EMERG, Volume X, Issue /2025 ISSN 2668-7003, ISSN-L 2457-5011

INERTIA, A CHALLENGE FOR THE TRANSITION OF THE NATIONAL POWER SYSTEM OF ROMANIA

INERȚIA, O PROVOCARE A TRANZIȚIEI SISTEMULUI ELECTROENERGETIC ROMÂNESC

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DOI: 10.37410/EMERG.2026.1.06

Abstract: *Starting from the latest findings in Europe and Australia with regard to the importance of inertia in power systems in which Invertor Based Resources/Power Park Modules gradually but rapidly replace Synchronous Power Generating Modules with Grid Forming Capabilities, authors discuss the implications for the Romanian power sector. The policy options for procuring inertia in Romania are discussed with pro and con arguments. Romania belongs to the South-Eastern part of the Continental Europe Synchronous Area that had difficulties to restore frequency upon the system split of 08.01.2021. Since that incident other power systems connected to such region, with war strikes likely to bring additional disruptions. It is essential that the inertia in the Romanian power system be measured often if not continuously with close attention to regions that have different characteristics of the power generation parks and relatively weak interconnections. Given the Romanian power system and market characteristics authors recommend creation of an inertia market using lessons learned from countries like Germany, UK, Ireland, Australia.*

Keywords: Grid Forming, Power System Inertia, Inertia Measurement/ monitoring, Inertia Market

Rezumat: *Pornind de la ultimele concluzii din Europa și Australia cu privire la importanța inerției în sistemele electroenergetice în care Resursele Bazate pe Invertoare /Power Park Modules înlocuiesc gradual dar rapid Modulele Generatoare Sincrone cu Capabilități de Surse de Tensiune (Grid Forming), autorii discuta implicațiile pentru sectorul energetic românesc. Opțiunile de procurare a inerției în Romania sunt discutate cu argumente pro și contra. Romania apartine părții de Sud-Est a Zonei Sincrone Continentale Europene,*

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care a avut dificultăți în a restaura frecvența cu ocazia separării de sistem din 08.01.2021. După acel incident la această sub-regiune s-au alăturat doua alte sisteme electroenergetice cu noi vulnerabilități potențial induse de lovituri de razboi. Este esential ca inerția în sistemul electroenergetic românesc să fie masurată frecvent dacă nu continuu cu atenția sporită către regiuni care au diferite caracteristici ale parcurilor de generare și interconectări relativ slabe. Date fiind caracteristicile sistemului elecroenergetic și pieței din România, autorii recomanda crearea unei piețe pentru procurarea inertței folosind lecții învățate din țări precum Germania, Marea Britanie, Irlanda, Australia.

Cuvinte cheie: Grid Forming, Inerția sistemului electroenergetic, Monitorizarea/măsurarea inerției, Piața de Inerție

1. Introduction

In [1] authors have discussed the notions of Grid Forming and Grid Following, providing examples from the international experience and have discussed the implications for Romania of the implementation of the energy transition with the retirement of Synchronous Power Generation Modules and extensive introduction of Power Park Modules. When discussing the features of Grid Forming generators, besides contribution to Dynamic Voltage Control, an important characteristic is the contribution to the system inertia.

Recent studies at ENTSO-E level and in general in countries with significant advances of the energy transition~~,~~ have enhanced the role of inertia in maintaining the safe operation of power systems. The present paper discusses implications in the field of inertia of the Romanian power system on the background of the energy transition implementation process related to massive integration of sources with low inertia. Authors also quote important conclusions from various dedicated studies, discussing their applicability to the Romanian power system and elaborating some policy recommendations.

2. Paper contents

2.1. Initial condition/ premises

The starting point of the analysis of the phenomenon is the definition of inertia from both points of view – system and generation modules.

The European Commission introduced in [2] the following definition: ‘inertia’ “means the property of a rotating rigid body, such as the rotor of an alternator, such that it maintains its state of uniform rotational motion and angular momentum unless an external torque is applied.”

Reference [3] uses the following definition of inertia:

“In this report, the term ‘inertia’ is used to refer in general to the power provided instantaneously in the event of a frequency change, i.e. without any intervention of a control system, and thus it includes the kinetic energy of synchronous generators and synchronous condensers as well as the contribution of converter-based devices with grid-forming capabilities.”

In last 10 years, power system inertia was affected by the major changes in the generation structure. This is the consequence of decreasing the percentage of conventional synchronous power generating modules, whose rotating masses inherently contribute to system inertia followed by increasing the percentage of power park modules connected through power electronics devices. The situation was accentuated by HVDC transmission lines extensive penetration and the increase of the number of consumers connected by power electronics.

Maintaining a high level of inertia value in a power system is important because system inertia determines the initial Rate of Change of Frequency (RoCoF) in case of a sudden imbalance between supply and demand (e.g. trip of a large MW source or demand) and sets the ramp of frequency evolution. The main consequences are:

– A slower RoCoF response, decreases the frequency stability at system incidents such as system splits;

– A lower RoCoF allows to activate a higher amount of reserves: Frequency Sensitive Mode (FSM) (normal state) or Limited Frequency Sensitive Mode (LFSM) (emergency state);

– Low inertia decreases the critical clearing time, with consequences in relays settings;

– Higher risks of corridor tripping and inter-area power oscillations “

2.2. Analysis of the phenomenon causes

In case of huge incidents such as loss of large generators or consumption located in same electrical region, or system splitting, the evaluation of general system parameter – frequency behavior, can indicate the level of inertia. We refer to the rate of change of frequency RoCoF value.

Figure 1 below shows the principal sequence of events in case of a frequency contingency, with the drop of the frequency down to the Nadir value, the speed of recovery depending on the inertia of the power system (considered strongly influenced by the ratio synchronous generation – power park modules) and the types of control/reserves required/capable of intervening at different time scales:

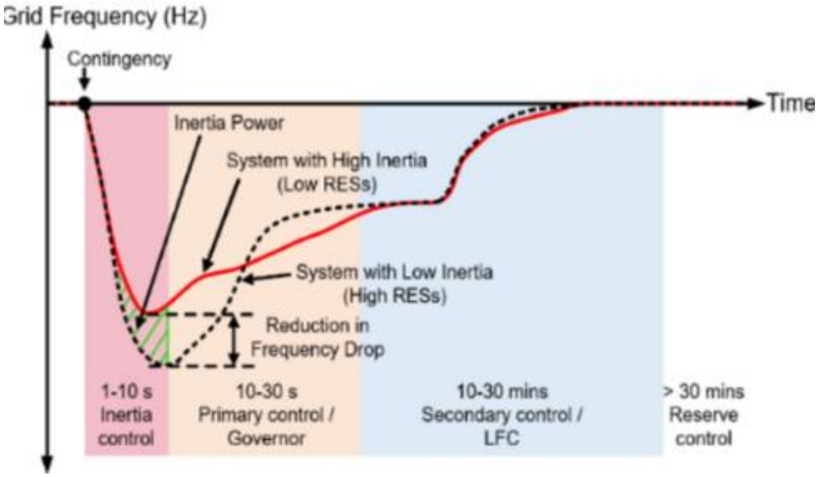
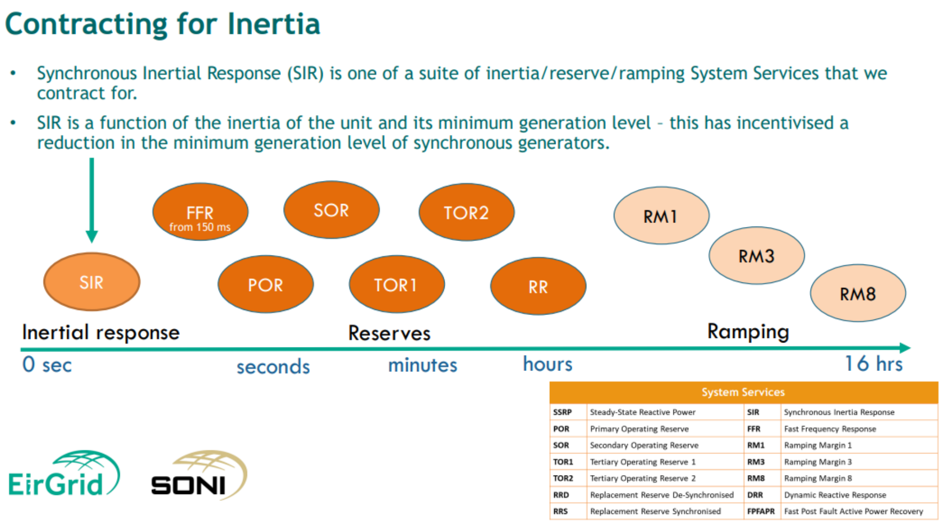


Figure 1: Frequency drop and inertia roles and time frames – Source: [4]

Reference [5] presents the time sequence of appeals to various system services, including what is defined as inertia:



Contracting for Inertia

- Synchronous Inertial Response (SIR) is one of a suite of inertia/reserve/ramping System Services that we contract for.
- SIR is a function of the inertia of the unit and its minimum generation level - this has incentivised a reduction in the minimum generation level of synchronous generators.

System Services			
SSRP	Steady-State Reactive Power	**SIR**	Synchronous Inertia Response
POR	Primary Operating Reserve	**FFR**	Fast Frequency Response
SOR	Secondary Operating Reserve	**RM1**	Ramping Margin 1
TOR1	Tertiary Operating Reserve 1	**RM3**	Ramping Margin 3
TOR2	Tertiary Operating Reserve 2	**RM8**	Ramping Margin 8
RRD	Replacement Reserve De-Synchronised	**DRR**	Dynamic Reactive Response
RRS	Replacement Reserve Synchronised	**FPFAPR**	Fast Post Fault Active Power Recovery

Figure 2: Various forms of inertia procured in Ireland – source [5]

One can identify the difference made in Ireland between SIR – Synchronous Inertia Response and FFR – Fast Frequency Response (which is expected to intervene after some 150 ms – time for measurement and action triggering).

Although initially insufficient inertia was considered as one of the main causes of the Iberian incident on April 28, 2025, gradually various reports and works tend to indicate poor dynamic voltage control as the main cause [6], [7]. The REE report [7] indicates that higher inertia would have slowed the phenomenon/evolution of the incident, but would not have prevented it.” The incident was NOT caused by a lack of system inertia. Rather, it was triggered by a voltage issue and the cascading disconnection of renewable generation plants, as previously indicated. Higher inertia would have only resulted in a slightly slower frequency decline. However, due to the massive generation loss caused by voltage instability, the system would still have been unrecoverable”

As per [3]:

“Two key issues have to be considered to limit the consequences of a lack of inertia:

• Value of RoCoF (rate of change of frequency), as high RoCoF can result in the tripping of grid components …

• Value of Nadir (minimum of frequency reached), as too low nadir can lead to load shedding and/or generation tripping, and, in the worst case, system collapse...”

As per [8]:

“To define the RoCoF withstand capability correctly, the characteristics of an entire synchronous area must be considered. The capability shall be determined based on analysis of a normative incident for the network concerned. Such a normative incident could be a system split in a large synchronous area with a significant change of inertia and power imbalance in the resulting subsystems (e.g. historic events like the Italy blackout in 2003 and the Continental Europe 3-way split in November 2006)…

Given the uncertainty on system characteristics and their future evolution, power generating modules need to be robust against changes to the system and shall provide RoCoF withstand capability which accounts for these varying system conditions (e.g. in Ireland, simultaneous penetration by non-synchronously connected generation shall be increased to 75% by 2020, which has significant implications for the RoCoF).

The RoCoF withstand capability should be assessed on not only the present network but also account for the expected capability that will be required over the asset life of concerned installations accounting for future changes in the network and its demand and generation portfolio. Also, the capability of existing connected generators will be taken into account."

As per [9]: "The following lists the elements of the system that are playing an impacting role during severe underfrequency events:

• Rotating masses Inertia • Primary control (FCR) • Secondary controller change control mode • LFSM-U (Limited Frequency Sensitive Mode at Under-frequency) • HVDC support from neighbouring synchronous system • Emergency start-up of generating units (e.g. turbojets or gas turbines) • Self-regulating effect of loads • Hydro pump storage disconnection • Interruptible loads shedding • Automatic Under Frequency Load Shedding (UFLS) shedding • BESS (Battery Energy Storage Systems) • Manual load shedding"

Obviously for Romania emergency start-up of generating units, HVDC support from neighboring synchronous systems, hydro pump storage connection/disconnection, BESS would not be of help at this stage. This raises the importance of the first topic – Rotating Masses Inertia, while Romania closes Synchronous Power Generating Modules and shifts the weight in power generation towards Power Park Modules. With this shift, also the FCR capabilities in the Romanian national power system will decrease dramatically.

[9] mentions a very important conclusion:

"Following the path of decommissioning of synchronous machines replaced by inverter connected generation, we can note two effects: the aforenamed decrease of inertia, but also short-circuit power reduction; the latter influences the impedance seen by generators, and thus affects the stability of the system and correctness of protection equipment operation. Moreover, here we also see the hidden relationship between active and reactive power: if short-circuit power is reduced (i.e. the impedance seen by generators is higher), the voltage dips are deeper and the perimeter of their influence is wider. A voltage dip may cause a commutation failure on HVDC links and, in general, disturb the correct operation of inverter-connected generators and loads; Concluding, a system with huge amounts of this kind of generation and load is weakened by reactive power phenomena and experiences active power transients."

2.3. Evaluation of reference incidents in reserve calculation

At this moment, there is an ENTSO-E assessment of the stability of the Continental European Area against a drop of 3 GW in power generation [10]:

“A single-busbar model is used to assess the system behavior during severe disturbances. That means, it is assumed that the power system remains interconnected during these disturbances, which include generation and load outages up to 10 % of the total system load. … The single-busbar model takes into account the influence of: inertia, primary control (FCR), LFSM, the behavior of different generation units and HVDCs, the self-regulating effect of loads, non-conform generation disconnection, interruptible loads/pump disconnections, and the underfrequency load shedding plan. The performed analyses show that, considering restrictions regarding frequency and RoCoF, the current system defence plan works well for power imbalances up to ± 5 % … of the total system load in 2022 and 2030, assuming that the European power system remains interconnected and the capacity of non-conform generation units do not exceed the values collected among RG CE TSOs. This is also valid for the 2030 scenarios considering the future decrease of the system inertia. In addition, the results show the importance of the implemented measures, such as disconnection of interruptible loads, disconnection of pump storages in pumping mode and activation of LFSM-O, which will become even more important in the future.”

In [11] the relevance of the Rate of Change of Frequency (RoCoF) is enhanced and the major risks for the European continental area power system are linked to system splits:

“…the energy system is evolving towards a configuration that might lead to the increasing relevance of frequency stability challenges: a variable and renewable energy sources (RES) intensive generation mix, more inverter-based resources, reduced levels of inertia1 and large and variable power flows. Although a high rate of change of frequency (RoCoF) and frequency excursions are not expected in the CE synchronous area under ordinary contingencies, they can be observed during severe events with high power imbalances and low system inertia, such as system splits, in which the interconnected system is separated into two or more subsystems. The power imbalance, determined by the power flow exchange prior to the split, and the subsystem inertia, determined by its generation mix, are the key factors that control the initial RoCoF after a system split.”

It is important to mention, the Continental System was split into parts during severe technical incidents:

– Croatian substation incident – which led to the Romanian system being split in two – so called- East-West separation – 8 January 2021 – see further below;

– System Disturbance on 4 November 2006 [21];

More and more reports indicate that analyses would need to be more granular, sometimes at the level of regions within countries, as there are different local inertia characteristics (different RoCoFs) and voltage deviations.

2.4. Efforts in order to mitigate the phenomena- possible solutions

The evolution of inertia is in the focus of the system stability group of ENTSO-E. Also the necessity of periodical evolution of system inertia evaluation is a task of each TSO as the article of [12] specifies:

„Article 39 a) all TSOs of that synchronous area shall conduct, not later than 2 years after entry into force of this Regulation, a common study per synchronous area to identify whether the minimum required inertia needs to be established, taking into account the costs and benefits as well as potential alternatives. All TSOs shall notify their studies to their regulatory authorities. All TSOs shall conduct a periodic review and shall update those studies every 2 years;

(b) where the studies referred to in point (a) demonstrate the need to define minimum required inertia, all TSOs from the concerned synchronous area shall jointly develop a methodology for the definition of minimum inertia required to maintain operational security and to prevent violation of stability limits. That methodology shall respect the principles of efficiency and proportionality, be developed within 6 months after the completion of the studies referred to in point (a) and shall be updated within 6 months after the studies are updated and become available; and

– (c) each TSO shall deploy in real-time operation the minimum inertia in its own control area, according to the methodology defined and the results obtained in accordance with paragraph (b).

– Dedicate system to monitor- WAMS”

Figure 3 below indicates the contribution of each TSO (national power system) to the TSI (Total System Inertia) constant of the region they belong to.

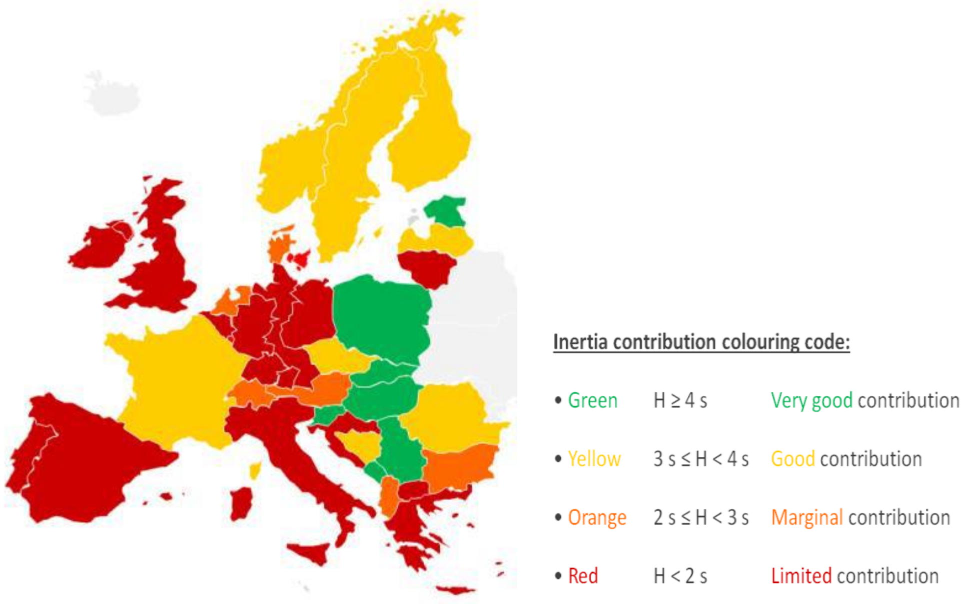


Figure 3 – evaluation of TSOs (control blocks) to the Continental Europe synchronous system Indicating contribution of each TSO to the TSI constant (source: TYNDP 2016 reflecting 2030 scenario), Source: [13]

Looking to the specific literature one notices two trends:

– Regulating the obligations of existing power generators (including Energy Storage Modules), consumers, providers of Demand Response to withstand variations of the frequency in case of disturbances in the system (sudden disconnections, system splits, etc) – in general this requirement is expressed in terms of RoCoF withstand capabilities for existing and new grid users – traditionally the Network Codes approved via European Commission Regulation and derived national regulation contain the relevant legal requirements;

– Assessing the capabilities of the power systems on the background of the energy transition and identifying new specific requirements that are not sufficiently covered by the existing capabilities imposed to existing grid users; given that higher values of RoCoF might occur when there is less Grid Forming capability in the system, questions arise whether new types of services should be introduced, regulated, remunerated, financed. The discussions about using batteries, synchronous compensators, static compensators, etc occur exactly because new analyses indicate that the existing capacities, fully compliant with the present legislation and technical norms, might be unable to respond to higher values of RoCoF and the system automatic may trigger load disconnection and other maneuvers before the frequency nadir is reached and the existing capabilities restore frequency to a normal value.

It is obvious that Romania will need development of inertia capabilities and resources should be allocated to reach such an objective.

[3] describes three modalities for fulfilling such a policy objective:

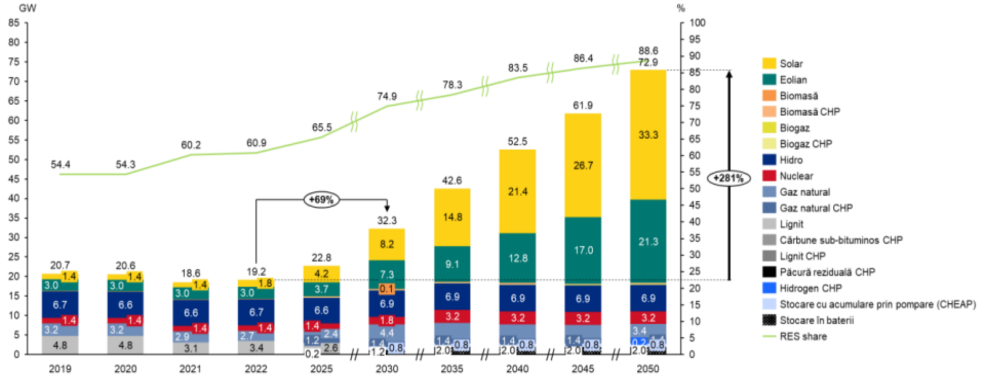
– Developing a new market for inertia services – Fast Frequency Reserve, etc, following also examples from Australia, Ireland, Germany, etc. In Romania where secondary control - aFRR (and most recently also primary control – FCR) are procured via a market mechanism, it might be possible and practical to develop such a market, as the set of rules would not differ in principle. Of course, the challenges would reside in qualifying providers, defining the products, certifying delivery of the service in view of remuneration, documenting non-delivery or partial delivery in view of non-payment of even penalization of inertia market participants. As Romania sees an important proliferation of BESS capacities for dealing with large imbalances brought by increasingly numerous RES generators, such BESS capacities would be perfect candidates for provision of inertia services. The example of Germany, that recently launched such a remuneration scheme for BESS providing inertia, could be followed in Romania;

– Empowering the TSO to invest into inertia dedicated equipment, such as synchronous compensators, static compensators and alike, to be financed from the proceeds for system services; for Romania this would be problematic: the Romanian TSO – Transelectrica - does not have a dedicated operational team for such equipment; Romania has a strong tradition of unbundling and forbidding grid operators access to power generating equipment, so there would be an institutional and pshychological barrier. On the other side, some lignite fired power generating units may be hypothetically turned into synchronous compensators – but commercial arrangements for lignite procurement, maintenance, etc – would be excessive for Transelectrica. Additionally, it would not be sufficient to have synchronous power compensators only in the South-West of the country where the lignite fired power generation would be placed~~.~~ It is important to have a spread of ROCOF and compensation devices as Statcom or synchronous compensators in each region of the country relevant for inertia purposes or with potential for national power system splitting. It would be more practical to leave the development of inertia providing equipment to other economic agents better fit for such CAPEX and OPEX ventures;

– Imposing inertia capabilities for most new grid users as part of the grid connection contracts. A new Network Code Requirements for Generators (NC RfG) would be critical in such case. However, the recent decision of the European Commission to postpone the approval of the NC RfG 2.0 has provided a serious blow to the expectations of grid operators for a harmonized legislation applicable throughout the EU, subject of a thorough work and consultation with all relevant stakeholders. For Romania this would be a challenge to start issuing similar legislation in the intermediary period, to be still aligned with the future NC RfG 2.0.

The Australian case (see [14]) is full of useful lessons for countries/systems in search for an optimal setup for securing system inertia. Recently the Australian Electricity Market Commission (AEMC), after receiving a request to amend the existing specific rules and more precisely to introduce “operational procurement” for inertia services (i.e. a Fast Frequency Response market) has determined that the downsides of going that way – investment in specific market infrastructure, amendment of rules, creation of specialized teams, etc – are not outweighed by the economic benefits that such an approach would bring. Therefore, although stating that the time of such “operational procurement” will come, AEMC determined that the arrangements presently in place are still satisfactory for the system needs, with several minor improvements to be implemented. Some participants to the public consultation have expressed regrets and concerns over such decision, mentioning that keeping investment in synchronous compensators in the Regulated Asset Base of TSOs would not provide any incentive for economic efficiency and final customers would bear the financial burden.

Figure 4 below shows the expected power generation in Romania in 2030 as per the National Energy and Climate Plan [15]. One can notice an expectation of a very strong weight of Power Park Modules. As the Network Code Requirements for Generators 2.0 is late in its approval process and it is expected that a grace period of 3 years for compliance with the new Grid Forming requirements would be legislated, Romania has chances to see a changed inertia of its national power system, unless it elaborates in due time suitable legislation on such obligations of network users.



Sursa: 2019-2022 Balanțe energetice EUROSTAT, 2025-2050 Modelul LEAP_RO

Notă: Începând din 2036, toate centralele pe gaze naturale vor fi alimentate, în proporție de cel puțin 50%, cu combustibili gazoși din surse regenerabile și/sau cu emisii scăzute de dioxid de carbon (inclusiv gaze verzi), ceea ce va determina apariția de capacități suplimentare „SRE" și reducerea nivelului de emisii GES. În graficele de mai sus, începând din 2036, prin gaze naturale, se înțelege gazul natural, biometanul și hidrogenul regenerabil.

Figure 4 – trajectory of installed power generation capacities in Romania, as per the NECP [15]

In figure 5 below, a forecast of hourly produced power in Romania per technologies is presented.

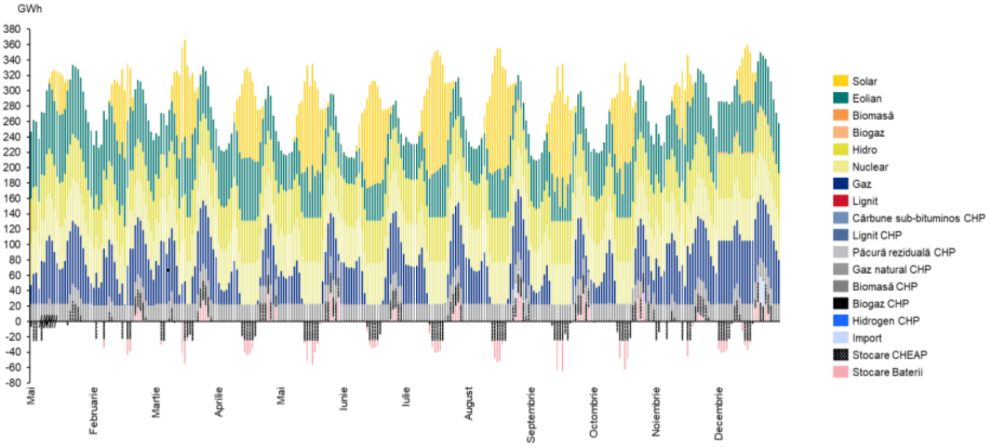
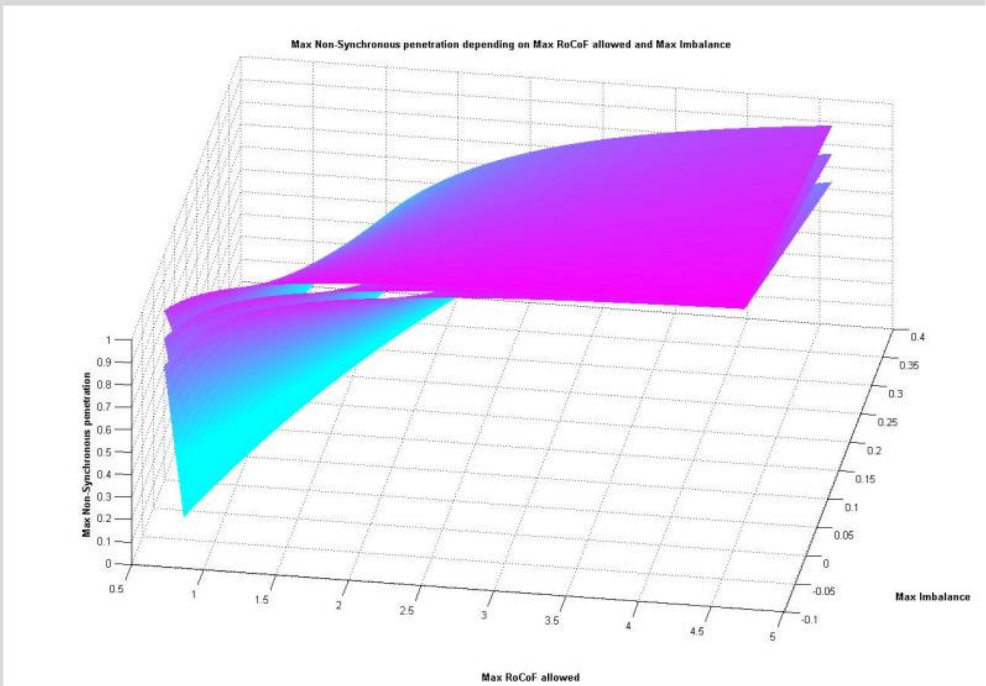


Figure 5 – Hourly power production in Romania in 2030 – Source: NECP [15]

The question is who would provide Fast Frequency Response in the future configurations? The contributions from batteries in terms of active energy for covering the load do not appear as significant, therefore the batteries should contribute upon request from idle statuses. Of course, the start time is convenient, below 0.5 s, this should not be a problem. Still, Figure 3 does not picture a trend of important capacities installed in batteries.

Figure 6 below, quoted by [16] discusses the maximum penetration of the non-synchronous power generating modules depending on the allowed value of RoCoF for Continental Europe.



Maximum system penetration with reference to RoCoF and system imbalance for the synchronous generation operating at 50%, 75% and 100% of rated output (extracted from "Frequency Stability Evaluation Criteria for the Synchronous Zone of Continental Europe", SPD WG, ENTSO-E).

Figure 6 – Maximum system penetration with reference to RoCoF and system imbalance for the synchronous generation operating at 50%, 75% and 100 % of rated output (extracted from “Frequency Stability Evaluation Criteria for the Synchronous Zone of Continental Europe”, SPD WG, ENTSO-E) – Source [16]

Definitely there are no such analyses available for Romania only, but the recent system splits lead to the need to monitor more closely the power systems inertia even at national level or sometimes at sub-country (region) levels.

Figure 7 below indicates the way the Continental Europe Synchronous Area System was split in 8 January 2021, with the relevant lines that disconnected in the Romanian National Power System, thus indicating how the Romanian national power system could be split into regions (with different inertias) in such contingencies.

Figure 7 - The Continental Europe Synchronous Area System split in January 2021 – Source: [17]

The following graph – Figure 78 - taken from the same source illustrates the vulnerability of the so-called South-Eastern sub-system that includes Romania:

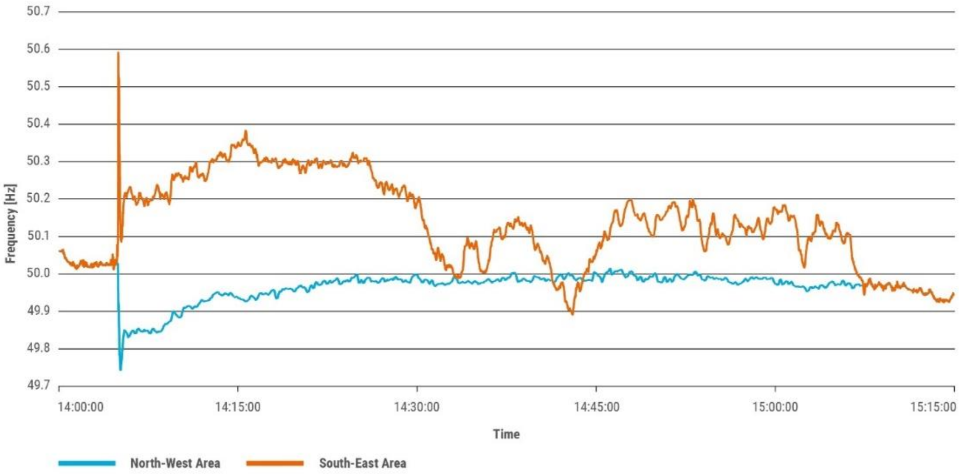


Figure 7 – Evolution of frequency in the two parts of the Continental Europe Synchronous Area System after the split in January 8, 2021. Source: [17]

It can be seen that the North-West sub-system saw its frequency drop due to unbalance between generation and load, but some Low Frequency Load Disconnection measures lead to a stabilization of the frequency. On the contrary, the South-Eastern part had a sudden frequency increase, amortized by disconnection of some generators in Turkiye, but a stable frequency has been obtained much later. It should be clarified that at that date Ukraine and Moldova were not connected to ENTSO-E.

Under such circumstances, [18] mentions: “The Network Development Plan (NDP) for 2035, dated 2021, also considers a so-called system split for the first time, i.e. a large-scale grid separation due to a disruption. To manage such system splits, significantly more instantaneous reserve is required than is the case to manage an outage of 3 GW of generation capacity. To meet the additional demand, new instantaneous reserve potential must be developed... The so-called instantaneous reserve, i.e., the inherent and immediate response to an active power imbalance, is to be procured in a market-supported manner, which is intended to prevent a critical exceedance of frequency control limits – even if only locally.”

Starting from such considerations, [18] defines the market approach for such inertia services:

“The procurement concept submitted for consultation stipulates that a provider offers a selected instantaneous reserve quantity at a previously known, uniform, fixed price determined by the TSO. The TSO is obligated to purchase the offered quantity and pay this fixed price. The amount of compensation depends on the availability of instantaneous reserve. Each TSO can form procurement regions within its control area. Various instantaneous reserve products are envisaged, which differ in their activation direction (positive or negative), availability requirements, and the amount of the fixed price.

To encourage the early provision of instantaneous reserve, a degression of the fixed price is planned. Offers submitted promptly will be remunerated at a higher rate than those submitted later. Furthermore, for plants that provide instantaneous reserve before this is mandatory under the Technical Connection Rules (TAR), the entire available instantaneous reserve will be contracted and remunerated. However, once the TAR obligates plants to provide instantaneous reserve, only the instantaneous reserve that exceeds the contribution stipulated in the TAR will be contracted and remunerated .” It is important to note that TSOs are allowed to define procurement zones within their control zones – a new acknowledgement that different areas of the power system may have different RoCoFs, different inertia constants and different inertia procurement needs. [EIR 2024] also mentions that the next step is “Inertia evolving from a single synchronous area requirement to regional requirements”.

What is also noteworthy is that the German rulings take into account the possible negative effect of providers of system inertia connected to distribution grids and sets the right of the “connecting agent” to oppose the usage of certain Distributed Energy Resources for needs of the TSO if its Grid Forming capabilities may trigger unintentional islanding and other negative effects on the distribution network. This is one of the most debated topics between ENTSO-E and EU-DSO at present on the background of the finalization of the new Network Code Requirements for Generators 2.0. On the other side, it is to be noted that first the inertia providers have an obligation to keep available for the TSO a certain amount of inertia reserve free of charge and only the additional capacities/capabilities available may bring revenue in a specialized/dedicated market.

Ireland has also adopted a forward looking approach [19]: “Yesterday (7 November), EirGrid announced that it had awarded four contracts for synchronous condensers to provide low carbon inertia services (LCIS) to the grid. The technology maintains stability on the grid while operating higher levels of renewable energy—inertia capabilities have typically been provided by large conventional generators…The contracts to build synchronous converters will see the firms provide synchronous inertia, reactive power support and short-circuit contribution without generating active power. These services will enable integration of more renewables into the system.”

3. Conclusions

In Romania, the present arrangements for provision of Frequency Containment Reserve by all generators connected to the grid are not any more sufficient for guaranteeing sufficient inertia, especially in cases of Continental Europe system splits. With the decrease of the system inertia, the speed of variation of the frequency, RoCoF, may reach values that may trigger undesired events before the Frequency Containment Reserve intervenes with full effect.

For the moment, Romania monitors strictly the access to the grid only of generation modules which respect the RoCoF of 2 Hz/s for renewable and batteries (Energy Storage Modules - ESM) and the respect of this requirement must by certified, following tests by an authorized certifying authority that is not yet in place. The respect of these requirements assures the fact that all power plant modules put in function from 2013 will remain in operation for the frequency excursion with the patent presented and verified according to the EN 50549-10 standard. This way the risk to lose more generation during incidents with large ROCOF values may be avoided.

On the other hand, starting 1 July 2025 the FCR reserves in Romania are subject of an ancillary services type market. It is necessary to permit the access into this market also for BESS and hybrid power plants which include batteries.

The model of other countries in which Inverter Based Resources have gained a relevant weight, leads to the conclusion of a need to create a dedicated reserve relative to the system inertia. Some countries as Germany and Ireland, have introduced this reserve. For Romania is important to evaluate its block inertia and to analyze the necessity to introduce a similar reserve following the ENTSO-E guidelines.

The basic hypothesis of “single busbar” that considers that national power systems are strongly interconnected may need to be revisited, especially when some countries are divided into regions with different ratios of Grid Forming/Grid Following generators. The actual principle of the reference incident calculation, based on a “single busbar” failure, must be revised, in relation with the actual spread of no inertia sources. This new situation imposes new principles for frequency curtailment and stabilization reserve calculation.

Although overall the Spanish system had a reasonable ratio SPGM/PPM, it seems that during the days of the incident the Southern region of Spain had a low weight of SPGMs.

Romania has a complex situation, with the heavy concentration of wind farms in the South-East, heavy concentration of Solar PV in the South, weak inter-regional “interconnection” lines crossing the mountains compared to the needs for exchange among such regions. Interconnection with Moldova and Ukraine may bring more uncertainty with regard to system inertia and stability while the war is still ongoing. The entry into retubing of U1 in Cernavoda NPP in 2027 will bring additional stress.

Therefore, inertia monitoring and analysis may be useful at regional level when such regions are separated by mountains crossed by lines with sometimes insufficient capacity for constituting a “national single busbar”. International technical literature talks about regional and temporal variations of inertia, concluding that inertia should be closely monitored and discussing methods for doing that, with the prevailing conclusion that measurement-based techniques are much more reliable than model mased techniques.

It should be clear that preparing the national power system for the challenges brought by the energy transition is not an exercise for a single economic agent like Transelectrica or a single institution like the Ministry of Energy or the National Regulatory Authority. The example of Germany is a best practice case – [20] under the leadership of the Federal Ministry for Economic Affairs and Energy, 4 working groups, with 11 subgroups, with over 150 participants, from over 80 institutions, gathered in over 70 meetings, in order to answer the questions: What? When? Who?

But for that awareness should be built at the highest decision levels necessary.

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