BENEFITS OF LONG-RUN INCREMENTAL COST PRICING FOR DISTRIBUTION NETWORK CHARGES

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ABSTRACT

Distribution networks are expected to accommodate increasing embedded generation (EGs) in near future, unfortunately, most utilities are still using un-economic charging models to charge customers for the use of their networks. In the UK, most utilities use rudimentary Distribution Reinforcing Model (DRM), which charges users the same price regardless the locations. Additionally, the model was created for a traditional distribution system that has little embedded generation.

To address the aforementioned drawbacks, a long-run incremental cost (LRIC) pricing was developed to provide locational economic message for future generation and demand, taking into account of network utilization. Compared with existing approaches, the proposed LRIC model produces forward-looking charges that reflect both the extent of the network needed to service the generation or load, and the degree to which that network is utilized. The benefit of the charging model is demonstrated through the long-term network development cost on a test system and compared with that driven form existing approaches

INTRODUCTION

Distribution network charges are charges against embedded generators, large industrial customers and suppliers for their use of a distribution network. The charges are to recover the cost of installation, operation and maintenance of the network. The aim of an ideal charging model is to closely reflect the extent of the use of a network by network user, help to release constraints and congestion in the network and be able to provide correct economic signals for the siting and sizing of future generation/demand.

The current DRM adopted by the majority of distribution companies in the UK has two major drawbacks [1-2]:

1) They are not economically efficient as they do not discriminate customers who have delayed and deferred network investment to those who cause additional network reinforcement and expansion.

2) They are unable to support the potential increases in embedded generation.

Because of these concerns, extensive consultations are carrying out by Office of Gas and Electricity Markets (Ofgem) since 2003, exploring cost-benefit reflective charging models that provide locational signals to future demand and generation, facilitating the ease of connection of embedded generation [3]-[5].

It is against this background that this study has been commissioned by Ofgem to examine whether other charging methodologies would be more efficient at encouraging the economic development of the distribution network [6]. In its consultation on the longer term structure of distribution charges Ofgem noted that it expected distribution network operators (DNOs) to advance solutions that would overcome the weaknesses in the current charging arrangements.

The aim of the study is to demonstrate whether there are potential benefits that could arise from changes to the DNO charging regimes, and thus help inform the consideration of any new charging framework. The associated analysis seeks to simulate the impact of any new charging regime on network development costs based on the response of new and existing network users. The study is intended to extend to both distributed generation and load.

The main focus of the study has been on the impact a new charging methodology would have on extra high voltage (EHV) networks. Consequently in this study the modelling of likely price changes that could emerge from a change of pricing methodology is restricted to the EHV part of the system. However, because all users of distribution networks make use of the EHV distribution system the impact on both customers connected at EHV and those connected further down the system will need to be considered.

The benefits that may be derived from a change to the charging methodology are measured in relation to the future investment likely to be needed on the system. The analysis seeks to simulate the prospective developments of the system given the changed pattern of the growth in demand and distributed generation. Using the existing charging methodology as the benchmark, the efficacy of different charging methodologies is assessed from the investment needed to meet the requirements of load and distributed generators that use the system over the term of the study. The study covers the 20 years from 2005 to 2025.

APPROACH

The analysis has been conducted in four stages.

The first stage has been to devise a reference EHV network. The reference network that has been devised shown in figure 1 comprises assets that serve three distinctive areas, namely urban, rural and industrial areas. It has been modelled as a series of nodes interconnected by lines, cables and transformers, with load and generation connected such that DC and AC power flow studies can be conducted. An associated asset register and price controlled revenue target enables the application of a DRM model to assess the charges that might apply under present pricing practices if the area were a self contained distribution system.

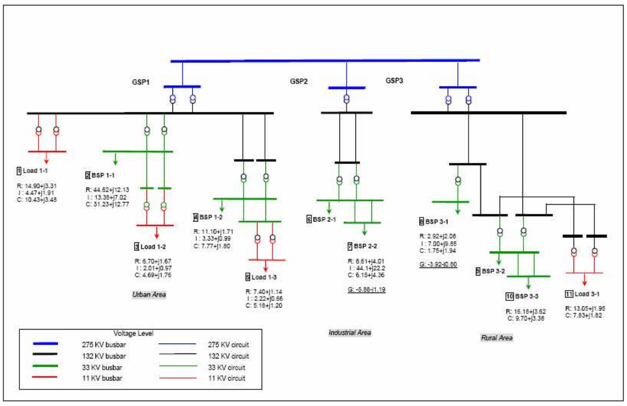

Figure 1 Reference network model comprising of rural, urban and industrial.

The second stage is to contemplate a number of pricing models that produce a range of prices:

- DRM with site specific EHV charges. This model is intended to reflect broadly the present charging arrangements for load supplied from distribution networks.
- DC load flow with ICRP (Investment cost related pricing). This model utilises the same approach as for the UK's present transmission charging arrangements.
- AC load flow with ICRP. Developed by the University of Bath, the AC load flows reflect more accurately the use that is made of a system since they also take account of reactive power. They tend not to be used for transmission on grounds of their complexity and the size of the associated data sets.
- DC load flow with LRIC. Developed by the University of Bath, the LRIC model utilises the same DC load flow calculation as for ICRP but the treatment of costs is different
- AC load flow with LRIC. Developed by the University of Bath, this employs the same AC load flow variations as for the ICRP but now with the LRIC cost model

In presenting the analysis the output from the DRM model is used as the benchmark against which the ICRP and LRIC models can be tested.

The third stage is to model the response of customer demand to prices derived from the various charging models, and thus the subsequent impact on system investment, a customer behaviour model has been developed (stage 3). For the generic customer classes connected at LV and 11kV price elasticities taken from published studies are used to derive anticipated changes in demand following a change in price. However, in the reference network half of industrial load is connected at EHV. EHV connected load is assumed be more price elastic than industrial load connected at lower voltages. Growth in this load is a taken to arrive as new large customers that site on an economically rational basis and choose those locations that have the lowest connection cost and use of system charges.

The final stage will model the consequence of differing patterns of demand and distributed generation on network investment that flow from customer reaction to the various pricing models is examined in an investment model. The respective costs developing the distribution network to accommodate demand and generation is used as the measure of the effectiveness of the charging methodology in encouraging efficient investment and thus the relative benefit of moving away from the present charging arrangements.

RESEARCH OUTCOMES

The objective of this study is to demonstrate the differences in network investment cost under different pricing models. The investment cost changes due to that different pricing models influence the location and to a lesser extent the amount, of future generation and load differently, the network investment required to maintain security and quality of electricity supplies will also differ significantly for each of the pricing approaches. The economic efficiency of each pricing approach can thus be assessed by applying the investment model described above to determine the quantum of capital expenditure required to accommodate the new load and generation under each pricing methodology.

Table 1 summarises the output from the investment model in terms of the present value of the investment needed over the study period under each of the pricing models.

Table 1. Present value of network reinforcement cost for each pricing model up to 2025

Pricing Model	Due to demand (£)	Due to generation (£)	Total (£)
DRM	564,945	439,099	1,004,044
ICRP_DC	431,582	398,598	830,180
ICRP_AC	431,582	202,358	633,940
LRIC_DC	0	367,966	367,966
LRIC_AC	0	171,725	171,725

Generation related investment under different pricing

models

Distributed generation is not a part of the DRM pricing model and there is no locational signal for the siting of generation under this approach. The output from the investment model shows that the highest system cost for accommodating generation and demand is associated with this pricing methodology.

Under the ICRP models the generation would tend to concentrate at the most distant nodes since these present the best credits for generation. However, these locations are also characterised by substantial network assets. Because of this the ICRP approach gives rise to the need for substantial investment to accommodate the increase in fault level. The attractiveness of these nodes in terms of price only ceases when the quantum of new generation causes the power flow at the node to reverse. As has already been noted this may be seen a significant weakness of the application of the ICRP approach to distribution systems.

The LRIC models also caused significant network investment to upgrade switchgear for increased fault levels. However, this model has a major advantage in that because the pricing incentive is to site where assets are most heavily loaded there is no investment needed to accommodate the growth in demand. Effectively the addition of generation at the chosen locations is offsetting the need to reinforce the system for the growth in demand. .

Figure 2 shows the cumulative network investment cost for new generation under different pricing models. When considered cumulatively over the study period the AC power flow models produced significantly lower investment costs than their DC counterparts, and the LRIC-AC model slightly outperforms the ICRP-AC model. The merit of the AC pricing model variant is that it can reflect the requirements of the network for reactive power.

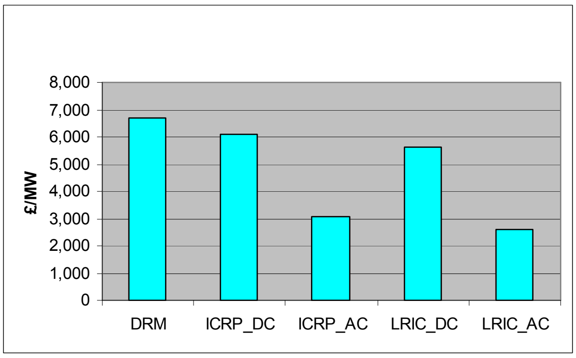

Figure 2. Present value, in £/MW, of cumulative network investment cost for new generation under different pricing models

Demand related investment under different pricing models

The principal investment cost resulting from the addition of new load was due to the need to increase transformer capacity and reinforce circuits as a result of thermal limitations and under-voltages. Because the LRIC models encouraged generation to locate at the most heavily loaded nodes this had the effect of obviating the need to reinforce the system at these locations for the growth of demand. The reinforcement cost for demand under this pricing model was therefore zero.

The ICRP models that encourage load to site at nodes that have the least distance from the associated GSP without reference to the utilisation of the associated assets, which in the reference network are the most heavily loaded circuits and transformers, causes these models to require the most investment for the connection of incremental
Over the 20 year study period the DRM methodology requires the greatest amount of cumulative network investment of any of the pricing models to accommodate new load. Since reactive power charge did not play a part in the modelling of demand response to the locational pricing signals the investment model has calculated the same investment cost for both the DC and AC variants of the ICRP pricing approach. .However, as noted above the LRIC approach substantially outperforms both the DRM and ICRP approaches since it does not require any investment to meet the forecast growth in demand provided new generation locates in an economically rational manner. Figure 3 shows the network investment cost associated with accommodating demand under different pricing models.

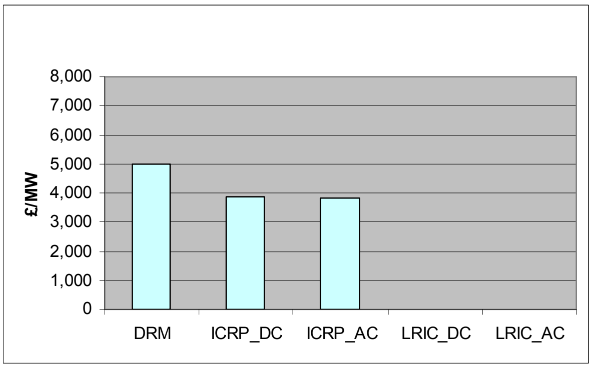

Figure 3. Present value, in £/MW, of cumulative network investment cost formeeting new load under different pricing models

When the investment cost of meeting new load and generation are taken together the ICRP methodologies generally outperform the DRM approach in the amount of investment that is required to reinforce the network. However, the LRIC charging methodologies demonstrate by far the lowest investment cost of the pricing approaches considered here, with the LRIC-AC approach producing the best result. This is shown in figure 4.

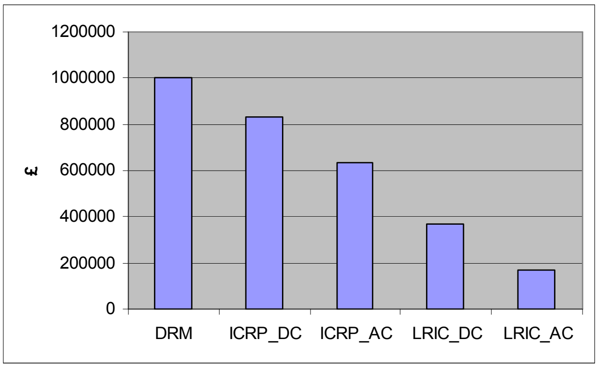

Figure 4. Present value of overall investment needed to accommodate new load and generation over the 20-year study period

CONCLUSIONS

The study explored potential benefits that can be introduced by adopting economic charging models. This study considered five pricing methodologies, the present charging models for the UK's transmission (ICRP) and distribution networks (DRM) and the new charging models LRIC, developed by the University of Bath. The conventional DRM charging methodology has been used as the benchmark against which the other models based on economic principles could be assessed.

Over the study period, LRIC charging model showed a reduction in the present value of the cost of reinforcing the EHV reference network, which served 275 MW of load and 10 MW of generation in the base year, of £830k. If this were extrapolated across the GB system is it would imply a cost saving in the region of £200 million

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