# EVOLUTION OF DEFENCE PLAN FOR ELECTRICAL SYSTEM TO TOWARDS THE SMART GRIDS

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## ABSTRACT

*Taking into account the dramatic increase of Distributed Generation (DG) connected both at MV and LV levels, driven by incentive policies mainly to photovoltaic (PV), during these last five years, Italian Transmission System Operator (TSO) elaborated a new Annex of Grid Code, Annex 72, called RIGEDI, foreseeing the disconnection of distributed power plant (wind and photovoltaic) connected on MV network, to ensure the balancing and correct operation of national system, in particular during the transient occurring in the period with minimum peak of load. Annex A72 is a further measure of grid code that together to other Annexes (f.i. number 9 or 20) realize the Defence Plan of national electrical system in Italy. Considering the needs described on all annexes of grid code regarding the electrical system defence measures with special focus to the requirements identified by the Annex A72, Enel Distribuzione thought to install a series of devices (remote terminal units, protection system, circuit breaker, acquisition of measures from the distributed plants and so on …), directly on distribution network, at the point of connection of MV plants or at the beginning of MV feeders, to improve the effectiveness of disconnection of generation and load respectively for over and under frequency transient in automatic (intervention of protection system) and manual (on request of TSO) application. However all these devices will allow to improve the controlling and measuring of distribution network, in general, over the disconnection of dispersed plants in emergency conditions*

## TYPICAL TRANSIENT OF ELECTRICAL SYSTEM

Each national grid code foresees a defence plant to ensure the balancing on the electrical system during the transient or perturbation that determines the frequency variation. The frequency transient can be divided taking into account the velocity of variation of frequency: **slow** and **fast**. First can be due to normal behaviour of load during the time; the second are associated to unpredictable phenomena occurring in the electrical system.
The same transients, slow or fast, can be classified considering the sign (+/-) of variation of frequency too, respect the rated value: 50 Hz.
The reasons that determine a frequency deviation (transient) can be: faults, evolution of power demand, availability of primary energy source, etc ...

| Phenomena | Time of evolution (t) | Deviation of frequency (Δf) | Cause |
|---|---|---|---|
| [1S] Increasing of load | Minutes or hours | < 0 | Natural evolution of load diagram due to environmental conditions not compensated by the generation |
| [2S] Increasing of generated power | Minutes or hours | > 0 | Increasing of primary source not compensated by load |

**Table 1. Examples of electrical system perturbation that determines slow frequency variation.**

| Phenomena | Time of evolution (t) | Deviation of frequency (Δf) | Cause |
|---|---|---|---|
| [1F] Opening of an EHV or HV line | << 1 s | < 0 | Faults in the line |
| [2F] Disconnection of generator of large power plant (thermal, TG o CCGT) | << 1 s | < 0 | Faults in the power plants or on interconnection line |
| [3F] Large decreasing of generation from DG power plants | < 1 s | < 0 | Rapid and not predictable decreasing of primary energy source on large area |
| [4F] Disconnection of a large number of DG power plants | < 1 s | < 0 | Following to electrical fault or system perturbation |
| [5F] Large increasing of generation, mainly contributed by DG power plants | < 1 s | > 0 | Unexpected disconnection of large amount of load (HV or large number of MV and LV customers) |

**Table 2. Examples of electrical system perturbations that determine fast frequency variation.**

At now, cases [2S] and [3F] are not managed by the TSO and DSOs, in terms of technologies, devices or procedures, so:

- a natural increasing of generated power, specially, in the sunny or windy days, with low load, can produce a deviation (+) of frequency and consequently a possible unbalancing of system;
- a rapid variation (vanishing) of primary source of energy (sun or wind) on systems with a large

penetration of DG, determines a deviation (-) of frequency and consequently an unbalancing of system.

## ANNEXES OF ITALIAN GRID CODE TO EMERGENCY CONDITIONS

Taking into account the Table 1 and Table 2, the Following table shows the Annexes of Italian Grid Code related:

| Transient – Perturbation | Grid Code Annex | Intervention mode |
|---|---|---|
| [1S] | Annex A20 – PESSE (Emergency and Security of Electrical System Plan) | Manual disconnection (by remote control) of MV lines by the DSOs on request of TSO |
| [2S] | Annex A72 – RIGEDI (Reduction of Distributed Generation) | Disconnection of DG power plant connected on the DSO network on request of TSO |
| [1F] / [2F] | Annex A9 – EAC or BME (Automatic Load shedding) | Automatic disconnection of MV line of DSOs network |
| [3F] | NO Annex | |
| [4F] | Annex A70 – Technical requirements for DG power plants | Automatic disconnection with wide frequency threshold (47,5 – 51,5 Hz) |
| [5F] | Annex A70 – Technical requirements for DG power plants | Automatic reduction of generated active power for over frequency transient (from 50,2/50,3 Hz to 51,5 Hz) |

**Table 3. Management of emergency conditions of electrical system and related annexes of grid code.**

## REQUIREMENTS OF ANNEX A72 OF GRID CODE

The new version of the Annex A72 of grid code titled "RIGEDI" (Distributed Generation Reduction) of Italian TSO classifies the generation power plant connected to the distribution MV network in the following kinds of distributed power plants:

- GDTEL: a single or group of power plant connected to the dedicated feeder of DSO. Manoeuvring the breaker installed at the beginning of the line directly by the DSO, it is possible to disconnect a determined amount of active power in case of need. Disconnection can be realized in real time.
- GDPRO: each distributed power plant connected to the distribution line. These plants are not controlled by the system of DSOs or TSO. Disconnection of these plants can be realized only by the owner of plant.
- GDRM: each distributed power plant connected to the distribution line equipped with all devices foreseen by the Italian connection rules (Standard CEI 0-16). Disconnection can be realized in real time directly by the DSO on request of TSO.

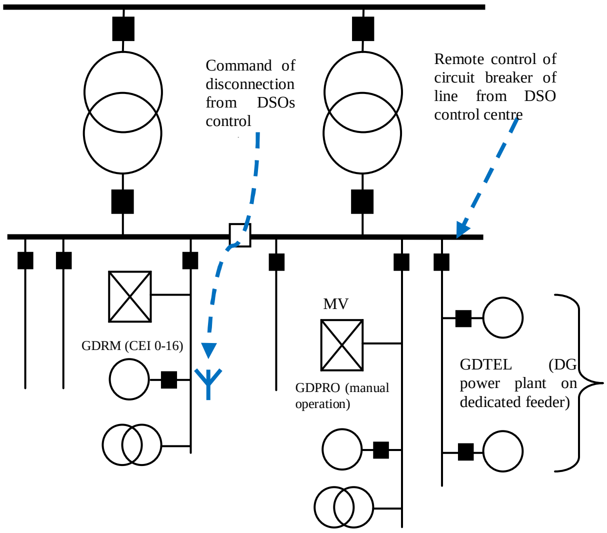


**Fig 1. The various kind of DG power plant classified in accordance with Annex A72 criteria.**

Equipping the protection system of DG power plants in accordance with the CEI 0-16 Italian standard (GDRM), it will be possible to send a signal of disconnection to all generators in case of emergency, in real time, ensuring the balancing of system. This solution allows to contrast only the problems due to the phenomena [2S], mentioned and described in Table 1. However this measures not ensure the real disconnection of power plant; the TSO and DSOs have the control of signal (sending and receiving), Them don't control the breaker position installed inside of the plant.

## SMART MANAGEMENT OF MV CUSTOMERS FOR A SMART NETWORK

To ensure a real and total management of system in emergency conditions and not only, Enel Distribuzione thought to extend the remote control system into the MV station where the MV customers are interfaced. This solution allows solve the problem related to system perturbation phenomena described in Table 1 and Table 2, in particular:

- [2S] → total management;
- [3F] → total management;
- [1S] → improving of management;
- [1F] → improving of management;
- [2F] → improving of management;

The possibility to install protection system and measuring devices interfaced with central control system of DSO will allow to improve the monitoring and operation of network too. The availability of data and control system interfaced with DSOs central system will allow to:

- improve the monitoring of network in terms of load flow state estimation and voltage profile;
- improve the continuity of supply in terms of SAIDI, SAIFI and MAIFI indexes;
- improve the TSO dispatching and system monitoring activities;

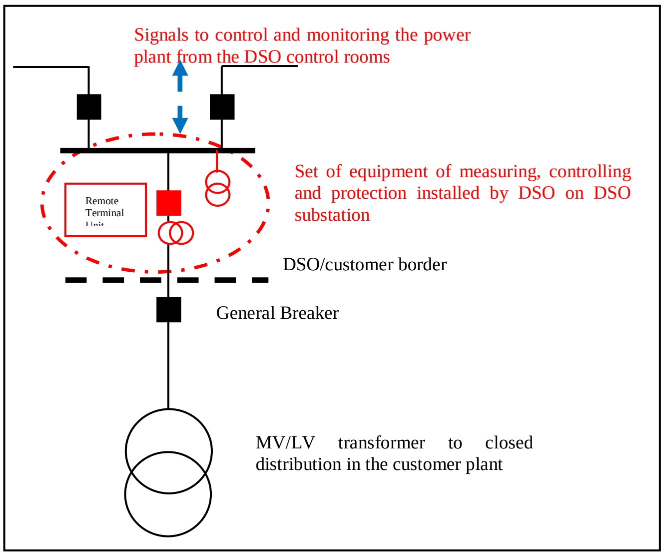


**Fig 2. Possible solution of equipment for a MV station supplying a MV customer.**

The installation of a set of protection system, remote terminal unit, circuit breaker and measuring devices (V, P and Q), interfaced with DSOs central control system, directly in the MV station, where the plant of MV customer are faced, allow:

- a rapid and automatic disconnection of a load power, in case of under frequency transient (total and supporting management of cases [1F], [2F], [3F] of Table 2);
- a remote control disconnection of load in case of emergency condition of operation with slow under frequency deviation (supporting management of case [1S] of Table 1);

but at the same time, allow:

- a rapid back-up selection of fault located in the closed grid of customer, avoiding the intervention of breaker at the beginning of MV line with larger interruption in terms of number of customers and consequently an improving of SAIDI, SAIFI and MAIFI;
- an improving of monitoring of network for the DSO in terms of load flow state estimation and voltage profile estimation on the MV feeders.
- a better dispatching and system monitoring activities. All data collected by the DSO should be sent to the TSO and used to refine the forecasting procedures.

At the same way the installation of a set of protection, measuring and controlling devices, directly on the section of DSO in the MV stations connecting the MV DG power plants (Fig 3), allows:

- back-up of over frequency protection for DG power plants (supporting to management of case [5F] of Table 2);
- a remote control disconnection of DG MV plants injecting active power in case of emergency conditions of operation with slow over frequency deviation (supporting management of case [2S] of Table 1);

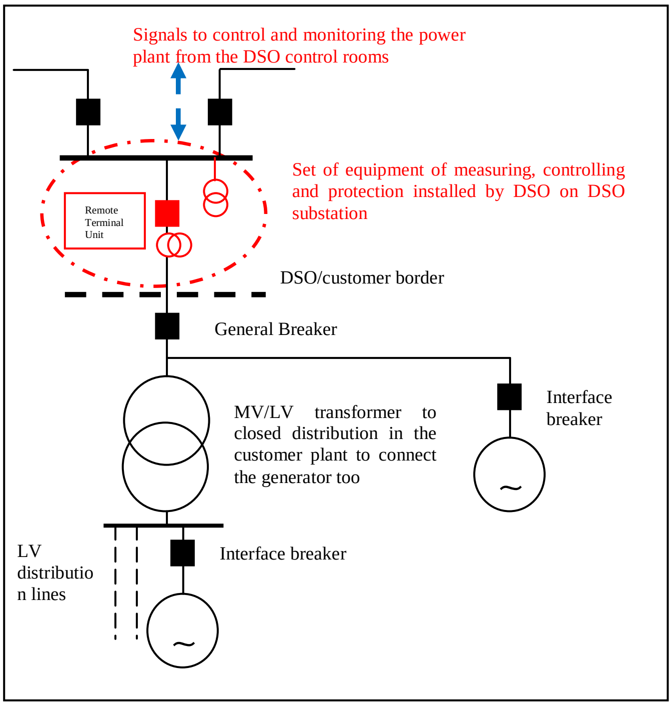


**Fig 3. Possible solution of equipment for a MV station of a MV customer with DG power plant.**

in addition the up mentioned solutions allow:

- a rapid back-up selection of fault located in the closed grid of active customer, avoiding the intervention of breaker at the beginning of MV line with larger interruption in terms of number of customers and consequently an improving of SAIDI, SAIFI and MAIFI;
- an effectiveness back up of interface protection systems for the DG power plants, in case of fault on DSO network and consequently a real improvement of grid control for DSOs in terms of safety and security;
- an evolution of automatic load shedding, at now realized by the automatic low frequency equilibrators (EAC). The disconnection of load based on the measuring of the sign of P should avoid the disconnection of MV plants injecting active power during the under frequency transients (supporting management of case [1F] or [2F]);
- a better dispatching and system monitoring activities. All data collected by the DSO should be sent to the TSO and used to refine the forecasting procedures.

## INNOVATIVE MANAGEMENT OF LOAD EQUILIBRATORS

To improve the effectiveness of load shedding foreseeing the disconnection of MV feeders, Enel

Distribuzione is studying also a new automatic equilibrators devices able to measures the sign of active power. In case of under frequency perturbation, the possibility to identify the flowing direction of active power, allows to select exclusively the lines and consequently, if is need, opens those which represents an equivalent load for the HV network. At the same time is avoid the opening of the lines injecting active power in the MV bus bar of the HV substation. Equipping the MV lines with a measuring system of active power sign and using that in coordination with automatic load equilibrators devices installed that allows to improve the management of [1F], [2F] and specially [3F] system transient.

## CONCLUSIONS

All solutions described are hypothesis finalize for reach a smart management of defence plan in compliance with requirements of grid code (European and Italian in specific case).
Obviously the proposed solutions will have to analyzed and discussed between the all stakeholders. If these will be approved, it will be need to:

- start a deep analysis of network to identify the correct solutions in terms of development, installation and management of components, equipments of measuring and central control systems (for TSO and DSOs);
- modify the annexes of grid code;
- identify mechanisms to cover the cost that each DSO will have to sustain.

## REFERENCES

[1] Annex A72 of Italian Grid Code "Procedura per la Riduzione della Generazione Distribuita in condizioni di emergenza del Sistema Elettrico Nazionale (RIGEDI)". Reduction of Generation in emergency condition.
[2] Annex A70 "of Italian Grid Code "Regolazione tecnica dei requisiti di sistema della generazione distribuita". Technical requirements for Distributed Generation power plants.
[3] Annex A20 of Italian Grid Code "PIANO DI EMERGENZA PER LA SICUREZZA DEL SISTEMA ELETTRICO (NUOVO PESSE)". Emergeny and security plan for the national elettrcical system.
[4] Annex A9 of Italian Grid Code "Piano di difesa del sistema elettrico". Defence plan for the electrical system.