

## COMPARISON BETWEEN LONG-RUN INCREMENTAL COST PRICING AND INVESTMENT COST-RELATED PRICING FOR ELECTRICITY DISTRIBUTION NETWORK

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### ABSTRACT

*Pricing of the use of the distribution system network is essential particularly in providing economic signals to serve two purposes: (1) to incentivise efficient utilisations of existing distribution facilities; (2) to guide the siting and sizing of future generation and load. While many of the existing methodologies satisfy only the first purpose, long-run cost pricing schemes are increasingly favoured, as they include the reinforcement and expansion cost in addition to the operating cost. Studies on long-run cost pricing schemes were carried out on the IEEE 14 bus test system and the initial findings show that they outperform the existing pricing schemes.*

### INTRODUCTION

In the UK, privatisation of the electricity supply industry was introduced in 1990 to promote competition (reducing price) and improve efficiency. The underlying concepts are to separate the contestable functions of generation and supply from the natural monopoly functions of transmission and distribution.

Distribution network owners (DNOs), hence, were formed at privatisation as regulated businesses, responsible for network planning, maintenance and operation of the charging the users for the provision of the network facilities, including both delivery of energy (distribution use of system (DUoS) charges) and for connection. The focus of this paper is on the pricing methodologies for the DUoS charges as it represents the vast majority of the DNOs' business income [1].

Distribution network charges should closely reflect the extent of use of the network by users, help to release constraints and congestion in the network, as well as be able to provide correct economic signals for the network expansion and reinforcement. However, the present pricing methodology, the distribution reinforcement model (DRM) in the UK, does not provide locational signals as the costs are average at each voltage level. The DRM's inability to reflect forward looking costs and its inconsistency in the treatment between generation and demand, increase the difficulty in facilitating the ease of connection of embedded generations.

Studies, therefore, have been extensively carried out over the years to solve the problems identified in the current

pricing methodology. Long-run cost pricing methodologies are recognised as more economically efficient since they are forward looking and provide locational signals, which reflect the extent of use of the network by potential user, essentially to encourage local generation meeting local demand. However, their implementations are often complicated as they involve solving the least cost expansion problem (which is beyond the scope of this paper) and allocation of the reinforcement costs among network users [2].

### LONG-RUN INCREMENTAL COST (LRIC) PRICING

LRIC pricing is a methodology developed by University of Bath in conjunction with Western Power Distribution (WPD) [3]. LRIC accounts for the change in total costs that is the investment cost for reinforcements (or credit for delaying or avoiding reinforcements) and the change in operating cost. LRIC pricing methodology is realised by injecting an increment of generation or load at a node of the studied system, where the increment will result in the advancement or deferral of the investment horizon.

#### Mathematical Model

The LRIC pricing model is a function of distance and also the horizon when the new investment will be required. Time taken for the load to grow from the current to full loading level,  $n$  is shown below.

$$n = \frac{\log C - \log D}{\log(1+r)} \quad (1)$$

Where  $D$  = current loading level  
 $C$  = full loading level  
 $R$  = load growth rate

With the increment, the  $n_{new}$  can be calculated by altering the  $\log D$  component with  $\log(D+\Delta P)$ . Detailed derivation can be found in [3].

Again for both with and without the increment of load, the circuit's unit cost  $U$  is determined

$$\begin{aligned} \Delta U &= U_{new} - U \\ &= \frac{Asset}{C} \times \left( \frac{1}{(1+d)^{n_{new}}} - \frac{1}{(1+d)^n} \right) \end{aligned} \quad (2)$$

Where  $d$  = discount rate

Hence the long-run incremental cost can be summarised by the following.

$$LRIC_N = \frac{\sum \Delta U}{\Delta P_{iN}} \quad (3)$$

### INVESTMENT COST-RELATED PRICING (ICRP)

ICRP is one the widely used long-run marginal cost pricing methodologies. Notably, ICRP is developed and used by the transmission network in the UK – National Grid Company (NGC) [4]. The principle of the NGC ICRP transport model is to inspect the changes of network power flow with respect to one unit power injection or drawn at a node. The increment will therefore increase (or reduce) the transmission capacity to accommodate the increment flow resulted. The routes taken by the additional flow will then be expressed into marginal cost.

#### Mathematical Model

ICRP, based on MW-Miles methodology, is determined as the product of the power change of each line, the line’s length and the line’s unit cost £/MW/km over all the affected circuit, due to the increment of load at the node. The line’s unit cost, in this case, is equivalent to the annuitised asset cost divided by the product of the line’s length and the rated capacity of the line.

$$Unit\ Cost = \frac{Asset\ Cost}{L \times C} \quad (4)$$

$$ICRP_N = \sum_l (Unit\ Cost_l \times \Delta P_l \times L_l) \quad (5)$$

Where  $L$  = the length of line  $l$

$C$  = the rated capacity

$\Delta P$  = the change of power flow along the line  $l$

### TEST SYSTEM

The efficiency of the pricing methodologies, LRIC and ICRP, are compared on the IEEE 14 bus test system [5] (Figure 1), with DRM pricing methodology as a reference.

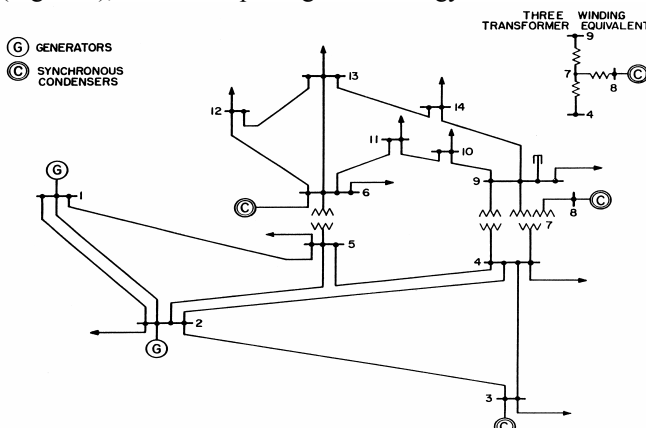


Fig. 1 IEEE 14 Bus Test System

The test system consists of the transmission ( 132kV) and distribution (33kV) system, with 2 generators and 3 synchronous condensers. Lines and transformers costs and ratings are estimated based on that of a practical distribution network. With these parameters, the utilisation of the branches varies widely from 6.5% to 50.7%.

### RESULTS AND ANALYSIS

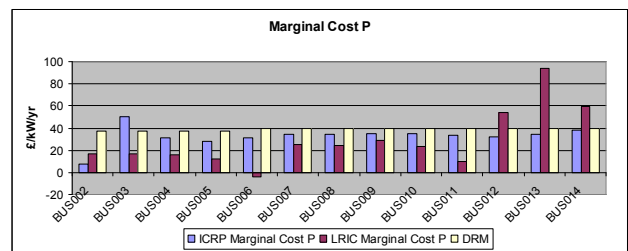


Fig. 2 Outcomes of ICRP, LRIC and DRM

As mentioned before, the outcome of DRM does not demonstrate any locational differences but a fixed charge at each voltage level, 132kV and 33kV.

#### Utilisation versus Distance

The outcomes of LRIC and ICRP are dependent on different factors, such as utilisation of the branches for LRIC and distance or length of the lines for ICRP. In Figure 2, notably, the line connecting Bus 6 and Bus 13 of the test system is eventually the line with the highest utilisation among all the other lines, resulting a significantly large charge for the LRIC marginal cost compared to the ICRP. This has also affected the LRIC marginal costs at Bus 12 and Bus 14, which are adjacent to Bus 13. Although ICRP gives steady charges taking into consideration the location of the node, and derives charges for both generations and loads; it neglects the degree of the network utilisation. The ICRP highest charge in this case is at Bus 3, where line connecting Bus 2 and Bus 3 is the line with the greatest length.

#### Counter Flows

According to Figure 2, in addition to utilisation, LRIC pricing also accounts for counter flows, where network users, in this case, are due to get credit for. The LRIC marginal cost at Bus 6, for instance, is negative because of the counter flows resulted to cover an increment of load at the node. This essentially hinder future reinforcement. Besides, counter flows benefit the network by causing line flow decongestions and provide correct signal for the system operation. ICRP, on the other hand, also reflects the influence of counter flows in a different way. The reason the outcome is not as significant as the LRIC is because of the lack of recognition of the influence of the network utilisation.

## CONCLUSION

While both pricing of LRIC and ICRP are locational and forward looking, it is demonstrated that LRIC methodology promotes better economic signals, regarding its ability to reflect the extent of use of the system instead of merely dependent on the length of the circuit. This eventually encourages users to locate to places where unused capacity is available, as well as facilitates the potential increases in embedded generation. However, there are still many issues of the LRIC pricing methodology that requires attention for, such as negative and zero load growth rate, time of use of the distribution network etc.

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