DISTRIBUTION REGULATION IN COMPETITIVE ENVIRONMENTS: INVESTMENT, PRICING AND ACCESS

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SUMMARY

The activity of "distribution", -comprising investment, operation and maintenance of the distribution network, but not retailing or commercialization of energy either to final customers or at wholesale level-, remains a regulated activity even in power systems that have been fully restructured and liberalized. The reason for this stems from the fact that distribution is a natural monopoly and therefore cannot be subject to competition. However, in a competitive power system the regulation of distribution also needs to undergo a thorough revision, in order to make it self-contained and compatible with the remaining activities. This paper reviews the most fundamental issues to be considered in distribution regulation in a competitive environment and presents basic lines of solution that have been proposed.

Keywords: Distribution network, distribution regulation, restructuring, liberalization, distribution network planning, distribution charges, distribution remuneration.

1. – INTRODUCTION

1.1. Nature of the distribution activity

The complete process of supply of electricity to the end consumers comprises a number of diverse activities, which require a separate regulatory treatment, see a detailed description in [Pérez-Arriaga, 1997]. In particular, it is very important to separate the activities of distribution and retailing or commercialization. **Distribution** is a network activity, with characteristics of natural monopoly, whose objective is to physically transport the electricity from the transmission network, and also from the generation embedded in distribution, to the end consumers. Distribution has the characteristics of a natural monopoly, since it is much less expensive to distribute electricity with a single network than with a multiplicity of them; this is why it has to be subject to a careful regulatory scrutiny, in order to avoid the extraction of monopoly rents from the consumers that are captive in a given network. On the other hand, **retailing**, whose objective is to make a commercial margin by purchasing electricity wholesale and selling it to the end consumers, is an ordinary competitive business under a regulatory viewpoint.

Note that, under the general term of distribution, several activities can be considered: network expansion planning, line construction, maintenance scheduling, actual maintenance of distribution facilities and operation of the distribution network. The same company may perform all of them, although it may be preferable to subcontract -even through competitive bidding procedures- some activities, such as construction or maintenance, to other firms.

One might wonder why the regulations of the transmission and the distribution networks are considered separately. There are three major reasons for this. Firstly, it is very important that the regulation of transmission makes sure that the entity in charge of this activity acts with complete neutrality, so that there is no discriminatory treatment of the agents in the wholesale market. On the other hand, expansion, maintenance and operation of the distribution networks have no influence on the wholesale market –they may affect somewhat the retail market, however–, hence the requirements for independence of the network ownership are of less significance in distribution. Secondly, the very large number of distribution physical facilities does not allow an individual regulatory treatment of them, -in particular regarding remuneration issues-, as it is the case with the transmission network. Thirdly, quality of service is an issue of utmost importance in distribution, since most end consumers are directly connected to distribution networks.

1.2. Major topics in distribution regulation

The relevant topics in distribution regulation may be organized under three major headings: investment, pricing and access. Quality of service may be considered as an indirect outcome of these three issues, although in this paper it has been awarded an individual treatment. By no means can distribution regulation be seen as a settled regulatory field. It can rather be said that most significant topics are still open, with a large variety of only partly successful approaches being tested throughout the world.

2. – INVESTMENT ISSUES

The final aim of a correct regulation of distribution investment is that the distribution network users (namely, end consumers, embedded generators and other distribution utilities) obtain the optimal trade-off between cost (investment and operation costs, including ohmic losses related costs) and quality of service. Since mandatory planning is out of question for the above-indicated reasons, this regulatory goal may have to be achieved by means of

economic signals: the remuneration for the distribution network service, including any economic incentives (either credits or penalties) for reduction of ohmic losses, as well as for meeting prescribed levels of quality of service. Another more direct approach consists of establishing mandated performance levels of quality of service, as well as network minimum design criteria, such that failure to meet them entails regulated economic penalties.

Distribution network investment is typically not regulated on the basis of individual facilities, but on the basis of global network performance. Some countries have applied to the high voltage distribution network the same regulatory treatment that is applied to the transmission network, which is fine, except that spurious incentives may be introduced regarding whether to invest preferably at the high voltage or at the medium voltage level. Here it will be assumed the same regulatory treatment for all distribution levels. A conceptual review of the most characteristic approaches to distribution network remuneration should include the following ones:

A. **Cost-of-service** remuneration of the existing facilities, which may be based on audited utility records. This method, besides the obvious practical difficulties derived from the very large number of facilities, has the problem of failing to convey the right incentives to address the above-mentioned regulatory goal, neither for adequacy of new investments, quality of service or reduction of network losses.

B. Another method, which totally avoids having to replicate the planning procedures of distribution networks, is the well-known **RPI-X approach**. A per unit remuneration P_t is assigned during the reference initial year t to a magnitude E_t (such as the circulated energy or the peak load distributed by the network) that is deemed representative of the volume of service that the distribution network provides during t. The retribution during t is therefore $R_t = P_t.E_t$. The efficiency factor X (and P_t also, in some systems) is only revised after a number of years (about 5, typically), so that the distribution utility may benefit from any cost reduction before the regulator makes adjustments to pass a fraction of the efficiency gain to the consumers. Mandatory standards of network design and quality of service ensure that network investments at least satisfy some minimum requirements, which, in the regulator's opinion, may correspond to the optimum trade-off level between quality and cost that was mentioned above. During each 5-year interval, the annual remuneration can be updated with the use of the following equation:

$$R_{t+1}=R_t \bullet (1+RPI-X) \bullet (1+Y \bullet \Delta E_t/E_t) + \text{Ohmic loss incentive} + \text{Quality of service term}$$

where Y may be seen as another efficiency factor that transforms a per unit increment in the volume of service into an increment in remuneration. It is important to note that the approach in the above equation for updating the remuneration from one year to the next may be applied also in some of the other methods. It has the advantage of introducing efficiency factors that are instrumental in promoting efficiency gains and sharing them among distributors and consumers.

C. Different versions of "**yardstick competition**" may also be used, either directly or as an auxiliary technique for the application of other methods. The starting point is a data base, as large as possible, of the elements of cost and the economic and technical characteristics of comparable distribution utilities. Then, sophisticated statistical techniques can be used [Kittelsen, 1995] to draw conclusions about the relationships between cost and the most relevant distribution variables and also to establish the adequate level of remuneration for a distribution utility which was not included in the data base.

D. It is also possible to derive the remuneration of the distribution service from **reference or ideal models** of the actual utility. Typically, the most relevant part of the model refers to the network investment costs, but models can be also developed for maintenance and operation costs, as well as for different types of overhead costs. One type of network model is the *total replacement network model*, see [Román et al., 1998] for instance, which develops the distribution network from scratch, i.e. taking as input data only the transmission substations and the load, with their spatial distribution and, sometimes, the orography of the terrain. Of course, the outcome of a model of this type will be an ideal network with important differences with respect to the actual one, which has been developed without the knowledge of the exact pattern of load growth and also subject to many other practical limitations. Therefore, the reference model may only be used to establish well founded quantitative comparisons between the ideal costs of distributing electricity in different areas, or within a given area in different moments of time. It always remains the exercise of finding by how much the cost of the ideal network has to be augmented in order to provide an adequate remuneration to the distribution company. The use of reference models (once they have a reasonable level of development) has the advantage of ensuring that the retribution of the distribution utilities will satisfactorily reflect the actual difficulties of distributing electricity in any given area.

E. The **average incremental cost method**, see [Bastos and Abdala, 1993], also requires a network model, but now the model starts from the actual network in the year t, when analyzing the costs of the additional investments for the year t+N that are needed to meet the estimated load growth. The interval N (about 5 years, typically) is made to coincide with the next revision of distribution tariffs. The model must be able to provide the sensitivities of the investment costs, i.e., the long term marginal costs of the distribution network, with respect to increments in the demand at any voltage level. Distribution tariffs, and therefore the remuneration of the network, are derived directly from

these sensitivities. A conflictive point about this method is the dependence of the results from the level of optimality, -i.e. adaptation to the demand-, of the present network. For instance, the more under-developed the existing network is, the larger the need for additional investment and the larger the resulting long term marginal costs and the distribution tariffs. Care must be exercised to prevent opportunistic behavior of the distribution utilities.

F. Some countries, the Nordic European countries in particular, have opted for some form of **light-handed regulation**, even for the typically heavily regulated distribution utilities. The idea is to let the distribution utilities themselves to set the network charges for their customers, with the only requirement of non-discrimination between the same type of customers. The resulting tariffs are subject to the scrutiny of the regulatory authority, who may require mandatory changes. The advantage of the approach is the flexibility for the distributor, who precisely knows its costs, its assignment to voltage levels and its dependence on load characteristics. One disadvantage is the need for a very careful monitoring, particularly when the distributor has the possibility of establishing cross subsidies among customers as an aid in its retailing activities.

In any sound regulation, an important ingredient of the mechanism of retribution must be the existence of economic incentives associated to required levels of ohmic losses and quality of service. In both cases the regulator must establish target levels, which in general will depend on the characteristics of the specific area, such as load dispersion, contracted capacity or environmental conditions. These target levels must be also used, when this is the case, in the models or methods that are used to determine the basic remuneration of the network.

Ohmic losses are not a cost of a distribution utility, who only incurs into investment, operation and maintenance costs, that do not depend on the network losses. However, a sound regulation must make the distributor feel that the cost of network losses is its cost too. The distribution network user should also receive an economic signal about the ohmic losses that are incurred in the system because of its position in the network and its consumption pattern. The regulator may achieve all this by setting realistic standard levels of losses for each network user, which will depend on its location (voltage and situation of the connection point) and load pattern. A consumer will have to pay for the demanded energy plus the corresponding standard losses. An embedded generator will have to pay (or to be credited) for the incurred increase (reduction) in losses. The distributor will be charged (or will receive a credit), at the wholesale energy price, for the difference between the energy that is actually retrieved from the transmission network and the energy that results from application of standard losses to all the load and generation that is connected to its network. The target levels for losses will also be updated every 5 years approximately, so that improvements in loss reduction are also partly transferred to the network users.

The quality of the service that is provided by a distribution network has a very strong dependence on the volume of investment in that network. Therefore, economic incentives (penalties and maybe also credits) must be associated with the relation between the target levels set by the regulator and the actual levels that are attained by the distribution network. This is a complex regulatory issue that will be examined in more detail in section 5 of this paper.

3. – PRICING ISSUES

Pricing of distribution services consists of allocating the already determined global remuneration of the distribution activity to the final users of the network, according to their contribution to this cost. These charges are a component of the regulated tariff for non-qualified consumers and also a part, -transmission is the other-, of the network access tariff for qualified consumers who buy from the power exchange or from any supplier of their choice.

This concept of the added value of the distribution service is behind any sound approach to distribution pricing. In order to send correct economic signals to the end consumers, distribution charges should be based on some type of marginal or incremental costs. Contrary to what happens at transmission level, see [Pérez-Arriaga et al., 1995], strict marginal pricing of distribution networks may provide sufficient income to cover the complete cost, therefore not requiring any complementary mechanism. Two approaches may be mentioned here who roughly satisfy the stated requirements of efficiency in sending the economic signals and sufficiency in recovering the network costs.

A. The average incremental cost method (see section 2) provides at the same time the global network remuneration and the distribution charges for each zone and each voltage level.

B. Sound distribution tariffs can also be obtained when the total network cost can be split into the partial costs corresponding to the different voltage levels. This is for instance the case of the total replacement network model (see section 2). A possible approach may be as follows:
   - Every end consumer must only pay for the costs of the distribution network at its connection level and upstream.
   - The charge ($/MW) should be primarily based on the coincidental peak demand of each consumer. For smaller consumers this should be estimated from monthly energy consumption, the amount of contracted capacity (MW) and an estimated load profile.
   - Other load levels also have an impact, albeit a minor one, on network development costs. This fact, together with the use of individual energy consumptions in the estimation of the coincidental peaks, provides the justification for the use of an energy term in the distribution charge.

A third approach, which is being used in Finland for instance, consists of letting the distribution utilities

themselves to set the network charges, which are permanently under surveillance of the regulator. Among other things, the regulator must make sure that there is no hidden cross-subsidization from the regulated distribution to free commercial activities (e.g. shifting distribution network charges from qualified to captive consumers with the purpose of promoting commercial contracts with the former ones).
Ohmic losses must be taken into account in these studies in two different forms. In the calculation of distribution network charges, each consumer demand must be affected by its corresponding loss factor, so that its MW contribution to upstream voltage levels is correctly accounted for. When charging each consumer for its energy consumption, the energy value must be affected by the corresponding loss factor, resulting in the actual amount that has to be paid at energy market price.
Special cases of utilization of distribution networks require ad hoc criteria in order to establish the corresponding distribution charges. This is the case of embedded generation, transits across distribution networks or supplies with specific quality of service requirements.

4. – ACCESS ISSUES.

Regulation of distribution access mostly concerns establishing the rules to solve the many types of conflicts that may arise among the agents of the system concerning the use of distribution facilities. Regulation in a competitive environment must make sure that non-discriminatory access is truly granted to all system agents and that there is no abuse of the monopolistic power that ownership of distribution networks may provide. Another aspect of interest is the regulation concerning the construction and charges for the specific facilities that are needed to connect new customers to the existing distribution network.

Access rights: Open access to distribution networks, such as it is established in the European Directive on the Internal Electricity Market, requires that all distribution networks must provide network services to any requesting party. A cost reflective fee will be charged for the service. System agents that may request distribution services are: embedded end consumers, embedded distribution utilities, embedded generation and any other agents whose transactions result in a transit through the considered distribution network.
Different types of conflicts may arise in relation with access to distribution networks. For instance, potential cases are: a) Abuse of dominant position by a large distributor with respect to embedded smaller distributors; b) Lack of definition of territorial franchises, therefore resulting in possible duplication of networks at the bordering regions between well-established utilities; c) Subsidies in the tariffs corresponding to specific voltage levels or consumer types; this may create the possibility of opportunistic behavior by existing or new distribution companies who may try to exploit excessive commercial margins between regulated tariffs.
The regulator must be empowered with the capability of solving these conflicts. Reasonable criteria for conflict resolution must, under all circumstances, try to prevent the abuse of market dominant positions and to create a level playing field for all involved agents.
Lack of sufficient network capacity is not a valid permanent excuse for denial of distribution network access, since obligation of supply is the primary duty of a regulated network utility. Obviously, the universal right to connection and access does not imply that the economic implications of any special requests should be born by those who incur into them.
Access rights (and the corresponding distribution charges) should not be affected by any possible change of retailer by end consumers. As already mentioned, strict transparency in network charges and accounting unbundling (at least) must be required in order to prevent discrimination and internal subsidies, whereby competitive retailing activities may be helped by regulated distribution network activities.

Connection charges: Whenever a new user is connected to the distribution network, or an existing user requests an augmentation of its contracted maximum capacity, specific connection costs are incurred, which must be paid by the network user. The dilemma is whether the charge should be individualized or not for each network user.
An individualized payment has the advantage of sending an economic signal that responds to the basic characteristics of the requested connection, namely, capacity, location of the load with respect to the network and network congestion level. User-specific connection charges will act as a restraint to many otherwise unreasonable connection requests. In this way a trade-off is created between the universal right to connection and the economic implications of special requests.
In order to avoid unnecessary and irrelevant distinctions among the majority of the connection requests, a pragmatic solution consists of charging a uniform connection charge to all new connection requests and an individualized extra charge only for those special requests that incur in costs above those covered by the common charge.
There is no reason why the physical construction of connections should be a monopoly of the incumbent distribution company. The regulator may establish maximum per unit tariffs for all the cost elements, so that the maximum regulated cost of any connection could be easily determined. Then the user may request tenders from the incumbent distribution utility (who cannot bid above the maximum allowed amount) and from any other firm. All connections will have to comply with minimum design and operational specifications.
The economic signals, resulting from a correct allocation of distribution network charges according to the different voltage levels (see section 3), may give rise to economic incentives for the connection of end consumers to voltage levels higher than their present level. These connection changes may be undesirable for reliability or other technical reasons. Specific connection access rules, besides the individualized connection charges, are therefore also needed.

5. – QUALITY OF SERVICE ISSUES.

Quality of service requires particular attention because it is directly perceived by consumers, who are showing a growing sensitivity on this issue. Quality of service is directly associated with distribution costs. This is why the regulator, while determining the global remuneration of the distribution activity, should also take into account the quality of service.

A perfect quality of service entails an infinitely large cost of service. Hence, as already indicated in section 2, the regulator must find the way of promoting that the optimal balance in the trade-off between price and quality may be achieved. An approximation to this optimal situation may be obtained if the regulator establishes adequate minimum quality of service requirements and maximum network tariffs, so that the remuneration of the distribution utilities is sufficient to provide the required level of quality of service.

Lack of compliance with these minimum quality of service requirements should result in economic compensations for the affected consumers. Some credits might also be awarded to those distributors with better than requested performance.

An objective evaluation of quality of service requires of quantitative indicators for each one of the relevant aspects: a) continuity of supply, which depends on the frequency and duration of the interruptions of supply; b) the different types of distortions that may happen in the voltage waveform; c) the attention to the client, comprising information, advise, contractual procedures and terms of contract, communication and complaints. Minimum quality of service requirements must be expressed as threshold values for these indicators, both at individual, zonal or network-wide levels.

Consumers with a quality of actual service below the established individual thresholds should be entitled to perceive prescribed economic compensations. Zonal thresholds should reflect an adequate balance between cost and quality, when considering the specific characteristics of each zone. These zonal thresholds permit establishing well-founded comparisons among the distribution utilities, based on their actual values of quality of service.

Establishing quality of service thresholds is a difficult task. In this regard, it is of much help to know the quantitative indicators of the actual quality of service that is currently provided by each distribution utility. Much effort should be devoted to develop homogeneous and easy to audit procedures to obtain these data.

The size of the economic penalties may only try to create an incentive for the distribution utility or, alternatively, may be designed to accurately reflect the economic impact that the service deficiency has had on the customer. Legal procedures may be avoided or reduced if the second option is chosen. Penalties should not be applied to deficiencies of supply that are incurred by scheduled maintenance activities, in order not to discourage them, which would be detrimental for quality of service in the long run.

6. – OTHER REGULATORY ISSUES.

This section presents brief comments on assorted regulatory issues, of relevance for the distribution activity, but which have not been covered so far in this paper:

Metering: Metering of electricity can be unbundled both from the distribution and the retailing activities. With an adequate regulatory treatment, the metering activity may be deregulated and performed under normal market conditions. The most significant technical issues have apparently been satisfactorily solved, although a high level of expertise may be required in metering for the large consumer segment. This should be considered by any prospective retailers. Cost does not seem to be a deterrent when reasonable simplifications, -regarding the accuracy of the measure-, are adopted for each consumer type. It is to be expected that, with time, metering will become a deregulated activity and its remuneration will be determined by market forces.

Multiutilities: There is a worldwide trend among utilities in different sectors to open new business lines in order to capture the economies of scale and synergies that are derived from offering multiple services to the same consumers. Typically, these services may include electricity, gas, water and telecommunications. Among the reasons for this trend one must consider the reduction in commercial margins of electricity retailers because of the introduction of competition, improvements in the technical capabilities of metering devices and the existence of cash-flow surpluses that cannot be easily reinvested in the electricity sector. From a regulatory perspective there are no grounds to disapprove this trend. However, care should be exercised to unbundle these commercial activities as much as possible from any regulated activity.

The single tariff principle: There is something paradoxical in giving the option to choose supplier to all consumers within an open market approach, while at the same time maintaining the single tariff principle. In the end every consumer would have a different tariff, except for the distribution component (the transmission component and other regulated charges might be also chosen to be equal for all consumers of a given type), which would be the same for every consumer. The time may be ripe to realize that the single tariff principle corresponds to an ill-conceived and economically inefficient implementation of the idea of solidarity among regions. Those countries that can be considered to be pioneers in the world in power sector restructuring have since long realized the incompatibility between cost reflective tariffs and the single tariff principle, and they have opted for the former solution.

Conceptually, however, implementation of the single distribution tariff is a simple problem. It is assumed that the regulator is able to compute the correct remuneration corresponding to each distribution utility according to the principles that were presented in section 2. The difference

between this correct remuneration for any distribution utility and the amount collected by the same distribution utility from the end customers and other network users as remuneration under the single tariff scheme, determines the volume of compensation payments that have to be made between the distribution utilities. After these compensation payments have been made, each distributor must receive a net amount that exactly corresponds to its correct regulated remuneration.

Settlement issues concerning embedded generation: For a number of years, all studies concerning generation that is embedded in distribution networks have focused on the potential technical impacts, such as short-circuit network capacities, power oscillations that might be induced by wind generators, or the implications on the design of protection schemes of the impredictibility of power flow patterns. A new topic that arises from the existence of wholesale competitive markets is the need to know, with the strict level of accuracy that is required by the settlement of economic transactions, the energy and losses contribution by each embedded generator. The task is made difficult by the nonlinearity of ohmic losses with respect to the volume of power flows. This is still a challenging topic involving metering, data handling, computer models of the network and adequate regulation.

Non-ohmic losses: Theft of electric energy is an issue of utmost importance in some countries. Regulation tends to ignore this problem, since acknowledgment of its existence may imply the acceptance of its inevitability. However, there are serious social situations that require the adoption of some measures. Some countries have opted for segmenting the territory and the consumer types, so that supposedly better off consumers subsidize the least affluent ones. Some other countries, where subsidies through electricity charges are not allowed, have chosen to make use of direct subsidies for the worse off consumers. In all cases, the distribution companies should receive clear economic incentives to reduce as much as possible these non-ohmic losses.

Distribution network operator: The Directive of the European Union on the Internal Electricity Market acknowledges the natural monopoly characteristic of distribution networks, while on the other hand opens a wide range of possibilities for commercializing electricity, both at wholesale and retail levels. The Directive establishes the concept of distribution network operator, as the entity who is responsible for distribution network development and first-instance conflict resolution regarding network access, among other matters. In most, but not all, European countries a license has to be granted by the government or the regulator as a pre-requisite to be allowed to perform the distribution activity. Distribution network operators should coincide with these licensees or, where no licenses are granted, with distribution network owners. Otherwise, there is ample room for the appearance of conflicts of interest and opportunities of abuse of dominant position.

Authorizations and other administrative procedures: Even where distribution licenses do not exist, distribution utilities must always fulfill a number of administrative requirements, since distribution is a regulated activity. Authorization procedures must take into account the diversity of regulatory issues that might have to be addressed: remuneration of the distribution network activity, as well as metering or commercial activities for consumers under regulated tariffs; declaration of public utility for the distribution facilities, which may reduce the possibility of conflicts between distributors and land owners; determination of compensation payments for the use of the land; procedures for dismantling old installations; obligations regarding underground versus overhead construction, depending on the legal qualification of the terrain.

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