REGULATORY INCENTIVE MECHANISMS FOR PROMOTING INVESTMENTS IN SMART DISTRIBUTION SYSTEM

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ABSTRACT

This paper focuses on the guidelines of the Italian Energy Regulator (AEEGSI) for large scale investments on innovative systems for electricity distribution (Smart Distribution System). The analysis undertaken leads to the identification of two innovative functionalities that are not promoted by existing incentive regulatory mechanisms, and could be developed even without challenging telecommunication systems. The paper is also focused on the incentive mechanism introduced by AEEGSI in order to stimulate DSO to deploy innovative functionalities where these are mostly needed (areas with huge RES penetration). Without such an incentive, the DSO could have no interest in developing innovative solutions, and the system benefits could be missed.

INTRODUCTION

Climate change policies are inducing a major transformation in power systems, that will not be completed without an adequate regulation of electricity networks and of network users. Traditional regulation has been progressively modified in terms of focus and objectives: new areas of concern have entered the regulatory agenda, and the challenge of promoting innovation has prompted several initiatives.

This paper focuses on the guidelines issued by the Italian Regulatory Authority for Electricity, Gas and Water (AEEGSI) for promoting large scale investments on innovative systems for electricity distribution (Smart Distribution System) which may result, in the span of a few years, in the achievement of a "basic" smart infrastructure. This development can serve as a platform for further improvements, according to criteria of interoperability, in order to safely develop the effective contribution of distributed resources to balancing and ancillary services [1].

The paper shows the evolution from "smart grid" to "smart distribution systems" concept, based on the results of tests conducted in smart grid pilot projects which were initiated in Italy in year 2011 (first part of the paper) [2]. The analysis undertaken leads to the identification of two innovative functionalities that are not promoted by existing incentive regulatory mechanisms; such functionalities could be developed even without the introduction of challenging telecommunication systems (second part of the paper).

Starting from an examination of the performance characteristics that are actually necessary, the cost/benefit analysis, related to these two functions, aims at ensuring that the most effective innovative functionalities at the lowest cost are promoted, so as to steer the correct deployment of the smart distribution systems (part 3 of the paper). As regards the active network functionalities, it is possible to attend to the definition of minimum requirements that might allow an evolution towards an incentivizing regulation, aimed at supporting the necessary financial effort for the large scale deployment of the smart solutions.

The paper is also focused on the incentive mechanism (last part of the paper). With the current tariff system, the benefits derived from the two identified features are not completely captured by the DSO which, therefore, could have no interest in developing such solutions (or even, might find it more convenient to develop different, perhaps more capital-intensive, solutions). On the basis of these considerations, the Italian Energy Regulator considers it appropriate to assess the development of an incentive mechanism that "internalises" part of the benefit in favor of the DSO [3].

EVOLUTION TOWARDS THE "SMART DISTRIBUTION SYSTEMS"

The expression "Smart Distribution System" is evolutionary compared to smart grid, hitherto utilized since 2011, and is preferred by the Italian Energy Regulator since it is more effective in identifying the true innovation in the system (system = network + enabled users) and not just in the network.

The pilot projects launched in 2011 by AEEGSI have highlighted some important functionalities for the development of Smart Distribution System [4]; more specifically, they consist in the following:

1. observability of power flows and the state of distributed resources;
2. voltage regulation at the medium voltage level (MV);
3. regulation of network users' active power;

4. remote tripping to prevent the phenomenon of MV "undesired" island;
5. advanced operation of the MV network;
6. utilization of storage systems owned by DSO.

The following table illustrates some general characteristics of the six functionalities, including the type of necessary communication links and the level of application of the Machine-to-Machine communication services that are classified [5] as:

a. monitoring: functionality of data collection and remote device configuration (no special latency requirements);
b. control: functionality of data collection aimed at sending implementation commands (not especially stringent latency requirements);
c. protection: advanced functionalities with immediate reaction capacity in the event of critical issues (very stringent communication times).

Some of these functionalities might be implemented in several ways, more or less advanced; in some instances, it is possible to implement functionalities even without telecommunication (TLC) system with users, generally with lesser benefits but at lower costs as well.

Function	Main role	Applicable without TLC with users	Machine-to-Machine services
1	Distributor	Yes	Monitoring
2	Distributor and enabled active users	Yes	Control
3	Distributor and enabled active users	No	Control
4	Distributor and enabled active users	No	Protection
5	Distributor	Yes	Control and Protection
6	Distributor	Yes	Control

Table 1. Characteristics of innovative functionalities for a Smart Distribution System.

INNOVATIVE FUNCTIONALITIES

The analysis undertaken leads to the identification of two innovative functionalities that are not promoted by existing incentive regulatory mechanisms; the functionalities could be developed even without challenging telecommunication systems:

- observability of distribution system (power flows and the state of distributed resources);
- ability to regulate the voltage profile of the MV networks.

Monitoring functionalities: observability of power flows and resources

The extensive penetration of distributed generation (DG), especially from renewable energy sources (RES), and the need to connect further new plants, thereby ensuring the safe management of the electricity system, necessarily require a greater observability on TSO's interface of energy flows on the distribution networks and of the state of distributed resources (DR), which include DG, storages and final users. The continuous monitoring of those aspects makes possible for the TSO to manage resources for dispatching more efficiently, thanks to a better knowledge of the energy flows through the Primary Substation (PS). The observability of the network might develop according to four levels of growing complexity, that begin with measurements in PS, to which measurements in Secondary Substation (SS) or along MV line might be added, to finally reach and utilize even measurements taken at the user's plants (Table 2).

	Description	Communication	Players
1a	Continuous estimations of DG and load based on weather forecasts and/or historical data integrated with the control system of the PS and with a DMS *(distribution management system)*	Only between PS and Distributor's Operational Centre (already existent) and between distributor and Terna (existent to be reinforced)	Distributor; TSO
1b	Correction of estimations through the utilization of sensors installed in PS or located in SS already remote controlled	Same as level 1a + between PS and sensors (already existent)	Distributor; TSO
1c	Correction of estimations through the utilization of production data of sample plants already reached by satellite system managed by the Dispatching User	Same as level 1b + between distributor/TSO and Dispatching User	Distributor; TSO; Dispatching User
1d	Correction of estimations through the utilization of production data sent by the plants connected with the distributor	Same as level 1b or 1c + always on communication between PS and active users	Distributor; TSO; active users

Table 2. Characteristics of observability of power flows and resources.

Control functionality: voltage regulation

As regards the voltage regulation on the MV networks, the pilot projects have underlined significant effects on improvement of the hosting capacity, and have also managed to highlight different innovation levels compared to the traditional "static" operation (if possible complemented by current compound).

The first implementing step consists in voltage regulation through devices installed in PS, capable of carrying out a regulation of the tap-changers of HV/MV transformers based on load flow results, or state estimation results, if corrected through measurements realized in PS or along line. An additional possibility is to activate the local voltage regulation function in the active user plants, by varying the reactive power injection. The last step in voltage regulation is based on a set point of reactive power, sent by PS to the active users, that has to be maintained in order to ensure the best voltage profile along line. Table 3 illustrates the different possible levels of the voltage regulation functionality.

	Description	Communication	Players
2 a	Regulation of voltage in PS through the improvement of the state estimation algorithm	Only between PS and Distributor's Operational Centre	Distributor
2 b	Same as level 2a but correcting the algorithm output values through the available measurements of busbar voltage and departing current value at every line	Same as level 2a	Distributor
2 c	Same as level 2a but correcting the algorithm output values even through the voltage measurements recorded at some SS	Same as level 2a + telecommunication with SS	Distributor
2 d	Same as level 2b; in addition, the distributor activates the local voltage regulation function at the active user plants. The plant regulates, within its own capability, the reactive power on the basis of the voltage at the connection point	Same as level 2a.	Distributor and network users
2 e	Same as level 2d plus set point of reactive power sent by the PS to the active user	Same as level 2a + telecommunication between PS and users	Distributor and network users

Table 3. Characteristics of voltage regulation.

CBA FOR THE VALORIZATION OF THE OUTPUTS

If we only take into account the functionalities that can be realized by the DSO without any involvement from widespread resources, it is possible to define the criteria for a cost benefit analysis for the large scale deployment. Starting from an examination of the performances that are actually necessary, the cost/benefit analysis aims at ensuring that the *most effective* innovative functionalities *at the lowest cost* are promoted, so as to steer the correct deployment of the Smart Distribution Systems [6]. The development of the cost/benefit analysis is based on the following steps:

1. examination of the performances that are actually necessary, so as to ensure, at the lowest cost, the innovative functionalities of smart distribution systems;
2. assessment of the costs associated with such performances, taking into account the economies of scale that might arise.

Observability of power flows and of the state of network resources

The main advantage of the function "Observability of power flows and the state of network resources" is linked to an improvement in the foreseeability of non-programmable renewable sources that is necessary for managing electricity markets and, generally, the system. Knowledge of correct information updated on weather forecast data or effective production measurements (as obtained through the observability function) might reduce the reserve quantities which Terna procures (and maintains in real time), with special reference to the ready reserve and the secondary reserve (fast reserve), in place of the replacement reserve. In fact, the availability of updated information on the DG flows might render quick actions no longer necessary, thereby managing the system through planned actions. Prudently, it might be assumed that the implementation of the observability function entails a 5% reduction in the request for such fast resources, with a saving for the overall system that amounts to approximately €50 million per annum. The period of validity of the benefits for the observability function is set, based on a conservative convention, at 3 years. As regards the costs, the investments for the observability function might be quantified at around 1.000 k€ for the development of the central data management and forecast system (hardware and software) for each operational centre, which has its own SCADA/DMS system and controls a certain number of PSs. Assuming the extension of such a system to all the DSOs, a preliminary estimation of the total necessary investment would be around €45 million. The benefit/cost ratio of the functionality "Observability of power flows and the state of network resources", is deemed greater than 3 with a prudential accounting of benefits over time.

Voltage regulation of the MV network

The main advantage of the function "Voltage regulation of the MV network" limited only to the distribution network is an increase in the hosting capacity and the deferral/reduction of necessary investments to integrate growing quantities of distributed generation. Analyses carried out in the pilot projects, showed that the introduction of voltage regulation "base" functions could entail 16% increase in hosting capacity. Taking into consideration this average delta hosting, it might be valorized in terms of new communication lines avoided. This economic valorization is equal to the value of the investments avoided/deferred in time, that would be worth approximately €0,5 million for each PS. As regards costs, the development of function "Voltage regulation on the MV network", limited only to the distributor network, is obtained by equipping the PS with an innovative control system (hardware and software update), and by installing a regulator of tap changer for HV/MV transformers. The investments for the voltage regulation function might be quantified at approximately 200 k€ for the hardware and software of the PS (partly to be apportioned to other functionalities as well). The benefit/cost ratio for functionality "Voltage regulation on the MV network" limited to the distributor's network is deemed close to 2.5.

INCENTIVE REGULATION

After a wide consultation process, the Italian Energy Regulator introduced an incentive mechanism to stimulate DSO to deploy the innovative functionalities. As highlighted above, without such an incentive, the benefits derived from the two identified features, are not completely captured by the current tariff system for the DSO. Therefore, the DSO could have no interest in developing such solutions (or even, might find it more convenient to develop different, perhaps more capital-intensive solutions). On the basis of these considerations, the Italian Energy Regulator considers it appropriate to assess the development of an incentive mechanism that "internalises" part of the benefit in favor of the DSO.

According to these guidelines, this incentive mechanism must have two characteristics:

- "output-based": it is correlated to an indicator that expresses in a simple manner the level of benefit from the intervention, since this mode allows the DSO to focus on the more efficient choices for the system;
- "selective" in nature: it is able to orient itself primarily toward those areas in which the intervention yields the greatest net benefits.

The observability of power flows and of the state of network resources is incentivized according two different levels of increasing complexity:

- OSS-1: real time information from DSO to TSO about busbar voltage and line current of at least one MV feeder in PS that connects a pure photovoltaic generator only;
- OSS-2: real time estimation of DG production through the utilization of available metering data, sensors (also for weather conditions), installed in already remote-controlled PS or SS.

The observability of power flows and of the state of network resources is incentivized according two different levels of increasing complexity:

- REGV-1: utilization of the tap-changer of the HV/MV transformers in PS on the basis of load flow calculations on the network suitably modelled (loads, generators, line, etc.);
- REGV-2: in addition to the use of the tap-changer, the DSO activates the local voltage regulation function at the premises of a minimum number of active users, by supplying the necessary data for the correct operation of the Q(V) control low, which is present in all the MV and LV photovoltaic and wind-powered plants (inverters, control system) since 2012.

The index to selectively steer the development priorities of the functionalities towards the most critical areas with the highest penetration of renewable sources, is based on the Reverse Power Flow Time Indicator that has to exceed 1% on each transformer of PS.

As for the outputs, the Italian Energy Regulator takes as benchmarks:

- as regards the observability of power flows and the state of network resources, the rated power of DG from RES, in standard network structure, associated with the transformers of the PS in which the "smartization" investment is put into operation;
- as regards voltage regulation on the MV networks, the rated power of transformers of PS in which the "smartization" investment is put into operation.

The incentive mechanism is today in place only for OSS1 and REGV-1. The incentive is calculated as follows [7].

For the observability of power flows and of the state of network resources function the incentive is equal to:

$$\mathbf{I_{OSS1} \ x \ P_{RES} \ x \ Month/12}$$

where:

- I_{OSS1} is equal to 20 €/MW;
- P_{RES} is the sum of the rated power of DG from RES in the area [MW]
- Month are the number of months in a year with a satisfying real time estimate (in comparison with actual measures collected ex post).

Finally, for voltage regulation, the incentive is equal to:

$$\mathbf{I_{REGV\text{-}1} \ x \ S_{PS}}$$

where:

- I_{REGV-1} is equal to 250 €/MVA;
- S_{PS} is the rated power of HV/MV trafos in the area [MVA].

REFERENCES

[1] M. Delfanti, A. Galliani, V. Olivieri "The new role of DSOs: ancillary services from res towards a local dispatch" CIRED 2014

[2] AEEGSI, Regulatory decision ARG/elt 12/11 "Valutazione e graduatoria dei progetti pilota relativi a reti attive e smart grids, di cui alla deliberazione dell'Autorità per l'energia elettrica e il gas 25 marzo 2010, ARG/elt 39/10"

[3] L. Lo Schiavo, M. Delfanti, E. Fumagalli, V. Olivieri "Changing the regulation for regulating the change: Innovation-driven regulatory developments for smart grids, smart metering and e-mobility in Italy" Energy Policy

[4] M. Delfanti, E. Fasciolo, V. Olivieri, M. Pozzi "A2A project: A practical implementation of smart grids in the urban area of Milan" Electric Power System Research

[5] AEEGSI, 457/2014/I/com "Indagine conoscitiva dell'Autorità per le garanzie nelle comunicazioni concernente i servizi di comunicazione machine-to-machine (m2m)"

[6] AEEGSI, Consultation document 255/2015/R/eel "Smart distribution system: promozione selettiva degli investimenti nei sistemi innovativi di distribuzione di energia elettrica"

[7] AEEGSI, Regulatory order 646/2015/R/eel, Annex A "Testo integrato della regolazione output-based dei servizi di distribuzione e misura dell'energia elettrica"