Network Charges for Micro-Generation

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Abstract--*Micro-generations (MGs)* have gain increasing awareness among general public, who begin to recognize its potential to reduce their carbon emissions and electricity bills. Their willingness of uptaking local generation technologies is stimulated through capital grant schemes and new regulations imposed on new building stock. Further growth will require the support from both markets and tight and timely building regulations.

It is possible to project the growth of microgeneration for a given area, thus to assess their potential contribution in energy provision and emission reduction. It is however very challenging to evaluate their collective effects on networks, i.e. their impact on network losses, operational costs, maintenance cost and capital cost. This is due to the extensiveness of the HV/LV network.

This paper explores potentially different approaches to evaluate the cost/benefits associated with a given level of MG penetration in the network at different countries, analysing their relative strengths and weakness in deriving network charges, and their potential to influence the growth and the points of connection of future MGs. The paper then uses a practical network to analyse cost/benefits to a low voltage network from different MG penetration, from which, the paper suggests a number of potential approaches to HV/LV network charges.

Index Terms**--Network charging methodologies, distribution network charges, yardstick marginal cost**

I. INTRODUCTION

Microgeneration is referred to generation technologies with a rated capacity below 50-100kW. They are connected at the load centre, supplying energy to small industrial, commercial or domestic customers. They differ from distributed generation in the sense that they tend to come at much smaller sizes but at much more extensive scale. For example, domestic MG could be installed in millions and they are typically below 3kWe.

Many European countries sees the huge potential in microgeneration as alternative means to improve efficiency and reduce CO2. They are keen to create “the conditions for microgeneration to become a realistic alternative or supplementary energy generation source for the householder, the community and small business” [1].

This condition can be stimulated through the injection of capital grant, the support from market and building regulation till the market is self-sustainable. As the market for MG progressive increases, their nature of impact on the supply network would change depending on their locations, the impact ranges from reducing/increasing network losses, deferring/accelerating network investment, improving/degrading network voltage profiles to over supply of fault current. It is critical to establish relationships between the level of MG penetration and their magnitudes of impact on network, this helps to inform the MG users and network operators of their contribution/cost to the network, which in turn will influence the future development of MG at low voltage networks.

II. CURRENT PRACTICE IN THE USE OF NETWORK CHARGES FOR MGS IN BRAZIL AND THE UK

A. The Brazil practice

The Distribution Wheeling Charge (DWC) in Brazil is designed based on two phases: the computation of the revenue requirement and the allocation of this revenue among the distribution users. The regulator determines the allowed revenue, which is the sum of the base rate returns and the operation and maintenance (O&M) costs. The base rate is determined based on a bottom-up approach where all the assets are evaluated using the acquisition value minus the depreciation. The O&M costs are also set by the regulator, which is based on a model company adjusted to the distribution company profile. The explanatory variables usually used for defining the model company are the number of consumers, the extension of the concession area, number of posts and the average distance between them. As a result, this company is then expressed in terms of the number of employees, number of vehicles, O&M costs and administrative costs. The number of employees and vehicles are also transformed into costs using the average salary and the car leasing costs of the region where the company is located. This evaluation is part of the tariff revision process, which occurs in average at a four-year period. This period depends on the concession contracts.

Given the required revenue, the problem is how to collect it among the distribution users. In the current stage of the distribution pricing in Brazil, only the voltage level is considered to establish the tariff. So, the marginal cost of each voltage level is computed and applied to allocate the distribution charges. It is like a “postage stamp” for each voltage level. Since the distribution companies are in charge

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of the entire network composed of voltage from 127 V to 138 kV, the consumers see one tariff for each voltage level no matter where they are located. For micro generators the current rule is to set the lowest tariff of all voltage levels regardless of the real voltage connection [2-3].

The users who are connected to one voltage level are listed and the load profiles are obtained. The load curves are then grouped based on a clustering process to find the typical load curves that will represent a set of consumers. These consumers are then classified in terms of their responsibility in the use of the system capacity. The more a consumer uses the system the more he will pay. In Brazil there are only two load periods that have different tariffs: the peak and off-peak load. The responsibility of each consumer is then measured for these periods to compose the tariffs.

The distributed generator and microgenerator profiles are not considered except the peak load responsibility. They pay the lowest peak load tariff defined for each voltage level.

It is possible to list the main problems of the current distribution pricing method in Brazil related to the distributed and micro generation:

- The voltage level is the only parameter to determine the distribution tariff not considering the structure of the system, i.e., if it is mashed or radial, if it is dense or sparse, and so on.
- In the interface between the distribution and transmission network and between the voltage levels at the distribution there is huge tariff gaps.
- There is no method to price the good and bad factors that arise from the connection of the generators to the distribution network.

B. The UK practice

The UK has a total of 7 distribution network operators (DNOs), the majority of them follows a very similar charging structure as for Brazil up to 2007. The model used in the UK is termed as distribution reinforcement model (DRM), assuming a 500MW increment each year to evaluate the incremental cost of the network. The incremental cost is then attributed to customers at different voltage levels for yardstick calculation. Customers at the lower voltages are assumed to use all upstream assets. The DRM model differentiates customers from their connection voltage, but within the same voltage level, they are charged the same regardless of their location, a typical example of the postage stamp allocation approach.

With the DRM model, the customers are clustered into different types, depending whether their energy consumption are half-hourly metered and their coincidence factor or their contribution to the system peak.

This model concerns the GB gas and electricity regulator Ofgem who could foresee a potentially large penetration of DGs and MGs in the network and such model cannot provide forward-looking message to influence the site and size of future DGs and MGs, which might require substantial network upgrading. Ofgem thus requested all DNOs to investigate alternative economic pricing model to send locational message to future network users, especially DGs and MGs.

Under the regulatory pressure, Western Power Distribution was team up with the University of Bath to research into alternative efficient pricing models in 2005. During the studies for WPD and Ofgem, a new pricing model was developed for the EHV network. The model is an improved version over the UK's transmission pricing model – ICRP in that it can reflect both the distance traveled and the degree of utilization of the traveling path. After a period of extensive consultation, WPD adopted the LRIC approach for their EHV networks (from 132KV to 33KV). The LRIC is expected to be taken up by two other main distributors - EDF and CE Electric. Other DNOs also move to a more locational network charge model, taking the key features of the LRIC - time to reinforce from the degree of utilization of their existing network.

The approach is however deemed to be too complicated to be practical for HV/LV networks due to the extensiveness of the network and lack of half-hourly metered customer information. The regulator is however very concerned the deficiency of the DRM model to reward MG customers who benefit network from reduced operational and investment cost, and penalize customers who cause adverse effect on the low voltage network.

III. A CASE STUDY OF MGS

This section shows the relationship between the magnitudes of micro-CHP uptaking and their effects on the HV/LV network. The effects are assessed in terms of network's loss, voltage profiles and investment deferral. A typical city in the UK is used to demonstrate the effects. .

The City of Bath is located 140kms west of London, a middle class, tourist city, famous for its natural spring and historical buildings. The City has a population 164 thousands, and 71 thousands household. The typical winter peak demand of the City is 103MW. Although a considerable amount of the building are listed, thus have limited scope for renewable icrogeneration, there are significant potential for micro-CHP.

As a middle-class city, citizens of Bath have less financial constraints and a high awareness of their impacts to environment. They are likely to be the enthusiastic consumers for domestic micro-CHPs. Using the trend projected for the uptaking of MG in the UK's governmental report [1], we have derived growth rates for micro-CHPs for the City in the time frame of 2010, 2020 and 2030. Table 1 shows the projected growth rates without any support from market and regulation, together with the number of units, total installed capacity and their potential CO2 reduction and energy provision.

TABLE I. THE GROWTH RATES OF MICRO-CHP FOR THE CITY OF BATH WITHOUT THE SUPPORT FROM MARKET AND REGULATION.

Year	Growth rates	Number of Units	Total Installed Capacity (MWe)	CO2 Saving (Tonne/ annum)	Electric Energy (MWh)
2005	Base	20	0.024	16	7

	year				
2010	1%	21	0.025	17	8
2020	28%	811	0.974	653	300
2030	34%	30,106	36	24,235	11,139
2050	22%	153,894	185	123,884	56,940

Table II show the potential in the city with the support from regulation, where all new build stock is required to install micro-CHPs.

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Year	Growth rates	Number of Units	Total Installed Capacity (MWe)	CO2 Saving (Tonne/ annum)	Electric Energy (MWh)
2005	Base year	20	24	16	7
2010	127%	1205	1447	970	446
2020	72%	68227	81872	54923	25244
2030	43%	152908	183490	123091	56576
2050	22%	153894	184673	123885	56941

The impact on the network from MG of different penetration level driven by the two schemes (with and without regulation) is shown in Figure 1. Figure 1 demonstrates that for the regulated case, as the MGs penetration increase, the loss reduction becomes smaller. Further, at certain point in the future, power flow will reverse, the network losses start increase.

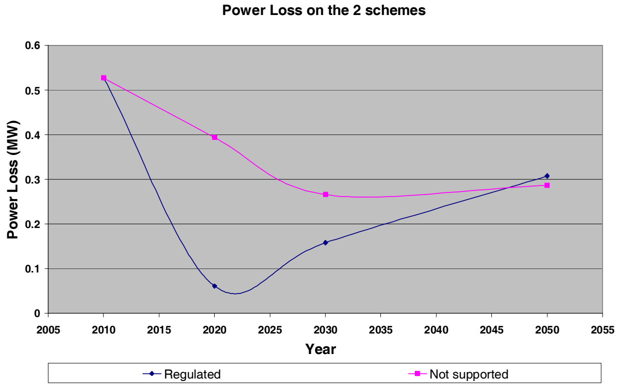

Figure 1. Network losses with differing micro-CHPs penetration, with and without regulatory support

Figure 2 shows the changes in line utilization as the penetration level increase. In this case, no support is given over the future time frames.

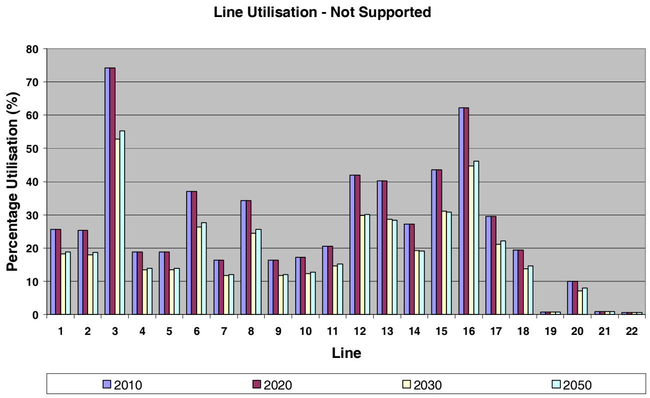

Figure 2. The level of line utilizations without regulatory support.

Figures gives the changes in line utilization the support of regulation, showing a generally much improved circuit utilization. This demonstrates that it has the potential to further defer the reinforcement horizon.

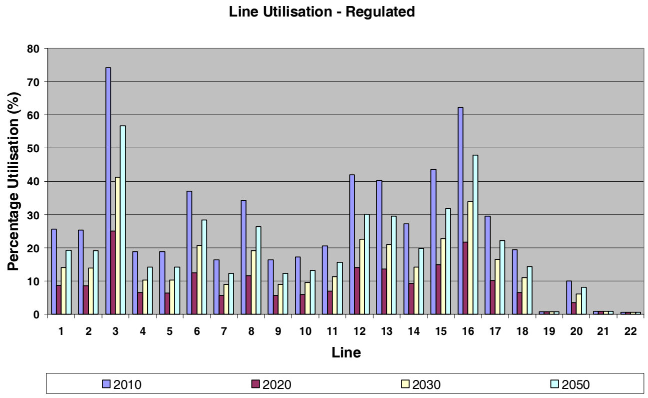

Figure 3. The level of line utilizations with regulatory support.

Figure 4 and 5 show the system voltage profiles with and without regulatory support. As the figure indicates, there will generally no problem up to 2030 for the unsupported scenarios. But for large penetrations as stimulated by regulation, voltage problems kick in much early on.

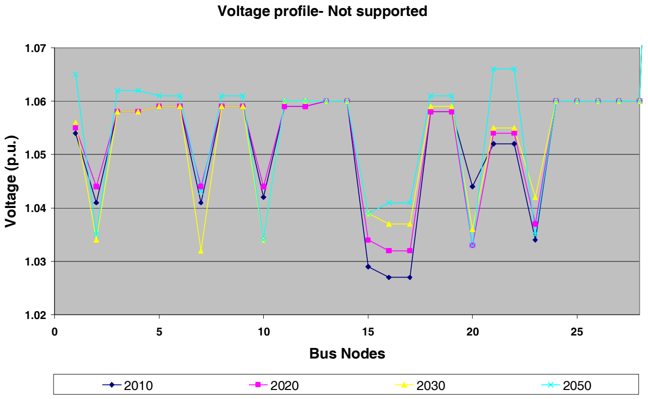

Figure 4. System voltage profiles with regulatory support.

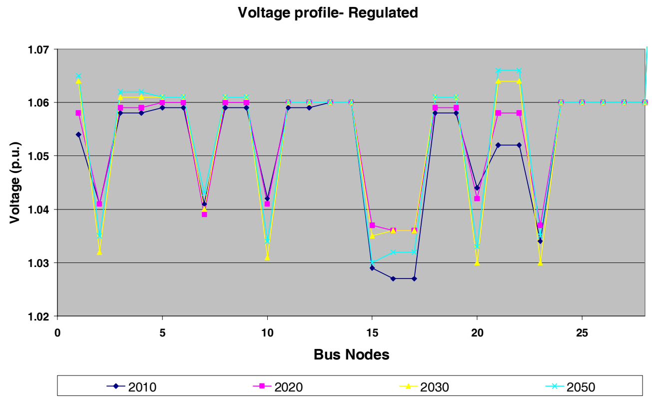

Figure 5. System voltage profiles without regulatory support.

IV. SUGGESTIONS

An ideal charging model should set up network charges against their users to serve the following purposes:

1) reflecting the cost of installation, operation and maintenance of the distribution network in supporting network customers, they can be individuals or a subset of customers.
2) Provide forward-looking signals to influence the future site and size of generation/demand.

Because of the extensiveness of the HV/LV networks and often the short of half-hourly metered information, the question for the MG charging is how one increment in the energy consumption of one specific customer affects the present value of the total cost of the distribution company? how much detail a charging method should reflect the true cost/benefit introduced by a MG or a cluster of MGs? In the absence of half-hourly metered information, how should MGs' effects on the network be simulated? Should the MG network pricing be real time, reflecting their impact on the network on half-hourly or hourly basis, or annual peak and off-peak charging are sufficient? How should a charging model's objectives be?

The first needed to be established is the extensiveness of the HV/LV network model for the MG charging purpose. Whether a generic network is adequate to reflect the present state of the HV/LV network and whether it should be adapted to reflect the surface area, population and number of households that are specific to an area. Or a more detailed model should be established to correlate a specific customer with a group of Primary Elementary Distribution System – PEDS and then identify its impact on the average cost of this group. Or the true cost/benefit can only be achieved through extensive, detailed load flow and fault current analysis.

A generic network would be favoured by most DNOs as it requires least accounting burden. It is possible to devise generic network for urban, rural areas, but they are less likely to reflect the actual state of the network, given there are large geographical difference in different service areas. It is however possible to better reflect the state of the network if the generic network can be adapt to reflect the local surface area, population size and the number of households and commercial premises.

A more detailed representation can be achieved by correlate a customer with PEDS. The distribution system is designed to satisfy the peak load and each customer contributes to this period in a different way. The measure of this contribution is more complex to the residential customers than to the industrial ones. Each customer has a load profile that may be assessed by measurement taken during a specific period. Given a set of load curves, it is possible to identify groups of similar patterns using cluster analysis. Representative customers are then obtained for each set and are used to compose the PEDS load curves.

Each representative customer has a responsibility in the PEDS peak period measured by the β coefficient. Each PEDS has also a responsibility in the sub-transmission zone, which is measured by the α coefficient.

The α and β coefficients may be calculated using the typical load curves of the representative customers and the typical curve of the PEDS or group of PEDSs. The method tries to encompass the load profile where the temporal costumer response is considered with the spatial aspect by adding the zonal tariff to the PEDS.

Like once, MG customers can be clustered into a specific PEDS identified Once the typical load profile is established, a load flow study is possible to establish the cost/benefits that may be introduced to the network from differing MG penetration levels.

As shown by table III, for different MG penetration levels, very different effects will be felt on network voltage profiles and time to reinforce. It is possible to use these nodal cost information to encourage or inhibit the growth of MGs.

The detailed load flow and fault current analysis are less likely to be taken up by DNOs. The extensiveness of the technical analysis and accounting required are beyond the resource that most DNOs can afford.

V. CONCLUSIONS

Microgenerations are likely to have large penetration in the future. They can be a major supplementary source for providing green energy, improve efficiency and reduce CO2. Addition to the market support and timely regulation, appropriate reward to MGs for their contribution to long-term network investment and short-term operation should further stimulate the market. Of equal importance is that excessive penetration of MGs at specific areas may raise the cost of operation and investment to an unacceptable level, their cost to network can easily outweigh the benefits in energy provision.

The paper presents the current practice in network charges in MG charging and their drawbacks. The paper then outlines the challenges in deriving cost/benefit reflective MG charging models and suggests possible options in striking the right balance between the cost/benefit reflectiveness and the level of the complication in accounting.

VI. REFERENCES

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VII. BIOGRAPHIES

Dr. Furong Li (M'2000) was born in Shannxi, China. She received her B.Eng. in Electrical Engineering from Hohai University, China in 1990, and her Ph.D. in 1997 with a thesis on Applications of Genetic Algorithms in Optimal Operation of Electrical Power Systems. She is a senior lecturer in the Power and Energy Systems Group at the University of Bath. Her major research interest is in the area of power system planning, analysis and power system economics.

Professor J W Marangon Lima (M'94–SM'06) received the B.Sc. degree from the Military Institute of Engineering, Rio de Janeiro, Brazil, in 1979, the M.Sc. degree from the Federal School of Engineering of Itajubá, Itajubá, Brazil, in 1991, and the D.Sc. degrees from the Federal University of Rio de Janeiro, Rio de Janeiro, Brazil, in 1994. From 1980 to 1993 he was with Eletrobras, the Brazilian holding company for the power sector. Since 1993, he has been with the Federal University of Itajubá as a Professor of electrical engineering. In 1998 to 1999, he was also with ANEEL, the Brazilian National Regulatory Agency, as a Director Advisor. In 2003, he was also with the Ministry of Mine and Energy as a member of the group that elaborated the New Brazilian Electricity Model. From 2005 to 2006 he was on his sabbatical year with the Operations Research and Industrial Engineering group of the University of Texas at Austin.