



Regulatory Challenges for Energy Infrastructure—Do Electricity Distribution Remuneration Schemes in Europe Promote the Use of Flexibility from Connected Users?

Miguel A. Ruiz¹ · Tomás Gómez¹ · José P. Chaves¹ · Rafael Cossent¹

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Abstract

Purpose of Review The electricity grid is facing important challenges in operation and planning due to the increase in intermittent renewable generation and the penetration of distributed energy resources. This article reviews the remuneration schemes of distribution system operators for fostering flexibility procurement in a representative sample of six selected European countries.

Recent Findings Regulatory agencies should incentivize distribution system operators to properly deal with the growing uncertainty and take advantage of flexible resources connected to their grids to minimize the impact on electricity bills that upcoming challenges may have.

Summary Most of the reviewed regulatory frameworks still need to evolve towards removing barriers to flexibility services. The necessary steps in the evolution of remuneration schemes for distribution system operators include (i) promoting non-biased cost-efficiency, capital expenditures vs operational expenditures, and (ii) the possibility of flexible planning to deal with uncertainty.

Keywords Power distribution · Distribution system operator · Network regulation · Grid planning · Flexibility services

Introduction

The increase in renewable generation and electrification of energy sectors such as heating and cooling, transport, and industrial processes could require massive investment in electricity networks. Efficiently developed flexibility mechanisms can partially reduce this investment need. Under this context, remuneration schemes of distribution system operators (DSOs) in most European countries should evolve and incentivize cost-efficiency, taking advantage of flexibility services; otherwise, the cost for bill payers during the energy transition may inappropriately increase more than needed.

Electricity distribution is a regulated monopoly; therefore, it requires regulation and definition of DSO remuneration schemes. The European Electricity Market Directive 944/2019 recognizes the need for DSO

remuneration schemes to evolve. This directive highlights the need to incentivize the procurement of flexibility services to delay network reinforcement when cost-efficient. Flexibility is defined as “*the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system*” [1]. Additionally, DSOs must submit network development plans to the regulatory agency every 2 years, covering the investment needs for the next 5–10 years. The requirement of updating the network development plans with a 2-year frequency is a measure to deal with the high uncertainty faced by DSOs due to the unknown uptake pace of new technologies and users’ requirements.

In order to assess how to foster flexibility procurement by DSOs, this article reviews the current DSO remuneration schemes in six European countries (i.e., France, Italy, Portugal, Spain, Sweden, and the UK). These countries were selected in the BeFlexible project [2] and are a good representation of the different DSOs’ remuneration schemes in Europe. France, Italy, Spain, and Sweden are subjects for this study, as they are relevant countries in the European

✉ Miguel A. Ruiz
maruiz@comillas.edu

¹ Instituto de Investigación Tecnológica, Universidad Pontificia Comillas, Madrid, Spain

context and they present different characteristics regarding the network, the climate, remuneration schemes, etc. The UK was also included because it has one of Europe's most advanced regulatory frameworks for procuring flexibility. Moreover, Portugal was considered to study one additional approach referred as TOTEX apart from the UK.

There are some key characteristics for a remuneration scheme to incentivize flexibility procurement as an alternative to grid reinforcement:

- First, it should incentivize long-term cost-efficiency. Otherwise, a remuneration scheme may result in unnecessary costs by not encouraging the selection of the most cost-efficient of the identified alternatives to solve potential grid capacity limitations. This is increasingly important as the inclusion of flexibility increments the number of alternatives in distribution network planning.
- Second, it should be a non-biased remuneration scheme. Traditional regulatory frameworks tend to be CAPEX-biased. Since flexibility procurement is an OPEX, these frameworks would discourage the procurement of flexibility over conventional network reinforcement.
- Third, the regulatory framework should consider an approach to deal with uncertainty. The DSOs face increasing uncertainty about the penetration of distributed energy resources (e.g., renewable generation and new loads due to increasing electrification). These uncertainties may lead to over-conservative plans and unnecessary costs if the national regulatory agencies require traditional deterministic plans from DSOs.

Additionally, any remuneration scheme focusing only on cost-efficiency may result in quality of service deterioration [3••]. Therefore, quality incentives should be included. Innovation incentives may also be desirable to foster innovative flexibility procurement approaches.

This article highlights the importance of these three topics based on current research and analyzes the status of the six European countries regarding these three aspects of DSO remuneration. The first two topics are discussed together as they are both closely related to the formulation of the DSO regulated allowed revenue.

Incentivizing DSOs to Non-biased Cost Efficiency Solutions

The distribution network is considered a natural monopoly, and as such, it should be regulated to prevent excessive prices for consumers. Thus, regulation must encourage the monopoly company (DSO) to seek and pursue cost efficiencies in its business.

The regulatory approaches to define the company's allowed revenues can be conceptually classified into two categories

[3••]. First, in the cost-of-service regulation, the DSO's actual costs are covered with a reasonable rate of return applied to capital expenditures. This ex-post approach does not encourage the pursuit of cost efficiencies by the DSO. Second, in the multi-year revenue trajectory, the regulator defines the company allowed revenues ex-ante. Since the revenues are fixed, the DSO's earnings will depend on its actual costs during the period; lower-than-expected actual costs will lead to higher earnings for the DSO and vice versa. Therefore, the second approach encourages the DSO to pursue cost efficiency.

Combining the first and second approaches would result in a multi-year revenue trajectory with a profit-sharing mechanism [4••]. The profit-sharing mechanism is an ex-post adjustment for the DSO's revenues. This mechanism defines the final allowed revenue as a weighted average between the ex-ante trajectory (second approach) and the actual costs (first approach). The weight given to the ex-ante revenue trajectory is known as the incentive rate. A 100% incentive rate would result in a pure ex-ante multi-year revenue trajectory. On the contrary, a 0% incentive rate would result in a pure cost-of-service regulation. This third approach, the multi-year revenue trajectory with a profit-sharing mechanism, allows the regulator to share the DSO's actual cost savings with consumers while incentivizing DSO to achieve cost efficiencies. This third approach, while encouraging cost-efficiency, may still retain a bias depending on what expenditures are to be included in the regulatory asset base (RAB), discussed in the following paragraph.

Flexibility services may represent an opportunity for cost-efficiency in distribution network as they allow the DSO to not commit to irreversible investment while at the same time avoiding the risk of service interruptions. However, traditional regulatory approaches tend to be CAPEX-biased, aiming to cover operational expenditures of the regulated firm and remunerate capital expenditures with an attractive rate of return, which may represent a barrier to the procurement of flexibility. This barrier has already been noticed by several researchers and some regulatory agencies [3••, 5–9]. Incentivizing cost-efficiency in the context of increasing penetration of distributed energy resources will require a non-biased regulation. Still, most European regulatory frameworks maintain the traditional CAPEX bias [10]. This traditional incentive to increase CAPEX can shift to reduce CAPEX instead if the regulator puts an unattractive rate of return in place. However, this shift is not desirable as the quality of supply may deteriorate. Moreover, it contradicts one principle of regulation: "provide a reasonable return on capital and attract new resources of funding to finance any new facilities needed to cope with demand growth" [11]. The UK overcame this CAPEX bias with a TOTEX approach, where a fixed portion of the total expenditures is capitalized and remunerated with an attractive rate of return.

Table 1 shows the main characteristics of current DSO remuneration schemes in the European countries selected for this study. Next, we describe these incentives for each country.

Table 1 Allowed revenue under DSO remuneration schemes in the selected European countries

Country	Allowed revenues for DSOs
France	OPEX: ex-ante allowance with 100% incentive rate CAPEX: cost-of-service, incentive to reduce unit investment price
Italy	OPEX: ex-ante allowance with 100% incentive rate + mechanism to capture previous efficiencies CAPEX: cost-of-service
Portugal	OPEX: ex-ante allowance with 100% incentive rate + mechanism to capture previous efficiencies CAPEX: ex-ante allowance with 100% incentive rate for new investments + rate of return ex-post assessment with profit sharing
Spain	OPEX: ex-post allowance based on standard costs CAPEX: cost-of-service + incentive to control unit investment price + investment limit
Sweden	OPEX: ex-ante allowance with 50% profit sharing on controllable OPEX CAPEX: leaning towards cost-of-service regulation
The UK	TOTEX: ex-ante allowance + profit sharing

France has an ex-ante allowance for operational expenditures (OPEX) with a 100% incentive rate. The allowed amount is defined by the regulator based on the DSO proposal and an external audit [12]. French regulation applies a cost-of-service approach for capital expenditures (CAPEX) where the allowed revenue covers commissioned network investments [12]. There is an incentive to reduce the unit price of investments in comparison to a reference unit cost model. If the total investment amount results lower than the sum of asset prices based on the reference model, the incentive rewards the DSO with 20% of the difference. This incentive is symmetric. If the total investment amount results higher than the model, a 20% penalty on the difference applies. The reward/penalty is capped at $\pm 30M$ /year. In conclusion, the cost-efficiency incentives in the French regulation encourage DSO to reduce OPEX and to control the unit investment price on CAPEX but does not encourage to reduce the total amount of CAPEX, assuming that the DSO considers the rate of return for CAPEX attractive.

Italy has an ex-ante allowance for OPEX with a 100% incentive rate and a mechanism to capture previously achieved efficiencies [13]. Each period's ex-ante OPEX allowance is calculated as a weighted average of actual OPEX and allowed OPEX from previous periods. Therefore, an actual OPEX resulting below the ex-ante OPEX allowance will result in a lower OPEX allowance for the following periods. This calculation considers multiple periods. On the other hand, capital expenditures (CAPEX) are covered with a cost-of-service approach. Therefore, the Italian regulation incentivizes the DSO to reduce OPEX and does not incentivize CAPEX reduction, if the remuneration rate is attractive for the DSO to invest in infrastructure.

Portugal has a regulatory approach referred as TOTEX, yet there are different incentives for CAPEX and OPEX, and only CAPEX are included in the regulatory asset base (RAB). Thus, this approach maintains a different treatment for CAPEX and OPEX and may not be considered as a full

TOTEX approach. There is an ex-ante allowance for OPEX with a 100% incentive rate, and similar to the Italian regulation, it has a mechanism to capture previously achieved efficiencies. Efficiencies achieved in previous periods are considered for the calculation of each period ex-ante OPEX allowance. Each period ex-ante allowance is calculated as a weighted average between actual OPEX (80% weight) and allowed OPEX (20% weight) from the previous, most recent, two audited years. This mechanism aims to capture 80% of the achieved efficiencies on OPEX from the previous period. Regarding CAPEX, there is a revenue cap for new investments. When the regulator approves the investment plan, an ex-ante revenue cap for new investments during the regulatory period is defined, and a 100% incentive rate applies. Then, assets commissioned during the regulatory period are included in the consolidated regulatory asset base (RAB) at the end of the regulatory period, thus, no longer affected by the revenue cap. There is a rate of return ex-post adjustment at the end of the regulatory period to share achieved efficiencies with the customers if the actual rate of return results higher than the predefined value. On the contrary, if the actual rate of return results lower than predefined, then this adjustment protects the company against low returns. As a result, the Portuguese regulation encourages DSO to reduce OPEX and CAPEX but with different incentives. Still, only CAPEX are included in the RAB. Therefore, a bias towards CAPEX/OPEX may appear if the rate of return applied to CAPEX is higher/lower than the DSO's cost of capital.

Spain has an ex-post allowance for OPEX and CAPEX. The allowed revenues for year n cover the expenditures of year $n - 2$. The calculation of OPEX uses previously defined standard costs (e.g., operation and maintenance costs increase with network investments). Regarding CAPEX, there is a cost-of-service regulation where commissioned assets are included in the RAB with the 2-year delay mentioned above. The Spanish regulation has an incentive to reduce the unit price of investments. There is a list of standard investment prices, and

an incentive mechanism applies after comparison with this list. Investment are included in the RAB at their actual cost if the sum of actual investment cost fall within a range of +5% and –10% of the sum of standard costs. A penalty/reward to the value of investment included in the RAB applies if the sum of actual costs results above/below the sum of standard costs by +5%/–10% [14]. In addition, there is a limit for the total amount of investment in each semi-period (3 years) [14], defined as 0.13% of GDP (divided between the different DSOs). There is also a penalty for surpassing the total investment limit. In conclusion, the cost-efficiency incentives in the Spanish regulation encourage DSOs to reduce OPEX and to control the unit investment price on CAPEX, while maintaining the total amount of investment per year at the investment limit, assuming the rate of return is attractive.

Sweden has an ex-ante allowed revenue for controllable OPEX (the regulator distinguishes between controllable OPEX that are subject to an efficiency requirement as the DSO is considered to be able to make an effort to reduce them, and non-controllable OPEX that are fully covered [15]) with a 50% profit-sharing mechanism. This ex-ante allowance is based on the most recent available historic costs [16]. Non-controllable OPEX (e.g., energy losses, agency fees) are fully covered. Regarding CAPEX, the ex-ante allowed revenue calculation uses a list of standard investment prices and the DSO investment plan. The regulator sets the list of standard investment prices based on an external audit and considers the feedback from the DSOs [16]. The ex-ante CAPEX allowance is adjusted ex-post up or down to reflect the real amount [16, 17]. With this ex-post adjustment, the Swedish DSO remuneration scheme is leaning towards a cost-of-service approach for CAPEX. In summary, the Swedish regulation encourages DSOs to reduce controllable OPEX and the incentives to reduce CAPEX may be limited.

The UK has a multi-year revenue trajectory with profit sharing for the total expenditure (TOTEX). Ofgem, the regulatory agency, sets the ex-ante revenue trajectory after evaluating the DSOs' business plans. Business plans shall be based on conservative low-growth-demand scenario. Ofgem conducts a cross-DSO benchmarking to assess cost-efficiency [18]. After evaluating their business plans, Ofgem fixes the capitalization rate and the incentive power ex-ante for each DSO. This capitalization rate is the percentage of the total expenditure that is included in the RAB and recovered as slow money. The portion that is not capitalized is recovered as fast money [19]. The incentive power is based on Ofgem's confidence in the DSO business plan. This incentive is limited to a 50% maximum [20]. The UK regulation includes an uncertainty mechanism named load-related expenditures [18] to increase allowed revenue beyond the baseline if the need for additional investment materializes. As mentioned before, the allowed revenue baseline is based on a low-growth-demand scenario. However, the business plans should include the

consequences of different scenarios in the foreseen investments. Then, additional revenue allowances are recognized if demand grows to a point where additional investments were planned. In conclusion, the UK regulatory framework encourages DSOs to reduce total expenditures where the bias between CAPEX and OPEX is mostly reduced since the capitalization rate is fixed ex-ante. The fact that this capitalization rate is affected by DSOs' business plans may incentivize them to increase CAPEX in their plans. At the same time, this may be reasonable since fixing a capitalization rate without considering the business plan could put the financial situation of DSOs at risk.

Any regulatory approach encouraging the DSO to pursue cost-efficiency should include quality of supply incentives; otherwise, it may incentivize the DSO to pursue excessive cost reduction while increasing service interruptions. This is not mentioned in the above regulation review as all the countries include this type of incentive in their regulation. However, if quality of supply results below the desired levels, the relationship between the quality of supply incentives and the cost-efficiency incentives should not be overlooked.

Uncertainty and Flexibility Services

The DSOs face increasing uncertainties about the penetration of distributed energy resources (DERs) in the upcoming years. Flexibility services are considered especially valuable under this circumstance. They may allow the DSO to maintain high service levels without committing to a costly irreversible investment in a traditional grid reinforcement. However, traditional deterministic network planning, where the decisions are fixed, may undervalue flexibility and result in higher cost for bill payers [21•, 22].

Flexible plans where future investment decisions are contingent on unfolding information (e.g., invest in a feeder when peak demand reaches 22 MW) may perform better than deterministic plans (e.g., invest in a feeder in year 3) in this context. The European Union regulation enforces the update of network development plans with a bi-annual frequency. This update is a reasonable approach for dealing with uncertainty. However, additional edge for cost-efficiency can be achieved with flexible plans. A real options approach may be suitable for flexible planning in the distribution network [23••]. The UK regulation has uncertainty mechanisms in place, allowing the DSO to receive additional funding only if certain conditions (e.g., demand growth) are met during the regulatory period. The other European regulatory approaches reviewed in this article do not have uncertainty mechanisms. Therefore, these regulatory approaches do not allow the DSO to present flexible plans. Table 2 summarizes some of the requirements for investment plans in the analyzed countries.

It is worth mentioning that regulating in favor of flexible plans is complex and requires additional auditing control from

Table 2 Characteristics of investment plans in the selected European countries

	Frequency	Are flexibility services included in the investment plans?	Deterministic/flexible plans
France	4 years	Not in the investment plan. The flexibility costs are covered by an ex-post adjustment mechanism CRCP [12].	Deterministic
Italy	1 year	No	Deterministic
Portugal	2 years	No	Deterministic
Spain	3 years	No	Deterministic
Sweden	2 years	Yes	Deterministic
UK	2 years	Yes	Flexible

the regulatory agencies, since the allowed revenues depend on the evolution of key variables. It also requires additional expertise to assess the selection of these key variables and supervise their evolution.

Additionally, it may be undesirable to allow flexible planning in regulatory approaches that are not explicitly encouraging cost-efficiency (e.g., cost-of-service approaches vs multi-year revenue trajectories). In a regulated monopoly: “the regulated firm may use its information advantage strategically in the regulatory process to increase its profits or to pursue other managerial goals” [4]. Therefore, the regulatory scrutiny of the firm’s investment plan is more crucial under cost-of-service approaches. As mentioned before, the business plan assessment of a flexible plan is more difficult. Thus, flexible planning increases the traditional information asymmetry over deterministic planning and may increase the potential of firms trying to justify higher costs, specially under cost-of-service approaches.

Conclusion Flexibility services can potentially reduce or delay the need for traditional network reinforcement in the distribution network, reducing network costs. Regulatory frameworks should adapt to achieve these cost efficiencies; different measures need to be taken.

First, some European regulatory frameworks use the cost-of-service approach, which may not correctly incentivize DSOs to choose the most cost-efficient alternatives. A multi-year revenue trajectory approach with a profit-sharing mechanism can potentially incentivize cost efficiency, and at the same time, customers partially benefit from these cost efficiencies.

Second, traditional different treatment of OPEX and CAPEX is still present in most European regulatory approaches. These approaches tend to be CAPEX-biased, which could represent a barrier to the procurement of flexibility services. Therefore, it may be desirable that regulatory frameworks in Europe evolve towards a towards more efficient perspectives that avoid CAPEX-bias and encourages innovative flexible solutions (e.g. the TOTEX approach).

Third, the uncertainty faced by DSOs can lead regulators to include uncertainty mechanisms and allow flexible planning. However, this may only be desirable if non-biased cost-efficiency is previously in place. The interaction between a cost-of-service regulation and uncertainty mechanisms may result in undesirable outcomes.

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