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EXECUTIVE SUMMARY DSO BRIEF

Distributed Generation: Towards a Sustainable Regulatory Model for Electricity Distribution

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DG AND ITS IMPACTS ON DISTRIBUTION SYSTEMS

In Latin America and the Caribbean, the expansion of Distributed Generation (DG) is accelerating at the pace of falling technological costs, growing environmental awareness and the user's willingness to take an active role in their energy management. In addition, its modularity – the ability to grow through small and replicable units, adapting to different user sizes and levels of demand – has made it an accessible, flexible and expansive technology, capable of integration into residential, industrial, or community settings.

This accessibility has democratized energy production, but it is also transforming passive grids into active systems, where small generators, batteries, and inverters interact simultaneously, creating planning, control, and stability challenges. As a source of flexibility, DG makes it possible to manage the variability of renewable generation and electricity demand, smoothing load peaks and alleviating grid congestion thanks to its proximity to consumption. In terms of resilience, DG reinforces the system's response capacity to face failures or contingencies. Finally, DG can contribute to energy equity, by facilitating access to clean and affordable energy for vulnerable sectors and rural communities.

Despite its benefits, DG expansion poses a series of technical, operational and regulatory challenges that redefine the role of distribution companies. The intermittency inherent in renewable sources and the increasing bidirectionality of electrical flows complicate the planning and control of low-voltage networks, where most connections are concentrated. On the technical level, DSOs are already observing significant alterations in voltage profiles, asset congestion and failures in protection systems. DG causes reverse power flows in transformers and feeders, local over-voltages during peak injection hours, and rapid voltage fluctuations associated with solar intermittency, requiring more sophisticated regulators and real-time voltage management. Added to this are overloads in low-voltage conductors and transformers, harmonic increases due to low-quality inverters and growing difficulties in the coordination of protections and safe maintenance operations. These conditions, previously marginal, are becoming recurrent and confirm that distributed generation is not harmless for the grid: its integration implies reinforcement, monitoring and digitalization costs that must be recognized if the security and stability of the electricity system is to be maintained. Added to this is the appearance of undeclared or non-standard installations, which operate without registration or certification and aggravate technical and safety risks, by introducing unsupervised injections and making network planning difficult.

On the economic level, three main impacts arise from the expansion of DG. The first is the reduction of billed energy, as a result of self-consumption and energy compensation schemes, which directly decreases the income available to cover the fixed costs of the network, which remain unchanged. This effect is especially visible in the migration of large customers towards self-generation, which reduces the user base on which infrastructure investments are amortized. The second impact is the increase in unrecognized operating and capital costs, associated with the need to strengthen networks, modernize metering and control, and implement bidirectional management technologies, investments that are not always reflected in the current tariff structures. Finally, the combination of lower revenues and higher costs generates a financial imbalance that puts the sustainability of the distribution business at risk, particularly in those regulatory frameworks that do not yet recognize these new roles and responsibilities. Without an adapted tariff design that clearly differentiates remuneration for the use of the grid from the sale of energy, the expansion of distributed generation may compromise the ability of distribution companies to sustain the quality, security and modernization of the electricity system.

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REGULATORY APPROACHES TO DG INTEGRATION

The regulation is an enabling and protective function with respect to the integration of DG, by establishing conditions for the connection, operation and valuation of these resources, and by ensuring that the modernization of the network advances safely and coherently with the real distribution capacities. The analysis shows that the regulation of DG is structured around six pillars that define its scope and operation. A first component is the segmentation of the DG according to its installed capacity, which allows each category to be assigned technical and administrative requirements according to its magnitude and potential impact. This approach reduces barriers to entry for small installations and enables more rigorous evaluations in larger capacity projects. This step-by-step approach reflects the principle of proportionality: requiring each project to have a level of analysis consistent with its potential impact on the grid. This facilitates the orderly massification of small-scale DG and protects the stability of the system against installations that can significantly impair it.

A second axis is the design of DG economic participation mechanisms and the way in which the surpluses that can be injected into the network are remunerated. The regulation tends to organize these mechanisms into three main categories: the first corresponds to self-consumption-only projects, in which the injection of energy into the grid is prohibited. The second corresponds to projects with the sale of surpluses. Within this scheme, two modalities predominate: net metering, in which the surplus injected is paid in energy credits (kWh) to the user-generator. This model equates the value of the energy injected with that of the energy consumed, which tends to undervalue the use of distribution infrastructure and auxiliary services, and can lead to cross-subsidies from users who do not generate to those who do, since the former end up assuming a greater proportion of the fixed costs of the network. The second is net billing, in which the energy fed into the grid is valued at a lower value than the tariff, reflecting the costs of transportation, backup and management involved in serving the user. In addition to these schemes, larger DG projects usually have the option of participating in the wholesale market or through bilateral contracts, subject to compliance with additional requirements. Finally, the third category corresponds to projects that participate directly in the electricity market, maintaining their DG status, but operating under a scheme similar to that of conventional plants.

A third regulatory axis refers to the technical connection conditions under which DG can be integrated into the grid, and which seek to ensure that each project meets the necessary requirements to guarantee system's safety, quality and reliability; requirements that are adjusted to the scale and potential impact of each installation. The regulation is supported by four main instruments, whose requirements are adapted to the magnitude and impact of each project. The connection procedure administratively orders the entry of new facilities, defining stages, deadlines and verifications. Electrical studies allow the distribution company to evaluate the technical feasibility of each project; on the small scale they are replaced by hosting limits or simplified criteria, while on the medium and large scale they require load flow, short circuit, voltage and protection modelling, which can condition the connection to grid reinforcements. The connection contract formalizes the operational and commercial relationship between the generator and the DSO, specifying the responsibilities and costs associated with metering, reinforcements, maintenance and eventual disconnection. Finally, protection and measurement systems ensure the safe and transparent operation of the installation. On the small scale, certified inverters with anti-island functions and basic bi-directional meters are usually sufficient, while on the larger scale, tight protections, remote control and monitoring systems are required.

The fourth axis refers to the administrative, technical, operational and supervisory responsibilities of the distribution companies. On the administrative level, they must manage connection requests, maintain up-to-date records of generators and publish information, such as maps of available capacity or lists of approved equipment. In the technical-operational field, they are responsible for evaluating the feasibility of each project, verifying regulatory compliance, inspecting facilities and, when necessary, limiting or disconnecting generators that compromise the security of the grid. In terms of commissioning and operation, they must coordinate switching operations, validate tests and ensure that the facilities meet the standards to allow the safe injection of energy. In terms of metering and settlement, they assume the installation, operation and maintenance of bidirectional metering systems, as well as the processing and valorization of data for billing. Finally, in the regulatory supervision level, they are responsible for enforcing DG standards, reporting to the regulator on the connected capacity and its performance, carrying out inspections to verify that the facilities maintain the approved conditions and, in case of serious anomalies, suspending the injection of the generator until the faults are corrected.

The fifth regulatory axis refers to connection restrictions, which delimit the conditions under which distribution companies can accept, condition or postpone the incorporation of new DG. In practice, these limitations respond to three main areas. The technical restrictions are intended to ensure that every connection is compatible with the network, maintains the technical parameters of the system and does not introduce distortions or instabilities. Operational safety restrictions are aimed at safeguarding the physical integrity of the network, personnel and users, preventing situations such as unintentional islands or dangerous feedback. Finally, the constraints associated with network capacity prevent infrastructure saturation, relying more and more on hosting capacity methodologies. This approach allows distribution companies to authorise, condition or defer connections based on objective criteria, and promotes transparency through the publication of capacity maps or equivalent indicators.

The sixth axis refers to mechanisms for allocating and recovering costs associated with the integration of DG. To address this issue, regulators typically apply three complementary approaches. The first is the direct allocation of costs to the generator, in accordance with the principle of causality: each project must finance the works, equipment or adaptations that its connection requires. The second approach addresses the systemic or shared costs that arise when DG expansion forces infrastructure modernization, monitoring platforms, automation, or network reinforcements; these expenses, not being attributable to a project, are recognized through fees or through charges for network use or backup services. Finally, some frameworks incorporate impact allocation mechanisms, which adjust compensation according to the effect that each project has on the network, rewarding those who reduce losses or alleviate the burden on the system and requiring a contribution from those who increase it.

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REGIONAL OVERVIEW OF DG

DG has gone from being an incipient option to becoming one of the main growth vectors of the regional electricity sector. In 2024, the installed capacity in the nine countries represented in ADELAT exceeds 39 GW. Brazil accounts for about 85% of the regional total, followed by Chile, Colombia and Costa Rica.

Regulatory parameters of the distributed generation regime in selected countries in Latin America (2024)

Country	Installed DG Capacity (2024)	% Total	Regulatory framework (year)	Upper power threshold	Predominant surplus remuneration scheme
Argentina	59 MW	0.1%	Law 27424 (2017)	12 MW	Net billing
Brazil	35,600 MW	15%	Law 14300 (2022)	5 MW	Net metering
Chile	4,300 MW	12%	Law 20571 (2012, amended in 2018)	9 MW*	Net billing
Colombia	487 MW	2%	CREG 030 (2018) and CREG 174 (2021)	5 MW*	Net billing
Costa Rica	100 MW	3%	DG ARESEP Regulation (2019–2022)	5 MW	Net billing
Ecuador	60 MW	1%	ARCONEL 005 (2024) and Connection Code (2024)	10 MW*	Net metering
El Salvador	340 MW	12%	UPR SIGET Regulations (2017)	Not defined	Net billing
Guatemala	210 MW	6 %	NTGDR (2014)	5 MW	Net metering
Peru	N/A	N/A	Law No. 28.832 (2006)	To be defined	To be defined

* In these countries, there are segments within the DG regime that, although they do not have access to regulated tariffs (net billing or net metering), are still legally recognized as DG and participate in the wholesale market or through bilateral contracts.

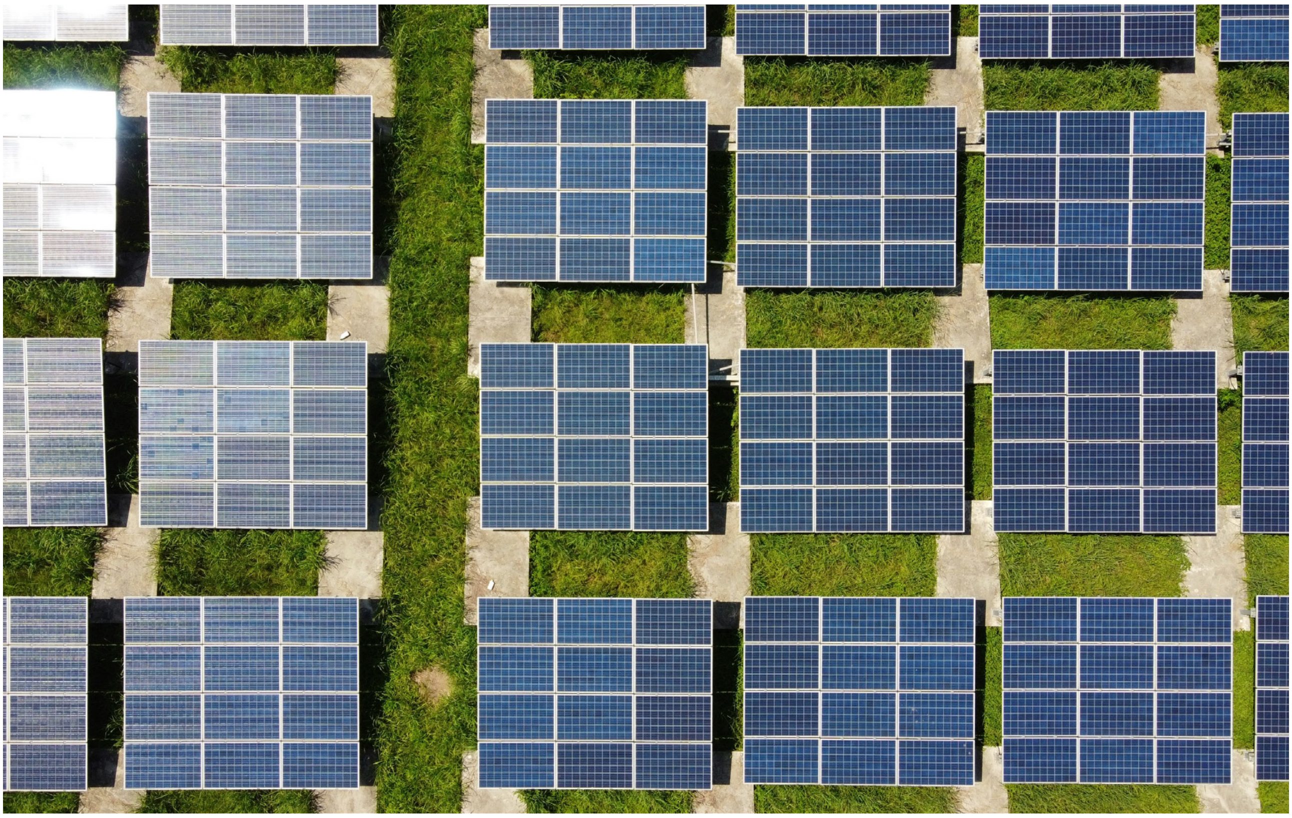
Companies operating with consolidated regulatory frameworks tend to register higher levels of DG penetration, while in other concessions the deployment remains incipient or focused on specific segments of users. In Brazil and Chile, regulatory frameworks combine open access mechanisms with prior technical evaluation schemes, establishing detailed interconnection standards, mandatory equipment standards and formal procedures that ensure electrical compatibility before authorizing any connection. A second group, made up of Colombia, Ecuador, Argentina and Costa Rica, presents frameworks that have incorporated technical, administrative and commercial elements to facilitate the integration of DG. In Colombia, regulation has strengthened the traceability of processes through unified portals and protection agreements. In Ecuador, feasibility and certification procedures have been introduced that seek to improve technical coordination between distribution companies and system operator. Argentina has prioritized the opening and protection of the user-generator through standardized contracts and national regulations, while Costa Rica maintains demanding quality and safety standards along with growing technical coordination between operators and distribution companies. Finally, Guatemala, El Salvador and Peru have adopted frameworks that prioritize the openness and simplification of connection procedures, with the aim of facilitating the incorporation of DG.

In Latin America, segmentation by power scale allows technical, administrative, and economic requirements to be adjusted according to the size and potential impact of each project. While most countries differentiate between micro, small, medium, and large-scale to graduate technical and administrative requirements, some frameworks opt for more centralized schemes. In microgeneration, Latin American frameworks privilege administrative simplicity, but under conditions of technical verification, reflecting a regional consensus around the need for simple, verifiable rules proportionate to the technical risk of minor installations. In medium-scale DG, Latin American frameworks differ in the degree of formality and depth of the studies required, reflecting different visions on the impact of these projects on the network. Some countries maintain procedures similar to microgeneration, prioritizing administrative agility, but with basic technical controls. Other regulations, more aware of the systemic impact of this scale, move towards schemes where the feasibility of connection depends explicitly on grid capacity and electrical compatibility of the coupling point. In large-scale DG, Latin American frameworks apply different models of technical and economic control that reflect their systemic impact and the need for coordination with the system operator. A first approach is operational integration, in which the generator must comply with national grid codes, and a second model is technical-economic conditioning, which makes the connection conditional on grid capacity and assigns the generator the costs of the necessary reinforcements.

According to the degree of interaction with the grid and the way in which the energy generated is valued, Latin American regulation distinguishes three levels of integration of DG: pure self-consumption, which operates without commercial exchange with the distribution company; regulated remuneration schemes, which allow the controlled sale of surpluses at prices set by the authority; and participation in the electricity market, reserved for larger-scale projects that can trade energy directly in the wholesale market or through bilateral contracts.

As for the schemes that allow the injection of surpluses into the grid, net metering and net billing mechanisms predominate. The net metering scheme exists in Ecuador and Guatemala, with differences mainly in the terms and conditions for the use of energy credits accumulated by surpluses injected into the grid. Net billing is applied in Argentina, Brazil, Chile, Colombia and Costa Rica, with regulatory differences that are mainly concentrated in the method and value of the remuneration applied to surpluses.

Although most Latin American frameworks enshrine the principle of open access to the network, this right coexists with the need for distribution companies to have clear powers to condition or limit new connections when there are well-founded risks to security or quality of service. The technical restrictions imposed by distribution companies vary according to the regulatory framework. Regarding operational safety restrictions, DSOs have specific powers to prevent risks and safeguard the integrity of the grid during the operation of DG. In terms of constraints associated with network capacity, Latin American frameworks apply two complementary approaches. The first is based on predefined thresholds, such as the 50% limit of the nominal circuit capacity in Colombia, which acts as a preventive quantitative control. The second, more dynamic, delegates to the distribution company the power to calculate the effective reception capacity and condition the connection when the admissible technical margins are exceeded. In Chile, the determination of the Permitted Installed Capacity (CIP) and the Permitted Surplus Injection (IEP) makes it possible to establish precise operating limits, and if exceeded, to require the applicant to finance the necessary reinforcement works. Similar mechanisms exist in Argentina, Ecuador or Guatemala, where approval depends on technical feasibility and the real availability of the network, and the adjustments are the responsibility of the interested party.



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INTERNATIONAL REGULATORY APPROACHES TO DG

In leading countries, the distribution company is moving from being an operator limited to energy transmission, to an active manager that facilitates the integration of DG. In these markets, many distribution companies already implement competitive procurement of flexibility services, contracting load reductions, reactive power injection or temporary storage to distributed resources (DER). The European Union's Clean Energy Package (2019) obliges DSOs to use flexibility services as an alternative to grid expansions, in order to optimize investments, integrate renewables, and reduce system costs. The Netherlands has promoted demand management programs and network services contracted to aggregators. In New York State, the DSO must integrate DERs into the day-to-day operation of the system, coordinate local transactions, contract flexibility services, and ensure transparency in information and pricing, under the supervision of the regulator.

On the planning front, DSOs have shifted from expanding infrastructure based on demand to developing plans that consider DG, EV, storage, and demand response scenarios. California and New York require utilities to submit DER Integration Plans or Grid Development Plans with horizons of 5 to 10 years, incorporating analyses of how much generation can be connected per circuit without reinforcements, and publishing this information. The European Union requires DSOs of a certain size to submit a Distribution Development Plan every two years that includes DG forecasts and demand response, evaluating flexibility options before proposing new investments, and coordinating their planning with the TSO. In the UK, Ofgem requires distribution companies to draw up grid plans that include the addition of electric vehicles, solar generation and storage systems, prioritising smart solutions and flexibility markets rather than relying on new infrastructure. In addition, DSOs develop annual processes to identify Network Flexibility Needs and launch tenders for services as an alternative to strengthening the network.

Network visibility and monitoring are a central hub of modern distribution management. In the UK, utilities are required to report annual LV grid visibility indicators to demonstrate how far monitoring has extended in substations and LV feeders. In addition, they are required to report the amount of flexible generation that has been reduced by congestion and the degree of use of automation to detect and manage those congestions. Sweden and Finland completed the installation of smart meters more than a decade ago, giving DSOs granular information that allows them to monitor bidirectional flows at low voltage and detect deviations in quality of service. Currently, the region is moving towards a second generation of visibility, which includes sensors in distribution transformers, smart reclosers, and extended SCADA systems to observe in real time the state of the grid against the variability of distributed resources.

Operational and market coordination is an essential function of the DSO in the face of the entry of new players such as aggregators, energy communities and active prosumers. DSOs should coordinate with TSOs and local participants, exchanging information on available capacity, dispatch, and operation of DERs that may impact the network. In Europe, the regulation establishes this data exchange obligation, while in the United Kingdom, Ofgem has established a unified database of all resources (batteries, electric vehicles, generators) participating in the flexibility markets, making it possible to avoid conflicts between local and regional services. In Finland, the TSO (Fingrid) and several distribution companies operate a joint flexibility market: the DSO declares its abatement needs, the TSO declares theirs for system balancing, and aggregators offer services to both through coordinated auctions.

Different countries have adjusted the economic regulation of the DSO to guarantee its sustainability and encourage the integration of distributed resources without compromising the quality of the service. A first strategy is to decouple DSO revenues from the volume of energy distributed, through decoupling or remuneration for allowed revenues. In Europe, tariffs operate under regulated revenue caps with adjustments for efficiency, ensuring cost recovery without relying on the flow of energy. Similar schemes exist in many U.S. states, which adjust rates periodically to cover approved fixed costs despite the drop in sales. Another axis has been the redesign of tariff structures to more accurately reflect the fixed costs of using the network. The Australian Energy Market Commission (AEMC) approved a reform that recognized that export services are a distribution function, and therefore must have adequate revenues. At the same time, it prohibited distribution companies from imposing zero export limits on new connections except in exceptional circumstances (Ashurst, 2024), which obliges them to accept a minimum level of DG and to plan the network to manage it. In Europe, most countries have increased the weight of fixed or capacity charges to distributed generators, reducing reliance on volumetric charges. In the UK, prosumers pay one component per grid usage, while in Spain, a fixed charge is applied for contracted power. Sweden and Denmark introduce hourly rates and variable injection charges that reflect local congestion, incentivizing the storage or movement of exports at excess hours. In the U.S., more than 47 states have migrated from traditional net metering to net billing rates, also introducing minimum or capacity charges. Finally, performance regulation models that align financial incentives with efficiency and innovation are consolidated. In the UK, the RIIO scheme rewards distribution companies for achieving flexibility and cost-saving integration goals, promoting efficient use of the network through digital solutions and alternatives to physical expansion.

In addition, many regulators have incorporated incentives, funding, and mandates for DSOs to invest in smart technologies, from advanced meters and sensors to network management systems (ADMS) and distributed resource management systems (DERMS), that give them visibility, control, and operational capability. In the UK, Ofgem has developed the Strategic Innovation Fund (SIF), which co-finances smart grid, digitalisation and flexibility projects. In addition, distribution companies must present digitization and data strategies within their business plans, including milestones for sensorization, automation, and data opening. The regulator assesses these developments and grants financial incentives. In Australia, the prohibition on DSOs from imposing zero export limits except in exceptional cases, forces them to actively manage the network, driving the adoption of DERMS and dynamic injection control algorithms. The ARENA agency has co-financed low-voltage control pilots, testing the operation of hundreds of solar inverters connected through cloud platforms. Germany requires the installation of smart meters and control systems in large facilities, while alternative management models such as the “energy traffic light” are explored, where the DSO defines, through monitoring infrastructure, the times when DERs can operate freely (green), with restrictions (yellow) or under direct control (red). At the European level, Regulation (EU) 2019/943 created the European DSO Entity, which standardises data exchange and develops common interoperability codes for future DERMS platforms.

Several regulators have accompanied these obligations with financing mechanisms and additional returns. In Italy, ARERA established a fund for smart grid pilot projects, granting an additional WACC on investments in automation, storage and control. In the UK, the Network Innovation Competition/Allowance programmes and the current RIIO have allocated hundreds of millions of pounds to digitalisation, DERMS and microgrid projects. These schemes seek to reduce the risk of innovation, rewarding distribution companies for adopting technological solutions that increase the efficiency of the system.

05

CONCLUSIONS AND RECOMMENDATIONS

The expansion of DG requires an update of regulatory frameworks to ensure its sustainable development. The decentralization of the electricity system cannot be sustained without an economic and technical structure that preserves the stability of the grid and guarantees that the costs are borne by those who cause them. In this context, three priority areas of adjustment are identified: economic-tariff, technical-operational and institutional, to strengthen the equity, transparency and sustainability of the system.

The most urgent challenge is the modernization of the remuneration model for distribution companies. It is proposed to decouple revenues from the sale of energy and move towards a tariff structure based on the capacity and availability of the grid, recognizing that the essential function of distribution is to provide a reliable and flexible infrastructure, regardless of the volume of energy transported. This redesign requires a decoupling of Distribution Value Added (VAD) from energy volumes and an update of the cost allocation mechanisms, so that the investments and adjustments derived from the connection of new generators are distributed in a fair and transparent manner. In parallel, the consolidation of net billing schemes would make it possible to value the energy injected under prices that reflect the real costs of backup and use of the network, avoiding cross-subsidies and guaranteeing the financial sustainability of the distribution system.

From a technical perspective, the sustainable development of DG requires a comprehensive update of connection and operation standards, aimed at establishing homogeneous criteria of quality, safety and control. The regulation must provide distribution companies with the necessary maneuverability to evaluate, condition or reject projects that represent well-founded risks to the grid, based on feasibility studies and the actual hosting capacity. Likewise, minimum requirements must be incorporated for interconnection equipment and remote monitoring and control systems must be required to manage bidirectional flows in real time and maintain operational stability. These requirements must be complemented by regulatory incentives for the digitalization and automation of networks, recognizing the value of technologies such as SCADA, ADMS or DERMS in the distributed resources management. Finally, the regulation must strengthen traceability and control over undeclared or non-standard installations, the proliferation of which represents a growing risk to personnel safety and system reliability.

At the institutional and planning level, it is necessary to move towards greater regulatory coherence and systemic coordination between regulators, operators and distribution companies. The regulatory framework must clearly define the rights, obligations and attributions of each actor, including new figures such as demand aggregators or local energy managers, to avoid overlaps and liability gaps. It is also recommended to incorporate joint planning of grids hosting capacity and planned expansion trajectories, so that the incorporation of new DG projects responds to technical and sustainability criteria, and not to spontaneous growth. Institutional strengthening of distribution companies, together with explicit recognition of new operational and administrative roles they assume in active networks management, is essential to ensure that decentralization proceeds in a safe, orderly, and financially balanced manner.

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