# ABOUT GRID FORMING AND GRID FOLLOWING IN THE ROMANIAN POWER SYSTEM

# *DESPRE FORMAREA ȘI URMĂRIREA REȚELEI ÎN SISTEMUL ENERGETIC ROMÂNESC*

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***Abstract:*** *Authors discuss the impact of the shift in weights of power generation technologies in the Romanian National Power System on the background of the energy transition. Synchronous generators based on high inertia rotating machines withdraw from operation, while asynchronous generators and inverter based technologies acquire an ever-increasing share. Grid forming capabilities of such new generators (traditionally grid following technologies) become critical for the future stability of the power system. The article presents several conclusions from power systems where the debate is more advanced and draws some recommendations of the Romanian power system.*

**Keywords**: Energy Transition, Grid Forming, Grid Following, Renewable Power Generation.

***Rezumat:*** *Autorii discuta impactul modificarii ponderilor raportului dintre tehnologiilor de producere a energiei electrice in Sistemul Energetic National pe fundalul tranzitiei energetice. Generatoarele sincrone cu mase inertiale mari in miscare se retrag din exploatare, in timp ce tehnologiile bazate pe generatoare asincrone sau conectate la retea prin electronica de mare putere (invertoare) isi cresc in permanenta ponderea in structura momentana de producere. Capabilitatile de "grid forming" ale acestor noi generatoare devin critice pentru stabilitatea viitoare a sistemului energetic national. Articolul prezinta cateva concluzii din sistemele electroenergetice in care dezbaterea este mai avansata si contine cateva recomandari pentru sistemul electroenergetic romanesc.*

**Cuvinte cheie:** Tranzitie Energetica**,** Grid Forming, Grid Following , Producere de electricitate din Surse Regenerabile

## 1. Introduction

The purpose of this paper is to discuss the status of transition of the Romanian power system from a "centralized model" (based on large capacity

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synchronous generators situated remotely from the consumption points) to a "decentralized model" where the bulk of power generation happens close to the consumption points from asynchronous generators and inverters without or with low "grid forming capabilities".

The base of system stability evaluation is given by the synchronous generators with different power, motor sources and a variety of inertia not too large. The synchronous machines are all equipped with voltage regulation and the intrinsic frequency response (as electromagnetic principle) which provide the electrical inertia The principle of large system operation is based on a minimum inertia which was assured by decades of synchronous machines (”grid forming”). Now, all renewables sources, even photovoltaics, wind, batteries and different forms of long distance power transmission as HVDC are based on a power electronic interface which copies the existent frequency value and shape of the power system (the phenomenon is called "grid following").

The today challenge is to determine the needed inertia for each moment of system operation and to create an artificial ("synthetic") inertia as response of various sources so that they behave as inertial ones. Due to the fact that the needed inertia is specific for each moment of the power system equilibrium, the easier modality to create the stability is that all new sources, above an installed capacity threshold, provide some grid forming functions. Irrespective of whether those functions can be considered system services or not, it is mandatory that all generating units without inertia be capable to provide grid forming proprieties as precondition to be connected to the grid and be able to deliver them in a critical system stability situation. That was the reason that all the requirements related to synthetical inertia are the object of European regulations.

The citation below, from [2] is considered a very synthetic description of the categories of generators subject to the comparison:

”Managing the stability of today's electric power systems is based on decades of experience with the physical properties and control responses of large synchronous generators, usually with the size of hundreds to even thousands of megawatts. Today's electric power systems are rapidly transitioning toward having an increasing proportion of generation from nontraditional sources, such as wind and solar (among others), as well as energy storage devices, such as batteries. In addition to the variable nature of many renewable generation sources (because of the weatherdriven nature of their fuel supplies), these newer sources vary in size—from residential-scale rooftop systems (a few kilowatts) to utility-scale power plants (hundreds to even thousands of megawatts)—and they are interconnected throughout the electric grid both from within the distribution system and directly to the high-voltage transmission system. Most important for our purposes, many of these new resources are connected to the power system through power electronic inverters rather than spinning electromechanical machines. Collectively, we refer to these generation technologies as inverter-based resources."

The Australian Electricity Market Operator has studied the role of advanced inverters on the background of the same trend of penetration of power generation using RES and replacement of SPGMs ("Synchronous Power Generation Modules") with PPMs ("Power Park Modules") based on inverters.

"The terminology surrounding advanced grid-scale inverters is not yet clearly defined.

Broadly, for the purposes of this paper:

• Grid-following inverters synchronise to the grid voltage waveform, adjusting their output to track an external voltage reference.

• Grid-forming inverters set their own internal voltage waveform reference and can synchronise with the grid or operate independently of other generation.

Grid-forming inverters with a firm energy source behind them may be able to replace many of the capabilities historically provided by synchronous generators. Initially, AEMO recommends prioritising deployment of grid forming capabilities on grid-scale battery energy storage systems (BESS) as this technology provides capability to deliver firm, flexible energy behind the inverter. While large, standalone BESS provide one way to deliver grid-forming capability, smaller batteries (with storage capability of several minutes) coupled to variable renewable energy (VRE) plant might also provide a flexible resource mix to cater for the applications described in this paper. " [6]

Figure 1, quoted from [6], presents the AEMO classification of inverters' categories:

Figure 2, quoted from [6] presents a comparative analysis of performance of grid following inverters, grid forming inverters and synchronous machines from the point of view of supporting the power system stability:

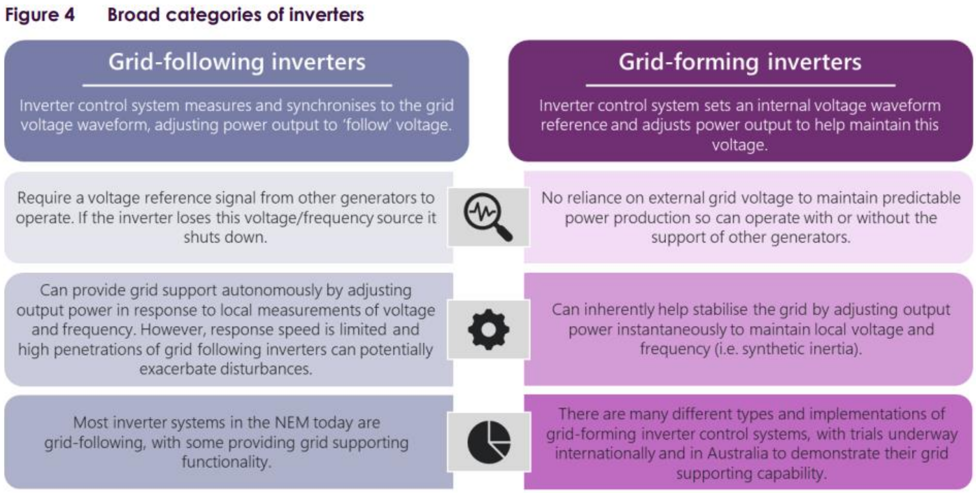


**Figure 1:** Broad categories of inverters.
**Source:** [6]

**Table 2 Performance comparison of grid-connected generation**

| Service/capability | Grid-following inverter system | Grid-forming inverter system | Synchronous machines |
|---|---|---|---|
| Can contribute to system strength | | ✓ | ✓[A] |
| Can have positive disturbance withstand (active power oscillation damping) | | ✓ | ✓ |
| Can have positive disturbance withstand (fault ride-through capability) | ✓ | ✓ | ✓ |
| Can contribute to system inertia | | ✓[B] | ✓ |
| Can contribute to FFR | ✓ | ✓ | |
| Can contribute to primary frequency response | ✓ | ✓ | ✓ |
| Can support a power system island with supply balancing and secondary frequency response | ✓ | ✓ | ✓ |
| Can initiate or support system restoration | ✓[C] | ✓ | ✓ |

A. Synchronous machines can usually contribute to system strength much more than IBR due to their higher overload capacity.
B. A grid-forming inverter system requires energy storage to deliver inertia. See Section 2.4.
C. Grid-following inverters can support but not initiate system restoration.

**Figure 2:** Comparison of grid connected generation technologies performance from the point of view of "grid forming". **Source:** [6]

Romania has in place a National Energy Climate Plan (NECP) that is obsolete and does not take into account the ambitious objectives set in the RePowerEU package adopted by the European Union. The NECP still considers significant investment in gas fired CCGTs, while the overall ambition around which it is construed aims at 30.7% overall share of renewables in the gross energy consumption of the country in 2030. The NECP is to be updated as per Romania's obligations under the EU Energy Union governance legislation.

Meanwhile, at the request of the Romanian Wind Energy Association, Deloitte+E3M have presented results of running two scenarios for the Romanian energy sector targeting the 2030 energy mix, using the PRIMES model. While the first scenario is based on the present NECP projections and demonstrates that Romania will fail to meet the level of RePowerEU ambitions in 2030 (the "AS IS" scenario), a second scenario has been proposed, aiming at fulfilling the 2030 commitments in terms of overall greenhouse gas emissions and shares of renewables (the "TO BE" of "RePowerEU" scenario).

Below is an excerpt from the final report issued by the consultants mentioned above, describing the expected power generation mix of Romania in 2030.

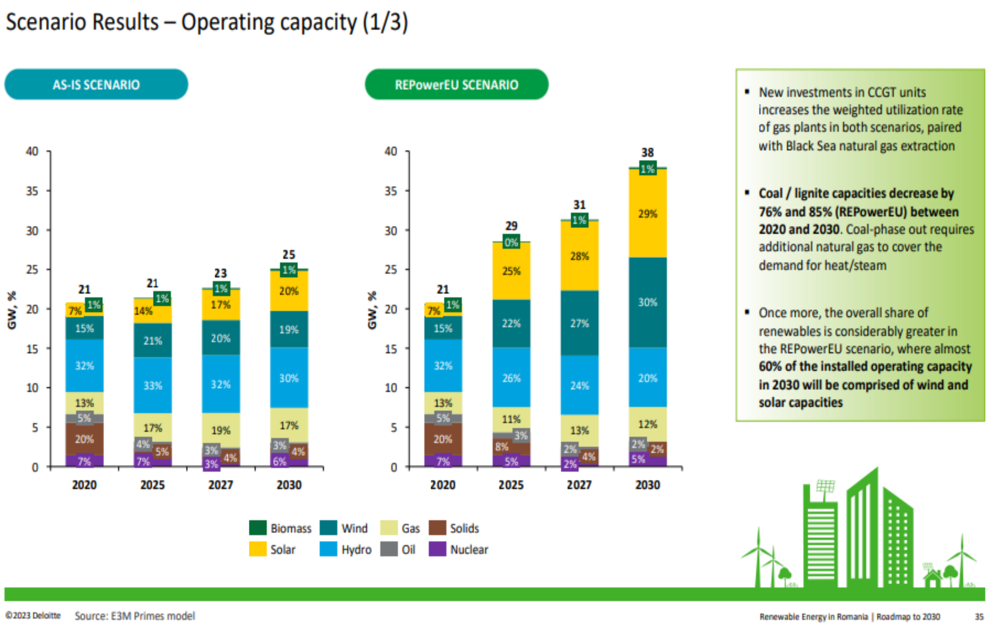


**Figure 3.** Shares of power generation technologies in the Romanian mix as per the AS-IS and TO-BE scenarios.
**Source:** Deloitte&E3M – Renewable Energy in Romania – Roadmap to 2030 – report for RWEA [3]

One can notice that the share of invertor based generation is to increase dramatically (solar PV to represent 20 % of the overall installed power generation capacity). Additionally, a large share of wind power generation will be based on asynchronous generators (total share of 19% for wind farms). At the end of the day, the capacity installed in synchronous generators with inertial masses seems to be around 61% of the total in 2030, if this scenario is the be implemented.

The same study estimates the weight of solar and wind power in the total power output of the country, in the TO-BE scenario at around 47%. Opinions from an island power system estimate that if the weight of synchronous generators with inertial masses stays above 65%, the system should not have major issues with the penetration of invertor based generation. In Romania some 53% in terms of output and some 61% in terms of installed capacity may raise concerns. However, the Romanian power system is synchronously interconnected with the neighboring system and probably the analysis about the weight of invertor based generation would become regional, not only national.

A large share of the solar PV capacities will be non-utility, pertaining to prosumers. The trend of increase of such installed capacities is stunning, one can talk of a "prosumer tsunami". Towards the end of 2023 one expects some 1500 MW to be installed in prosumers' installations. This raises huge challenges for DSOs, mainly with regard to distributed flexibility (voltage control, reactive power flows, distribution networks congestions, possible islanding, blackstart capabilities, etc). But the purpose of the present paper is to discuss only the ratio "grid forming/grid following" in the Romanian power system in the years to come and some implications.

Additionally, the penetration of electric vehicles is not directly taken into consideration in the statistics mentioned above, although the drafts of the new NC RfG (Network Code Requirements for Generators) consider EVs from the V2G ("Vehicle to Grid double sense") family as active contributors to the stability of the power system. Practically the V2G vehicles of categories EV1, EV2, EV3 – "banding categories" still to be firmly approved – are covered by provisions of the new draft NC RfG and there will be standardization of the requirements applicable to them as storage installations connected to the electricity grids. It is expected that such installations will have to demonstrate frequency response capabilities and voltage stability contributions (FRT – Fault Ride Through, etc), same as storage modules, who, at their turn, are considered generators for purposes of the technical regulation.

The table below presents the classification of power generating capacities in Romania, such definition being a transposition of requirements of Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators.

*Table 1.* **Technical parameters for various categories of Power Generating Modules in Romania**

| **Power Generation Modules Categories** | **B** | **C** | **D** |
|---|---|---|---|
| **Technical parameters values** | U<110 kV and 1MW<=P<5MW | U<=110 kV and 5MW<=P<20MW | $U \geq 110$ kV and $P \geq 20$ MW<br>or<br>$U \geq 110$ kV and $P < 20$ MW<br>or<br>$U < 110$ kV and $P \geq 20$ MW |

**Source:** ANRE Order 79/2016.

## 2. Paper contents

The European energy community felt well in advance the approach of such challenges and started analyzing their potential impact and the potentially necessary measures to adapt the power systems to the new reality.

On 07 December 2021, the Grid Connection European Stakeholder Committee (GC ESC) formally initiated establishing an expert group (EG) to review the Advanced capabilities for Grids with a High Share of Power Park Modules. The Terms of Reference were approved by the GC ESC 02 March 2022. A coordinated effort among European stakeholders to define such grid-forming capabilities for converter based facilities has been initiated.

It has been identified [7] that a new or extended class definition of power park modules (PPMs) and high voltage direct current (HVDC) converter stations is required to ensure stable operation with the high penetration of non–synchronous generation. More specifically, this class definition offers a set of grid–forming capabilities defined as follows:

– contribution on system voltage stability and control;

– contribution to total system inertia (limited by energy storage capacity and the available power rating of the PPM or HVDC converter station);

– contribution to fault level / fault current contribution (short circuit power);

– sink for harmonics – to counter harmonics and inter–harmonics in system voltage;

– sink for unbalances in system voltage;

– system survival to allow effective operation of Load Frequency Demand Disconnection ;

– preventing adverse control interactions/ Supporting system survival to enable the effective operation of low frequency demand disconnection for rare system splits.

At the moment of presenting this paper, a consultation is launched by ACER on the revision of the existing Grid Codes, and with regard to NC RfG – Network Code on Requirements For grid connection of Generators. There are long debates with regard to Grid Forming contributions of Power Park Modules (especially solar with convertor based generation and wind with asynchronous generators) depending on their categories (B, C, D). The debate is very complex, as the equipment producers and the investors in such generation capacities are very concerned about the financial (CAPEX) but also operational implications of various new requirements. As synchronous rotating machines with high inertia withdraw, TSOs and mostly RSOs (Relevant System Operators) are concerned about putting more effort on the shoulders of operators of such PPMs, with an accelerated assumption of grid forming tasks. The compromise is in the making, but it will be important that the voice of Romanian economic agents and authorities be heard and taken into consideration and the final version of the revised grid codes and new grid codes be compatible with the Romanian specific conditions.

It is, however, worthwhile mentioning that the expected proliferation of non-utility solar PVs, representing practically class A Power Park Modules, will generate high risks of mass disconnections in case of system disturbances especially due to same location and the impact on instantaneous change character of low voltage and medium voltage lines from injection to consumption. Therefore, at this stage there are intense debates about imposing Fault Ride Through obligations for type A PPMs. Moreover, one cannot allow variations of requirements in different systems part of the same synchronous ENTSO-E area, therefore the requirements in the new NC RfG have to be very strict. This means that Romania will not have too much freedom in relaxing requirements for new solar PV modules and will have to be aligned to the EU trends and technical regulations.

Discussions are ongoing about the grid operator having the right and technical possibility of activating remotely the grid forming mode for type A PPMs.

It should be mentioned that the overall EU transformation effort is much larger and numerous codes to be updated or elaborated at EU level are to be taken into account when estimating the necessary CAPEX both for new generators and for the grid operators:

The European Commission identified two areas for developing new grid codes: demand side response (Art. 59 of Regulation (EU) 2019/943), cybersecurity (Art. 59 of Regulation (EU) 2019/943), while interoperability requirements and procedures for the data (Art. 24 of Directive (EU) 2019/944) will be subject of implementing acts in accordance with the advisory procedure referred to in Article 68(2) of Directive (EU) 2019/944. All these in parallel with the update of the NC RfG.

And an important breakthrough is related to the transition of DSOs from network operators to system operators – a lot of roles that were natural for the TSO as system operators for capacities connected to the transmission grid, are to be assumed by the DSOs as RSOs (Relevant System Operators). This would require extensive communication infrastructures, new teams, procedures, platforms, etc.

The existing installed capacities that concur to ensuring the adequacy and the flexibility of the Romanian National Power System are aged and are gradually preparing for mothballing and retirement from operation. Therefore, the problem is twofold: the existing capacities retire, while the new capacities are invertor based, with intermittent production and in need for a large storage capacity.

The storage capacities (”Independent Storage Operators”) also deliver their output into the power system via invertors and not via synchronous rotating machines.

The draft new NC RfG submitted by ACER for public consultation in 2023 stipulates[8]:

”Within the power park module's current and energy limits, the power park module shall be capable of behaving at the terminals of the individual unit(s) as a voltage source behind an internal impedance (Thevenin source), during normal operating conditions (non-disturbed grid conditions) and upon inception of a grid disturbance (including voltage, frequency and voltage phase angle disturbance). The Thevenin source is characterized by its internal voltage amplitude, voltage phase angle, frequency and internal impedance.”

It is important to mention that apparently the requirements for power storage modules with regard to cases like power frequency response or similar, will be the same for independent storage modules (connected directly to the transmission or distribution grids) and for modules connected within power park modules.

As per Commission Regulation 2016/631, "'synthetic inertia' means the facility provided by a power park module or HVDC system to replace the effect of inertia of a synchronous power-generating module to a prescribed level of performance;"

"Synthetic inertia is achieved by reprogramming power inverters attached to wind turbines so that they emulate the behavior of synchronized spinning masses." [5] In principle, the batteries added to inverters are crucial to ensuring grid forming capabilities, as shown in AEMO recommendations [6].

## 3. Conclusions

Romania is about to redraft its NECP, putting much more emphasis on RES technologies for power generation and withdrawing from operation large "classical" synchronous power generators with grid forming capabilities. In principle it is expected that the new NECP would define a roadmap closer to the "TO BE" (RepowerEU) scenario described in the Deloitte study mentioned above [3]. This means that more and more the Romanian system operator will have to request from new entrants the grid forming responses which disappear with the mothballing of the classical capacities.

Adopting the amendaments to the RfG Grid Code is a complex, complete and laborious process. Once the public consultation will be finalized and ACER will submit the final text to the European Commission, a new Regulation will be proposed and published. Such regulation will contain technical obligations for connection of generators, but most likely will not impose such obligations to existing installations or to installations commissioned (or with investment decision taken) within certain time frame from the publication the new version of the RfG Grid Code. This will be a critical milestone for investors, as the new grid forming requirements will likely be costly with regard to equipment performance, and many of such investors will prefer to avoid such obligations.

This means that in the period expected for the new grid codes final debate and approval and entry into force a large number of new power park modules (PPMs) will have to either observe the new requirements (meaning increased technical requirements, implying additional expenditures/CAPEX) or will be exempted from such new requirements as they will be commissioned prior to the entry into force of such new codes or revised versions of existing grid codes. Experience shows that the Romanian TSO has been tough enough in requirements to new RES generators, causing the Regulatory Authority to issue technical regulations asking the latter to be towards the upper limits of operational performance, so that existing RES power generators (PPMs) have already invested in some grid forming capabilities.

Romania should also be prepared for the adoption of rules related to grid forming capabilities of Electric Vehicles (EV) and for performances of the charging stations to serve such EVs (V1G – just absorption from the network, V2G – bidirectional relationship with the grid). Debates are ongoing at this moment with regard to categories of EVs and expectations towards their batteries as grid forming contributors.

It is also worth mentioning that at this stage, following the invitation from the Relevant System Operator – Transelectrica – to the RES based generators to qualify for provision of ancillary system services, there have been no applications/offers from such generators, the system being left uncovered from the flexibility and even adequacy point of view in front of the new variable production “tsunami”. But there is an important investment flow in grid scale batteries. Transelectrica should formulate requirements to such Independent Storage Operators with an eye to the evolving landscape and future flexibility needs.

One of the hottest debates in the Romania power sector is whether the prosumers should be obliged to invest in storage equipment, that will allow them to provide synthetic inertia and eventually contribute to frequency response. On the background of gradual withdrawal of the conventional inertial mass synchronous generators, the request to assure the inertia and viability of covering the load curve forces all renewable power generators, including prosumers, to contribute to a minimum flexibility and system support. This support can be assured only by a correct system behavior of prosumers in order to inject and absorb instantaneous power to and from the grid and system. The storage installations (batteries) installed at the level of prosumers provide frequency response capabilities and thus contributions to system flexibility behavior, by providing synthetic inertia

During such debates, three ways of action have been identified in this respect:

– Legislative intervention, imposing installation of storage equipment with prosumers, without too many technical arguments; such measure might be not very popular ahead of 2024 elections;

– Conditioning the support scheme in the form of grants for rooftop PV panels on the absorption of grants for associated storage equipment – a new dedicated financing line has been just launched;

– Imposing installation of storage equipment on technical grounds, for the need to contribute to (limited) frequency response (system flexibility), through technical norms to be applied by DSOs upon processing new connection applications.

The DSOs, for their own needs (distributed flexibility – mainly voltage control) might be entitled through technical norms to impose special settings of inverters, and batteries could provide similar functions. It is not realistic to consider that such numerous granular distributed storage facilities could be coordinated by the TSO for frequency control purposes. They could provide limited frequency response, that might prove marginally useful given their proliferation.

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