Trade-off between UoS Charge and Investment Cost for New Distribution Network Users

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***Abstract*-- This letter investigates the situation that high Use-of-System Charge (UoSC) might appear for new network users and studies the potential of network investment to avoid the high charge. It proposes a method to strike the trade-off between UoSC and investment cost, in the form of Connection Charge (CC). It determines the utilization level where UoSC and CC reach equilibrium. Beyond this level, it is more economical to conduct network investment for new users to avoid high UoSC. The trade-off between the two type charges provides effective signals for new network users to manage their connecting size and location. The concept is illustrated on a two-busbar system.**

***Index Terms*-- Use of system charge, Connection charge, Equilibrium, Investment, Long-run incremental cost, Tradeoff**

I. INTRODUCTION

When customers use power systems, they need to pay for Use-of-System Charges (UoSCs) according to the effects they impose on the systems [1]. Particularly, the increasing penetration of distributed generation (DG) driven by renewables at distribution networks needs large-scale investment, which thereby incurs UoSCs. There are cases that new customers would see very high UoSCs if the system is already highly loaded. It might be more economical to invest in networks even if the system is not overloaded. The investment can bring down UoSCs, but will produce Connection Charges (CCs). In some cases, the summation of UoSCs after investment and CCs might be smaller than the original UoSCs. There is a trade-off between the two type charges that should be identified to justify investment.

This letter discusses the interaction between UoSC and CC. It strikes the trade-off between the two charges by determining at which level: i) they equal to each other, and ii) the UoSC without investment equals to the summation of new UoSC after investment and CC. The tradeoff enables customers to manage their sizes and locations in use of systems.

II. UOS CHARGE VS. CONNECTION CHARGE

In the UK, new connectee is subject to all investment cost up to one voltage level plus on-going UoSCs, where the reinforced assets should be included. The existing customers, on the other hand, are only subject to UoSCs. There are two types of CCs - deep and shallow, and only the latter is examined as it is beneficial for promoting DG penetration [2].

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Fig.1 demonstrates the trade-off between UoSC and CC. UoSC rises with the increase of utilisation level, while CC keeps constant. The two charges cross at an equilibrium point-I. Beyond point-I, the UoSC increases exponentially and is extremely higher than CC. At the equilibrium point-II, the original UoSC (blue dashed line) equals to the summation of new UoSC and CC (red solid line). As seen, it is more economical to make investment beyond point-II in order to avoid excessively high UoSCs.

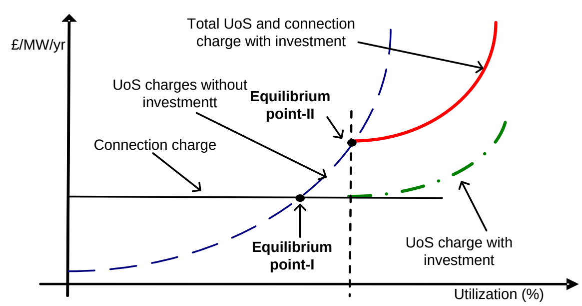

Fig. 1. Trade-off between UoS charges and connection charges

III. IDENTIFYING EQUILIBRIUM

One of the common methods used in the UK for deriving distribution network UoSC - Long-run incremental cost pricing (LRIC) -is used here to derive UoSCs [3]. With a sensitivity approach [4], the unit UoSC from the circuit allocated to *D* in Fig. 2 is

$$LRIC = \frac{Asset}{C} \times \frac{\log(1+d)}{\log(1+r)} \times \left(\frac{D}{C}\right)^{\left(\frac{\log(1+d)}{\log(1+r)}-1\right)} \times AnnuityFactor \quad (1)$$

where, *Asset* is the circuit cost, *C* is its available capacity, *d* is discount rate, *r* is load growth rate, and *D* is current load.

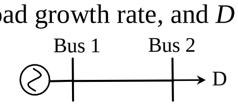

Fig. 2. Diagram of a two-busbar test system

As *d* and *r* are fairly small, replacing *D/C* with utilization level, the above formula can be approximately with

$$LRIC = \frac{Asset}{C} \times \frac{d}{r} \times (Utilisation)^{\left(\frac{d}{r}-1\right)} \times AnnuityFactor \quad (2)$$

Accordingly, the annual UoSC paid by a customer is the unit nodal price multiplied by its size, given in (3). Charge scaling is ignored as revenue is largely recovered from UoSCs.

$$UoS\ Charge = LRIC \times Size \quad (3)$$

If the same new asset investment is invested, the annul CC paid by D is the annuitized cost of the asset in (4).

$$Connection\ \ Charge = Asset \times AnnuityFactor \quad (4)$$

Equating (3) and (4) can find the equilibrium utilization

$$\frac{Asset}{C}\times\frac{d}{r}\times(Utilisation)^{(\frac{d}{r}-1)}\times AnnuityFactor\times Size = Asset\times AnnuityFactor \quad (5)$$

Simplifying (5) and taking logarithm of it produces

$$\log(Utilisation)=\log(\frac{C}{Size}\times\frac{r}{d})/(\frac{d}{r}-1)=Y \quad (6)$$

The utilization level (point-I) without new connectee is

$$Utilisation_{before}=Utilisation-\frac{Size}{C}=10^{Y}-\frac{Size}{C} \quad (7)$$

At this utilization level, the two charges equal to each other and beyond it, UoSC is higher than CC. The point-II, at which the original UoSC equals to the total CC and new UoSC, is

$$UoS\ Charge_{Without}=Connection\ Charge+UoS\ Charge_{With} \quad (8)$$

Simplifying (8) produces

$$\frac{Asset}{C}\times\frac{d}{r}\times(Utilisation)^{(\frac{d}{r}-1)}\times Size = Asset+(Asset/C)\times(d/r)\times(Utilisation/2)^{(\frac{d}{r}-1)}\times Size\times 2 \quad (9)$$

Rearranging (9) equation and taking logarithm of it gives,

$$\log(Utilisation)=\log(\frac{C}{Size}\times\frac{r}{d}\times\frac{1}{1-2\times(1/2)^{(\frac{d}{r}-1)}})/(\frac{d}{r}-1)=Y' \quad (10)$$

The utilization (point-II) without the connectee is

$$Utilisation_{before}=Utilisation-(Size/C)=10^{Y'}-(Size/C) \quad (11)$$

where, Y' can be obtained from (10).

Beyond point-II, the original UoSC is bigger than the total new UoSC and CC, thus more economical to invest for D.

IV. Demonstration

The network in Fig.2 is utilized to demonstrate the concept. The circuit has a rating of 50 MW after security redundancy and costs £3,193,400. A rate of return of 6.9% and 40-year lifespan produce an annuity factor of 7.41%. The initial demand is set as 44MW and a growth rate of 0.5% is chosen.

Table I provides UoSCs for three new customer sizes, 3MW, 5MW, and 6MW. Without investment, they incur high UoSCs: £88,306, £246,528, and £379,879 respectively. Table II provides the equilibrium point-II, new UoSCs, CCs and the total costs when a new branch is built. The UoSCs with investment for all sizes drop dramatically compared to those without investment in Table I. The total annual costs are the summation of new UoSCs and CCs. The results in Table II illustrate that new investment is uneconomical for 3MW size but can sharply bring down costs for 5MW and 6 MW sizes.

TABLE I ANNUAL CHARGES WITHOUT INVESTMENT

Demand	3MW	5MW	6MW
UoS charge (£)	88,306	246,528	379,879

TABLE II ANNUAL CHARGES WITH INVESTMENT

Demand	3MW	5MW	6MW
Equilibrium point-II	95.49%	87.52%	84.14%
UoS charge (£)	12	35	55
Connection charge(£)	236,631	236,631	236,631
Total cost(£)	236,644	236,668	236,688

Fig.3 illustrates the original UoSC and new total costs for 5MW connectee. The solid line is original UoSC, growing dramatically with utilisation. The dashed line is new total cost with investment, which grows as well but at a lower speed. Beyond point-II, the dashed line is below the solid blue line, justifying the cost reduction by new investment. (The X axis unit for the dashed line should be halved due to investment.)

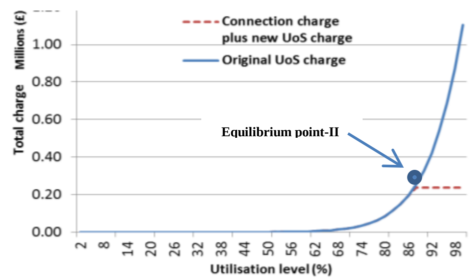

Fig. 3 Cost comparison for 5 MW connectee

In network charging [3], generation is normally modelled as negative demand. As the unit UoSC is derived by sensitive approach, the only modification for generation in deriving UoSC is to use absolute value of the 'size' in (3)–(11). If generation can reduce system utilisation (determined by power flow analysis), the UoSC is negative, i.e. reward for the generation, otherwise the charge is positive, i.e. cost for the generation. CC can be quantified in the same way as for load.

The proposed method is only for new users. For existing users at the same level, they still pay for the original UoSCs without investment. The investment cost of the new asset is only recovered from new users who trigger the investment. In calculating UoSCs for existing users, the new investment is excluded from the system and the cost is set to zero.

V. Conclusions

This letter proposes a method for new network users to manage their costs in connection to and use of systems. When they face high UoSC, they can require local network operators to invest in systems, as the annual asset investment cost plus new UoSC could be smaller than the original annual UoSC without network investment. The method is able to find the equilibrium points at which level the two charges equal to each other. As demonstrated in the case study, the total cost is reduced by 4% for a 5 MW connectee, from 246,528 £/year to 236,668 £/year. For a larger new customer of 6MW, the total cost is reduced by 38% if new investment is conduced, from 379,879 £/year to 236,688 £/year. The results justify the capability of the proposed method to provide insight into how the tradeoffs work. The equilibrium provides effective signals for new customers to manage their network usage.

VI. References

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