PROSUMERS: STANDARDS' REQUIREMENTS AND THE SAFE OPERATION OF THE POWER DISTRIBUTION NETWORK

PROSUMATORII: CERINŢELE STANDARDELOR ŞI OPERAREA ÎN SIGURANŢĂ A REŢELEI ELECTRICE DE DISTRIBUŢIE

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Abstract: *According to the international standards, the EU regulation and the ANRE norms, it is necessary to have appropriate measures both in terms of electrical protections at the interface between the network and the prosumer, as well as in the generating plant. The management of electricity generation and load flows are important at the network level, but the first step in integrating the distributed generation is the operational one in which we must determine how these installations will work and how they will be protected against abnormal regimes. The prosumer, unlike the passive consumer of electricity, can consume, store or sell electricity into the grid. By this behavior and his additional capabilities is an active participant in the electrical grid. The electrical protections seen as the basic solutions for integrating prosumers are presented in this article.*

Keywords: prosumer, standards, electrical protection, safe operation.

Rezumat: *Conform standardelor internaţionale, regulamentului UE şi normelor ANRE, este necesar să se adopte măsuri adecvate atât în ceea ce priveşte protecţiile electrice la interfaţa dintre reţea şi prosumator, cât şi în instalaţia generatoare. Gestionarea producţiei şi a fluxurilor de energie electrică sunt importante la nivelul reţelei, dar primul pas în integrarea generării distribuite este cel operaţional în care trebuie să stabilim modul în care vor funcţiona aceste instalaţii şi cum vor fi ele protejate de regimuri anormale. Prosumatorul, spre deosebire de consumatorul pasiv de energie electrică, poate consuma, depozita sau vinde energie electrică în reţea. Prin acest comportament şi capacităţile sale suplimentare este un participant activ la reţeaua electrică. În cadrul articolului, protecţiile electrice sunt tratate ca soluţii şi măsuri de bază pentru integrarea prosumatorilor,*

Cuvinte cheie: prosumatori, standarde, protecţii electrice, electrosecuritate.

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1. The regulatory framework for prosumers' electrical protections in Romania and abroad

In this chapter shall be presented the standards and regulatory framework concerning the electrical protections of the prosumers. According to [1] Regulatory Authority's Order no. 228/2018, at Art. 14, "*The connection solution of the prosumer with active power injection in the network, with installed powers less than 1 MW, must not allow their operation in islanded mode, including by equipping with protections to interrupt the injection of the active power in the network of prosumers at the occurrence of such a regime;*" It is however accepted to operate on island with its own consumption, disconnected from the public network. This article does not refer to the inverter or the user protections, but to the connection interface unit. The inverter's protections and the user's installation are mentioned in "*Chapter IV. Protections*"of the same document. The article is also valid for plants smaller than 11 kVA, according to articles 23 and 24 of the Order [1].

It is the field of the technical norm that regulates the conditions for connection to the electrical grid for prosumers with active power injection in the network, to establish a unitary way, a strategy at principle level for the protection of prosumers, respectively:

a. The technical conditions regarding the connection to the network of prosumers in the chapter corresponding to the technical connection conditions for generator modules / synchronous generators of the prosumers with active power injection (Chapter II);

b. Protections for the electrical installation of the prosumator, for the production plant, the storage system, and the installation related to the place of consumption, in Chapter IV (Protections);

The protections of the prosumer's installation against failures in the user's installation or against the impact of the network are mentioned in Chapter IV, art. 18. - „*The prosumer with active power injection in the network is obliged to ensure the protection of the electricity production plant, of the inverters and auxiliary installations, of the energy storage system and of the electrical installation related to the place of consumption against failures in the installations or against the impact of the electrical network on them, when operates the protections or the incidents in the network (transient overvoltages, network protections trips, short circuits with and without grounding), as well as in the case of exceptional technical conditions / abnormal functioning*". The protections in the utilization facilities of the prosumer must be coordinated by the "Setting Order" of the

dispatch center with the interface protections at the delimitation point, from the connection or the measuring block and protections. The prosumer has the obligation to communicate the type of protection and the electrical schemes.

Regarding the international known practice, the conditions of the Order 228/2018 result from the European standards adopted in our country, first of them being SR EN 50438:2014 [2] or EN 50438:2013 "*Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks*"[2].

Another important standard, maybe the most important in this moment for a wide range of specialists, in the field is [3] SR EN 50549-1+AC:2019 or EN 50549-1:2019, "*Requirements for generating plants to be connected in parallel with distribution networks – Part 1: Connection to a LV distribution network – Generating plants up to and including Type B".* The standard EN 50549-1:2019 supersedes EN 50438:2013 and CLC/TS 50549-1:2015, giving detailed descriptions, according to the RfG European Network Code requirements. EN 50549-1:2019 allows full implementation of the European Comission Regulation 2016/631 (RfG), including issues necessary for a stable distribution network management as well as for the interconnected system. The standards introduces also the notion of "responsible party", meaning, usually, the National Regulatory Authority, which approves national implementation. The document specifies the technnical requirements for the protection functions and the operational caoabilities for generating plants, intended to operate in parallel with LV distribution networks.

The requirements of the European Standards apply for any kind of energy source to generating plants, generating modules etc.. There are obviously limits of the scope, and these are:

- The selection and evaluation of the connection point;
- Power system impact assessment, for example, consisting in the effects on power quality, local voltage increase, impact on line protections operation;
- Connection evaluation, for example, the settings of the technnical verifications;
- Island operation of the generating plants, intended or unintended, when no part of the power network is involved;
- Safety rquirements, covered by other documents or standards;
- The connections of the generating units in a DC network.

Therefore, we can see, the connection point, its protections and system impact management, are mainly within the scope of regulations and good practices of the "responsible parties", including the DSO [3].

In this review we mention also the Italian norm [4] CEI 0-21/04.2019 „*Regola tecnica di riferimento per la connessione di Utenti attivi e passivi alle reti BT delle imprese distributrici di energia elettrica (Reference technical rules for the connection of active and passive users to the LV electrical Utilities)"*[4]. This norm resulted by the alignment with the requirements of the standard EN 50438 and the EU Regulations 631, 1388 and 1447/2016. These regulations were also adopted in Romania by the order mentioned in the References, so that the Italian norm has practically common roots with the ANRE norms in force. However, the Italian norm has the advantage of bringing together in a comprehensive document both the provisions of the European codes and the notions of a technical guide, it has many references to the quality of electricity, therefore, we consider that a brief presentation is appropriate.

The Italian norm contains concrete provisions regarding active users, which aim at:

 Commissioning, operating and disconnecting the production plant;

 Taking the necessary measures so that the production facilities do not operate in isolation with portions of the distributor's LV network;

 To specify the requirements regarding the production facilities that are in operationnisolated on the internal network.

The norm deals with power plants higher than 800 W, up to those of 10 MW, according to a classification in 4 types, which do not correspond to the thresholds of Order 79/2016. In addition, the standard defines a level of micro-power plants up to 350 W, called "*Plug & Play power plants*". These (Plug & Play) are small, portable photovoltaic installations (1-2 panels and a small single phase inverter).

For the purpose of this standard, energy use plants may be characterized, in addition to the available power, according to the following criteria:

 the power required by consumers;

 sensitivity to network disruptions;

 disturbances introduced by the plant in the network;

 the capacity to resume production after interruptions.

These criteria, which are not exhaustive, are intended to characterize, in a simplified way, the prosumers' plants in terms of minimum requirements and the factors that influence them. It is noted that the standard takes into account the system "production plant - consumer installation". Being a large standard, over 200 pages, it is sufficiently detailed to serve as a user guide. In the author's opinion, the Italian standard is a highly valuable document. I think there should be an equivalent in Romanian language.

2. Standards requirements, working thresholds, typical disturbances of consumers and power plants

The scope of the SR EN 50438: 2014 standard is for single-phase or three-phase micro-generators, regardless of technology, with a current value of up to 16 A per phase (therefore, 11 kVA). Chapter 4.6 of the standard indicates the necessary requirements for the interface protections with the distribution operator's network and basic conditions for the entyre chain, from the plant to public network. According to Table 1, the default settings for interface protection are presented, as they result strictly from the application of SR EN 50438: 2014, but the maximum frequency value has been changed from 52 Hz to 51.5 Hz, as is the current requirement, according to Ord. 228/2018.

Table 1. **Default interface protection performance, resulting from the Table 4 of SR EN 50438: 2014 [2]**

Parameter	Maximum tripping time	Minimum tripping time	Disconnection threshold
Overvoltage – stage 1[a]	3 s	-	230 V + 10%
Overvoltage – stage 2	0,2 s	0,1 s	230 V + 15%
Undervoltage	1,5 s	1,2 s	230V – 15%
Overfrequency	0,5 s	0,3 s	51,5 Hz
Underfrequency	0,5 s	0,3 s	47,5 Hz
LoM (if required)	National conditions		National conditions
	The voltages are effective values or the values of the fundamental component		
	Overvoltage – stage 1: value per 10 minutes in accordance with EN 50160 The calculation of the value for 10 minutes must be in accordance with the 10-minute aggregation presented in EN 61000-4-30, class S. The function must be based on the calculation of the square root from the arithmetic mean, of the values of the square input, over an interval 10 min. As a deviation from EN 61000-4-30 a mobile window can be used. It is sufficient to calculate the sliding value every 3 s of a new value over the 10 min interval to be compared with the disconnection value. The tolerance for disconnection time is ± 10%		

It is not a question of the absence of protections, but of their regulation. The protections envisaged in Table 1 are U_{max}, U_{min}, fmax / min,

LoM – loss of main, e.g. df/dt, if required by operators, according to country-level practices (national conditions).

In the annexes of SR EN 50438 are presented the protection requirements in some European countries, according to this standard absolutely all countries impose anti-insularization protections by requirement of the DO, the more developed countries having more stages of protection, to which are added ROCOF and Voltage shift (df / dt and "voltage vector jump"), and countries in the area of Romania (Czech Republic, Cyprus, Austria) are usually limited to the basic functions mentioned above.

In accordance with the requirements of standard EN 50438, a number of manufacturers offer relays for interface protection, respectively, Bender GmbH from Germany [5], ABB [6], Lovato Electric SpA from Italy and so on. It is obvious that the existence of such a supply of interface relays, which meet the functions and requirements of the standard EN 50438, has started from a request in the field. In view of the above, a safe operation of the prosumers in the network must take into account the need to realize the anti-insularization protections at the delimitation point, in the connection line (the measuring and protection block) according to the regulations in force.

Every engineer in the field knows from experience how many uncertainties and discussions sometimes occur regarding the origin of the disturbances in the network and if the quality disturbances of the electricity can be associated with one mode or another of generation. The Italian standard CEI 0-21 / 04.2019 summarizes this aspect, is detailed and informative (Table 2).

It is noted that the most disruptive tasks are induction and electric arc furnaces, asynchronous converters and motors that drive compressors. The production units, the distributed generators can also be cataloged according to the disturbances introduced in the network in the following categories:

– plants that do not introduce disturbances;

- plants that have devices that introduce quality distortions of electricity, for example, installations connected by static converters;

– plants with fluctuating production (for example, wind farms).

Table 2. **Disturbance consumers after the Italian standard CEI 0-21/2019[4]**

Load type	Disturbances					
	SQ	**FT**	**VT**	**AR**	**FS**	**RE**
Heating with resistance, stove	(1)	(3)	(2)	(3)		
Domestic ovens microwave infrared	 (1) (1)		 • •		 •	 •
Induction industrial ovens High frequency Ultra high frequency Plasma Electric arc	 • •	 •	 • • • •	 • • •	 • • •	 • •
Welding: with resistance arc	 •	 • •	 • •	 (3)		
Asynchronous motors (for example compressors) With variable speed	 • •	 • •	 •	 • •		
Power transformers			•	•		
Converters: AC / DC AC/AC and cyclo-converters			 • •	 • •	 •	
Electroerosion				•		
Discharge lamps				•		
TV-sets				•	•	
Radiology				•	•	

Typical disturbances :

SQ – voltage unbalance between phases;
FT – voltage fluctuations, flicker;
VT – voltage variations;
AR – harmonic voltages;
FS – frequency deviations;
RE – radio disturbances.

(1) – if single-phase load;
(2) – for the starting current, when it is not negligible in relation to the shortcircuit one;
(3) – if power-adjusting thyristors are used.

A non-exhaustive list of the generating type of installations with typical power quality disturbances is presented in Table 3.

Table 3. **Power plants or generating modules that produce power quality disturbances after the Italian standard CEI 0-21/2019**

Power plant type	Type of disturbances generated					
	SQ	FT	VT	AR	FS	RE
Wind power plants connected by:						
asynchronous generators		•	•			
asynchronous dual power generators		•	•	•	•	•
Synchronous generator + AC / AC inverter		•	•	•	•	•
Power plants connected by asynchronous generators			•			
Power plants connected by converters:						
AC / DC				•	•	•
AC / DC - DC / AC				•		

Note: The same typical disturbances as in Table 2 are taken into consideration

The value of the maximum short-circuit current, which must be taken into account when selecting the user's equipment, must be of the order:

– 6 kA for single-phase equipment;

– 10 kA for three-phase equipment for users with installed power up to 33 kW;

– 15 kA for three-phase equipment for users with an installed power greater than 33 kW;

– 6 kA for the phase-neutral short-circuit current in the three-phase system.

According to the norm CEI 0-21/04.2019, in the operation of portions of the low network, in the intended island, in the case of prosumers who have this possibility, the distribution operator as coordinator and the owners of production facilities must:

– guarantee the safety of persons at the same level as expected under normal operating conditions;

– to ensure the elimination of defects by using the protections installed in the network and on the individual production facilities;

– adopt appropriate precautions or procedures to avoid possible hazardous conditions for the connected equipment, when restoring the parallel with the rest of the distribution network.

It is interesting that exactly these actions (stipulated in § 5.2.2 of the aboved mentioned norm) open wide the door, in the opinion of the author, both for the elaboration of a rigorous operating agreement between the distribution operator and the prosumer, as well as for the setting of adequate interface protection.

SDEE Muntenia Nord has always supported the necessity of the operation agreements between prosumers and operator, which should include conditions established for the protections' setting, normal schemes, responsible persons. The prosumer is no longer a mere consumer but an active participant in the operation of the network, a fact correctly noticed by the authors of the standards. Even if the protections adopted by the distributor for the network are not intended to protect the user's facilities, but they constitute a backup for their own protections; consequently, the protection of the user circuits is solely in the responsibility of the user (Figure 1).

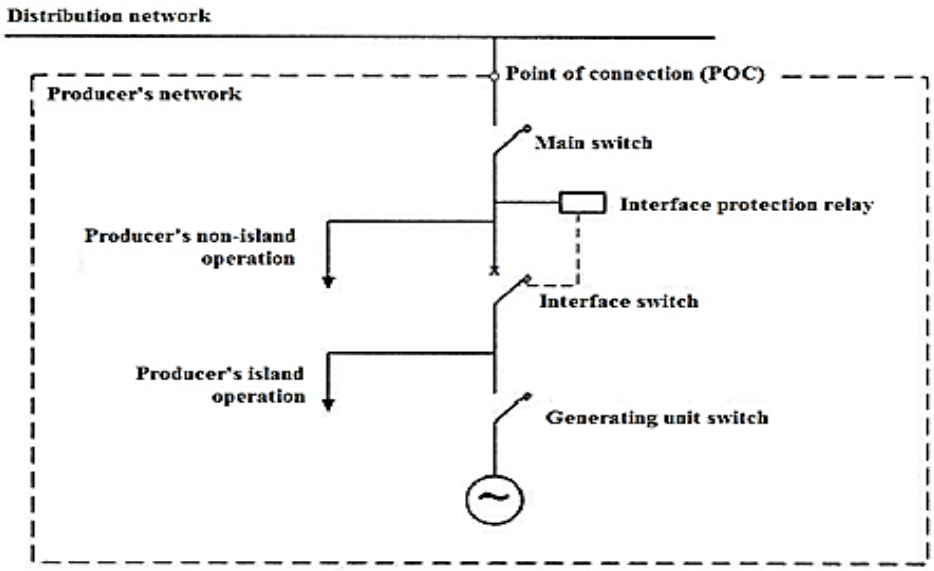

Figure 1. Example of generating plant connected to the distribution network after SR EN 50549-1+AC:2019[3]

The example shown in the Figure 1 does'nt refers to a specified technology, but to any type of generating unit. Low voltage distribution networks are generally protected against overcurrent by overcurrent protection devices. The low-voltage network protection system must be structured and coordinated to eliminate short-circuits, adequate to the performance of the equipment and the protection systems that the technology provides. The DO should take appropriate measures to ensure continuity of the neutral conductor in the network, avoiding unbalanced regimes and the surges that appear in the absence of the neutral.

The protection must meet the requirement of "single fault tolerance", respectively, that the failure of a component of this chain should not affect the correct functioning of the assembly, when there are operating conditions. The precision requirements for the interface protection according to the Italian standard are more stringent than those corresponding to the international standard SR EN 50438: 2014. Thus, according to the standard CEI 0-21/04.2019, the precision requirements for measuring the voltage and frequency for the adjustment of the interface protection are:

- Voltage: ± 1% V_n;
- Frequency: ± 20 mHz.

According to SR EN 50438, the minimum accuracy required is:

• For measuring frequency ± 0.05 Hz;

• For measuring voltage ± 1% from V_n.

Therefore, the required precision difference is only when measuring the frequency and higher accuracy is required according to the Italian norm. We can also conclude from the ones presented in this brief paragraph that the norm CEI 0-21 / 04.2019 is a document of complex technical value, which establishes necessary provisions for the operation of the power generation plants, while also providing a useful guide for the design and testing of these installations.

3. Interface protections in the case of hybrid systems

Intelligent hybrid inverters, manage the photovoltaic panel, battery power storage and network consumption [8]. These modern systems, may be all in one and are usually extremely versatile, so they can be used for applications running parallel to the grid or on the island (on-grid or off-grid).

Their main function is to produce electricity for user's own consumption using also battery storage. If we do not have a network and it is night, for example, a part of the system may still produces electricity from batteries, for important consumers that can not be interrupted, such as: lighting, refrigerator, aquarium, computer, surveillance cameras, communications, etc.

We will present a principle diagram of the arrangement of the equipment and the protection in the case of hybrid inverters, in an installation that can be insulated on the important consumers, provided when the network main switch is open (Figure 3). The scheme is an adaptation from [4], thus representing the Italian standard.

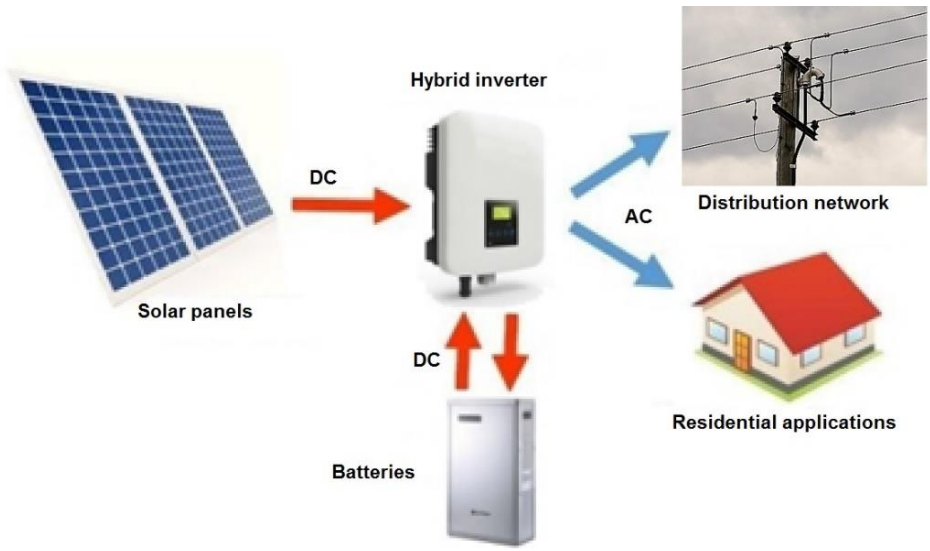

Figure 2. Configuration of the hybrid photovoltaic system

We will present a principle diagram of the arrangement of the equipment and the protection in the case of hybrid inverters, in an installation that can be insularized on the important consumers, when the network switch is opened. The scheme is according to [4], thus representing the Italian standard, perfectly compatible with international norms.

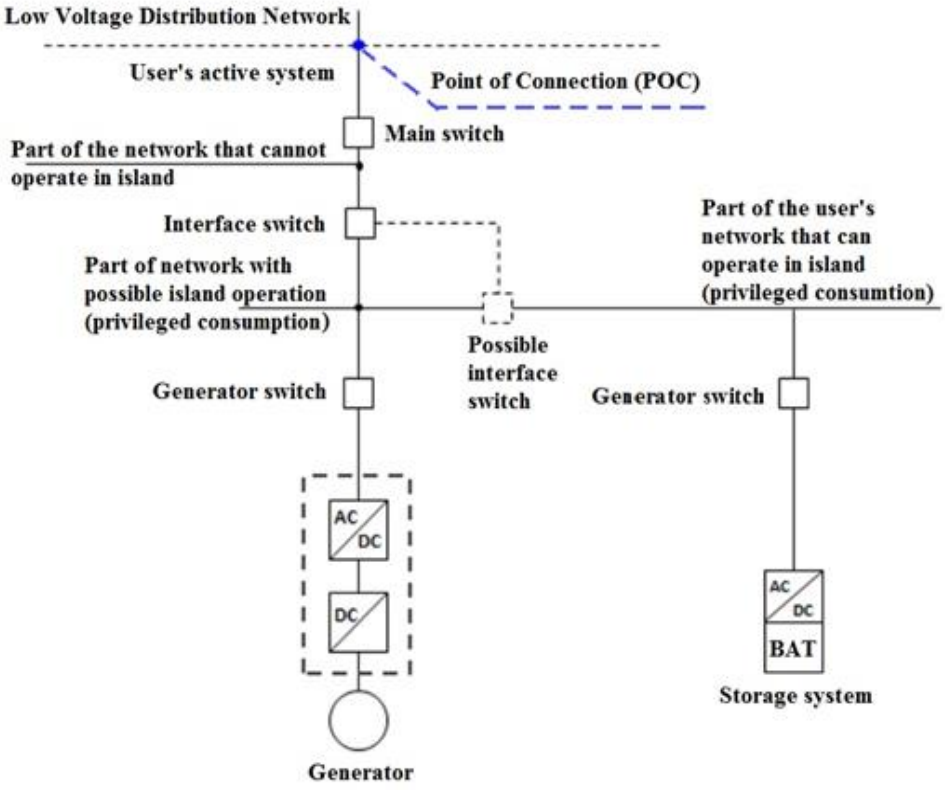

Figure 3. Hybrid system with storage batteries

We consider that the arrangement of the equipment, from Figure 3, is reflecting an European (Italian) practice, so it is of interest to present it. Some basic principles of hybrid inverter operation would be as follows:

- In order to avoid interruptions to the prosumer during the works or the temporary interruptions of the electrical distribution network, based on an operating agreement between the DO and the user, it is permitted and possible to change uninterruptedly the inverter regime, operating on the island as a backup source for important consumers.
- The duration of the parallel should not exceed 30s for three-phase systems and 10s for single-phase systems;
- At the end of the preset time, the source will trip out if the parallel operation is maintained;
- The existence of the interlock, so that the interface switch does not operate simultaneously closed with the switch of the backup system.

4. Conclusions

The necessary protections for the prosumers category are an important factor in ensuring the safe operation of the electricity supply in the low voltage network. We are moving to a new stage in the operation of the power distribution networks, that of microgrid or multi-microgrid, as a result of distributed energy production. The plants of this type work in the proximity of the homes, goods, families and daily life of the users. The production of energy from photovoltaic sources is more frequent, but the protective measures must be taken for any technology to produce electricity.

In accordance with the provisions of standard EN 50438 and EN 50549-1:2019, a number of manufacturers offer the relays required for interface protection. It is obvious that the existence of such a supply of interface relays, which satisfy the functions and requirements of a European standard, has started from a demand in this field. The safe operation of the prosumers in the network must take into account the need to carry out anti-insularization protections at the delimitation point, but there are also schemes, namely inverters, specifically built that are suitable for operation on the island by their own consumers.

In practice, we often try to find out and adopt the best possible solutions for safe operation both for prosumer and the others distribution network users, to provide the power quality according to the standards for each user, within acceptable equipment configurations in terms of the price of the connection solution [7]. The author strived to present hier at least some of the basics in this matter.

The author of the article emphasize the complexity of problems, practical aspects, devices and technologies relevant to prosumers. A prudent approach to all these aspects is necessary, both for the safe operation of the networks and for ensuring maximum electrosecurity for users. Protections of hybrid inverter installations, their correlation and interlocking are also a very complex area to be further analyzed.

R E F E R E N C E S

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