Yona, A., "Notice of Violation of IEEE Publication Principles, A Hybrid ARIMA and Neural Network Model for Short-Term Price Forecasting in Deregulated Market," Power Systems, IEEE Transactions on , vol.25, no.1, pp.524,530, Feb. 2010.

[7] Tan Z, Zhang J, Wangb J, Xu J., " Day-ahead electricity price forecasting using wavelet transform combined with ARIMA and GARCH models," Applied Energy, , vol.87., pp.1,9, 3606–3610, 2010.

[8] Lei Wu; Shahidehpour, M., "A Hybrid Model for Day-Ahead Price Forecasting," Power Systems, IEEE Transactions on , vol.25, no.3, pp.1519,1530, Aug. 2010.

[9] Conejo, A.J.; Plazas, M.A.; Espinola, R.; Molina, A.B., "Day-ahead electricity price forecasting using the wavelet transform and ARIMA models," Power Systems, IEEE Transactions on , vol.20, no.2, pp.1035,1042, May 2005

[10] ELEXON, "New Electricity Trading Arrangements NETA, Balancing Mechanism," ELEXON , http://www.bmreports.com/bsp/SystemPricesHistoric.htm.

[11] National Grid, "Metered half-hourly electricity demands, "National Grid website: http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data

[12] A. M. Ihbal, H. S. Rajamani, R. A. Abd-Alhameed, and M. K. Jalboub, "The Generation of Electric Load Profiles in the UK Domestic Buildings Through Statistical Predictions," Journal of Energy and Power Engineering, vol.6 no.2, pp.250-258, 2012.

[13] A. M. Ihbal, H. S. Rajamani, R. A. Abd-Alhameed, and M. K. Jalboub, "Statistical predictions of electric load profiles in the UK domestic buildings," in Energy, Power and Control (EPC-IQ), 2010 1st International Conference on, 2010, pp. 345-350.