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Design Conditions of Romanian Power System in the Presence of Large-Scale Wind Power Plants

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Abstract — **The paper deals with aspects related to the impact of connecting wind power plants to NPS, representing an important share in the total generated power, on the development of the new sources and transmission network.**

At the present moment there are installed not more than 10MW in wind power plants but Romania faces a large number of connection request from wind power plant investors. Thus it is important do determine the impact of wind power production of 2000-3000MW in Romanian Power System. The paper indicates the values obtained needed for the additional tertiary reserve as well as regarding the capability to integrate wind power in the demand curve.

Index Terms— **adequacy, national power system (NPS), power transmission network (PTN), tertiary reserve, wind power plant (WPP).**

I. Introduction

The problem of the NPS development planning on a medium and/or long term has always represented and still represents one of the major concerns of power engineers.

The development of the interconnections between the national power grids but especially the introduction of the electricity market – at national and international level – has largely changed the way of dealing with this aspect.

The needs and development opportunities of electric power system installations are influenced by the entry data:

- the evolution of the consumption as a whole but also on each individual area, established with an acceptable level of risk;
- evolution of existing and future power sources – on the whole system and on areas – as structure, location, availability indicators and probability of participation to the covering of the electricity consumption in market conditions;
- electricity markets defined, determined,

which allow the establishment with a certain risk level of deficit/surplus of power in areas, of the needs regarding the development of the transmission grid and of the interconnections.

The purpose of transmission networks planning is to ensure a coordinated development of a reliable, efficient and economic electric power transmission system for the long term benefit of the users.

The main criterion in the planning of transmission network is maintaining the electric power system integrity for a series of pre-established events. The achievement of the adequacy and the reliability of the supply of any consumer or area are subordinated from the main purpose.

It is necessary that the integrity of the power system is maintained both for the contingencies with a high probability, as well as for those with the lowest probability.

The performances of the planned power system are determined based on simulations.

By simulating the "electricity market", considering the power plants with fixed operating conditions – nuclear power plants (NPP), cogeneration power plants (CPP) etc. - the contracts with their load characteristic, including those for import/export, the restrictions in the operations of hydroelectric power plant (HPP) and – for the rest – the order of merit, a covering of the consumption (MW) for a given load level, without considering wind power plants can be achieved.

It can thus be established the "reserve" of loading – unloading of the power plants in the balancing market and thus the power that can be covered by WPP can be determined. For this judgment it shall always be considered that at peak demand level the WPP production could be almost zero and that the conventional power sources will have to participate to the peak demand level, so that the plants at which loading reduction have been made be able to generate – if needed – the entire available power.

It is important to agree the participation manner of WPP on the electricity market due to the fact that this problem is not regulated in Romania.

As it is known, most WPP have theoretically the possibility, by regulating the pitch angles, to reduce the active power generated down to the values asked by Transmission System Operator (TSO)/dispatch centre. One must establish the manner in which this compulsory reduction of the delivered power is treated commercially and financially, that is:

- if the producer does not ask for compensations (the payment of the damages resulted from non delivering the production) in which case the reserve has to correspond only to the sudden unavailability of WPP (as in the case of disconnecting any generating unit / power plant in NPS);

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- if the producer requests the payment of damages, in which case it has to be mentioned from the beginning the value of the production (electric energy) that can be taken over from system conditions (the load curve and the structure of the power plants, other than WPP).

Thus, one must establish a regulated risk level (Loss of Load Probability – LOLP, Loss of Energy Probability – LOEP indicators) that should represent one of the criteria for choosing a strategy for PTN development.

II. ASPECTS REGARDING THE INTEGRATION OF WPP INTO NPS

The wind power plants connection to NPS, according to the solution studies for grid connection made so far, mainly to 110kV networks (up to 150 – 200 MW) and of 400kV (300 – 1000 MW), imposes the reconsideration of the of elaboration manner for NPS development planning.

The connection of WPP to NPS has technical and economical implications. Unexpected high fluctuations of power flows due to the variation of the wind power are likely to appear. These variations are not always balanced by sources close to WPP location and may cause operation security problems. Special equipment for controlling power flows may be necessary. Additional high voltage lines may also be needed, which are both expensive and time consuming. Network congestions may take place due to WPP, which require new management methods and also introduction of FACTS. For the participation of WPP at the covering of consumption curve, the technical requirements for WPP have to be at the same level as for the conventional power plants in order to ensure the quality and safety of the supply. Primary, secondary and tertiary frequency control are largely influenced by WPP. The participation at the primary control of WPP for an important wind generation is still being discussed.

The necessary control reserve, mainly for tertiary control, can be significantly changed, according to the characteristics of the consumption and of the generation (except for WPP) in each power system.

The wind forecast management is very important, as well as the WPP production on areas, first of all on a short term: two days, one day, 4- 8 hours.

The long-term voltage stability is influenced by the replacement of the large synchronous generators connected to the high voltage grid, with small generators integrated in the 110kV and less voltage distribution networks. Thus the reserve of reactive power, without adequate measures, can be considerably reduced. Judging from the experience of other countries, one came to the conclusion that an additional support of reactive power (SVC, STATCOM, switchable capacitor banks, etc.) without which the voltage stability limit would be reduced a lot, is necessary.

As far as the short term voltage stability and transient stability are concerned, it is necessary that all the wind turbines provide the "ride through capability", therefore ensuring – as a rule – the operation security.

For the dimensioning of NPS, it is very important to know the participation capability of wind power plants to the peak demand level and to assure the required electric power.

It is important to mention that currently in NPS the total installed power in the existing sources (without WPP) represents 200% of the peak demand level. This is largely due to the radical decrease of consumption after 1989 (currently the peak demand is ~80% as compared to that of 1989) and the installation of the two nuclear units in Cernavoda NPP. The situation is estimated to remain the same also after 2018 – 2020, taking into consideration the installation of the following two units at Cernavoda NPP and the commissioning of some TPP and CPP (over 4000MW). The plants with fixed operation condition (NPP, CPP, run of river HPP) represent over 40% P_{inst}.

Taking into consideration that at the level of 2018 – 2020 the peak demand represents 60% of the available power, and the light load level for winter day (with heating, so production on CPP) represents ~26% of the available power without considering WPP, it is obvious that the production of the WPP requires that conventional plants take over, to a large extent, the frequency control, and operate often in partial load or stop more frequently. This manner of operation increases the costs and reduces the lifecycle of equipments in conventional power plants.

In order to analyze the development conditions of NPS one must select different scenarios regarding the consumption on area and in NPS as a whole and the power sources.

While the consumption is geographically attached, the sources can be theoretically considered in the scenario in different locations, the analysis being made considering the technical and economic aspects.

The following aspects have to be taken into consideration on stages:

- for WPP:
  - the installed and the available power, on each NPS area;
  - the power probably produced on consumption levels, with a certain risk level (with a certain probability).
- for sources excepting WPP:
  - their structure, with the indication of those with quick start up possibility;
  - the possibilities of operation with minimum technical load on a long term (hours);
  - control possibilities in real time.

The main aspect that has to be taken into consideration for NPS development scenarios is the fact that, as compared with the current methodology regulated by UCTE and EU for checking the operation conditions of power systems at the peak level of consumption, it is required to check the operation conditions on light load level each day when, for the national power system, the designed wind power to be installed (~ 7000MW in 2012) is approximately 70% of the light load level on working day.

In this situation, on one hand a structure resulted as necessary for the NPS sources has to take into consideration a regulation referring to the development of new sources and

power storage installations correlated with the appearance – in a high share of wind power sources – with a random production and on the other hand the PTN structure has to allow the operation in safe conditions considering modified power flows as direction and value.

The takeover of the surplus/deficits would involve an analysis considering – on each consumption level – of the WPP production in a range equal to zero and up to 100% of the installed power.

Depending on the characteristics of the consumption curve and structure of the power plants, the impact of the variation of wind power plants production at different levels of consumption can be highly important due to the influence on the economic and safety indicators in operation of the other plants.

Also, the imposed loading on some conventional power plants due to the production of wind power plants may bring very high variations of the losses in the transmission networks, due to the loading variations of the PTN installations, but also to the voltages in its nodes.

III. Considerations regarding the WPP connection to NPS

Regarding wind power plants Romania faces a large amount of grid connection requests for the period 2009-2020 of about 7000MW (grid connection studies approved by network operators).

A characteristic is represented by the future location – so far – of WPP in the same eastern part of NPS (70% in Dobrogea area and 25% in Moldavia area).

There are special problems regarding the power delivering from these areas – characterized by a reduced consumption – to the rest of the system. There are capacity limitations but also voltage stability limitations. For solving these situations it is necessary the construction of additional lines, long, costly and time consuming in conditions of uncertainty of these wind power plants construction and of the real power production.

In this situation the TSO decided to allow the construction of a minimum necessary number of 400kV lines and their related substations, taking however into consideration both the involvement of the wind power investors in a part of the necessary installations, but also their agreement that – at system congestions – the generated power should be curtailed to values requested by system operator.

It is also taken into consideration the building of a hydro pumped-storage power plant with an installed power of 4x250MW which however will be practically designed for assuring the tertiary reserve necessary for the 4^{th} nuclear unit at Cernavoda with a total installed power of 2800MW and which cannot provide frequency control.

It is considered that the improvement of the integration of WPP in NPS could be achieved by the Regulator and by new regulations through a correct consideration of WPP influences on the NPS development, such as:

- the issuing of establishment permits for the power capacities of electric power generation of public interest with an installed power of over 10MW taking into consideration the presence of wind generation;
- the issuing of establishment permits for the development of new transmission lines and substations;
- the correct establishment of the transmission tariff – which represents the only income source for the Transmission Grid Company (Transelectrica), in relation with WPP estimated development.

The increase of the wind power requires additional contribution of the conventional power plants and of interconnections to the ancillary services.

The medium and short term studies (including annual studies) have to consider a sufficient number of scenarios in order to determine the impact of wind power operation with fluctuating generation, on different levels of consumption, on the development of PTN and also on the interconnections (operation and also achieving the adequacy in the power system).

In this sense it is necessary to revise/complete the contingency criteria with reference to the system performance, to the economic criteria of achievement of the investments, including reinforcement of the interconnections.

The studies made in Romania analyzed levels 2012 (considering an installed wind power of 2635MW) and 2018-2020 (respectively with 3760MW).

In this stage, with the existing regulations, considering the uncertainty in the consumption prognosis, in the prognosis of conventional power plants availability and in the forecast of the wind production, the additional necessary tertiary reserve for the operation of WPP was evaluated first of all.

In order to satisfy the operation conditions for a period of 1 hour, taking into consideration the tertiary reserve necessary at present (the equivalent of the maximum power disconnected in a simple contingency of 12% from the peak demand level) and the takeover condition of 99,7% of variations, there resulted for 2635MW installed power in WPP (year 2012) 460MW, and for 3760MW (year 2020) 714MW.

A detailed analysis was made regarding the possibility to meet the load curves for characteristics winter and summer days, working days and holidays for the 2012 and 2020 stages (when the installed wind power may represent 60-70% of the consumption at light load hours), considering that all the TPP will observe the provisions of the Transmission Grids Technical Code and they will operate unlimitedly at 40% of the rated power and that for the storage hydropower plants there will be no contracts to limit the control participation, and the following results were obtained:

- in 2012 the possibility to integrate in the load curve a generated power of 450MW;
- in 2020 the possibility to integrate in the load curve a generated power of 558MW.

The power that could be installed in these conditions in WPP depends on the adopted probability for the development of the generated power.

If we take into consideration the fact that in most of the

areas where the WPP are to be installed the wind speed rarely exceeds 6 m/s, and the rated power is generally obtained at 10 – 11 m/s, a reduction [$6^3/11^3 = 0.16$] of 20% is obtained. In the instructions of TSO the wind power production is considered 30% of the installed power in WPP. It would thus result a possibility to take over an installed wind power of ~1500MW in 2012 (as compared with 2635MW approved) and of ~1850MW (as compared with 3760MW approved).

IV. Conclusions

The connection and operation of WPP within the Romanian Power System depends on the characteristics of the existing structure of power sources and networks, as well as on the consumption characteristics. With very high available power reserve, without WPP, with a consumption curve in which for the same day the light load consumption is 60% of the peak demand level, but without capable sources of safely and economically achieving the tertiary reserve, currently the connection of WPP cannot be accepted except to a limited extent and with corresponding measures.

Thus, at the level of the year 2012, a generated power of about 450MW could be integrated in the load curve (corresponding to ~1500MW installed power), and a generated power of about 558MW (corresponding to ~1850MW installed power) at the level of 2018-2020.

The assurance of the tertiary reserve corresponding to the installed wind power plants in the period 2012 – 2020, which is however a lot above the integration capability in the load curve, requires the installation of sources capable to continuously take over variations of up to ~700MW.

For operation security of NPS, the development of the 400kV network has to be achieved considering credible production limits for WPP and of their commissioning terms.

A special role is considered to be that of the regulations (including methodology) and of the Regulator which, through the establishment permits for the energy capacities of production of the electric power of public interest with an installed power of over 10MW, should take into consideration the presence and the features of WPP. Obviously, it results that the development of the new sources has to take into consideration the capability to provide frequency control (including Cernavoda NPP).

The information presented above represents a first stage in approaching the problems related to the impact of WPP connection to NPS. Next there have to be thoroughly analyzed the exposed problems having as an important element the accuracy of wind production forecast on a short, medium and long term.

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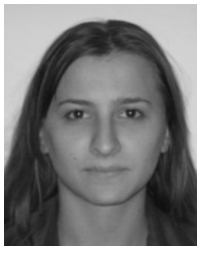
VI. Biographies

Anca Popescu is director of Institute for Studies and Power Engineering (ISPE). Member of the Romanian National Committee for World Energy Council and CIGRE. Mrs. Anca Popescu was coordinator and expert for different projects concerning: climate change, renewable sources, evaluation of GHG emission reduction options, least cost power and heat generation capacity, power system analysis, integrated resources planning studies, energy efficiency, forecast of electricity and heat demand, environmental impact, tariffs. Distinctions: The CIGRE Technical Committee Award in recognition of his outstanding contribution to the work of Study Committee C1 in 2005. Distinguished member of CIGRE in acknowledgment of his long standing collaboration to the work of Association in 2006.

Hermina Albert received the M.Sc. degree in electromechanical engineering from Bucharest Polytechnic School, Romania, in 1949. Currently, she is a Senior Consulting Engineer with the Power System Planning Department, Institute for Studies and Power Engineering. Author of 10 original books in power fields; 8 translated books from English and Russian; more than 350 articles of which 40 in foreign revues and conference books in power field. Initiator and co-worker at the achievement of the Romanian National Power Dispatcher Center; first chief dispatcher and manager (1955-1964). Author of the analysis method of the power installations safety using stochastic processes Markov type (Invention certificate 1965). Dictinctions: Aurel Vlaicu Prize awarded by Roumanian Academy 1974. She was a member of the Romanian Electricity Authority Technical Scientific Committee from 1953 to 1985 and member of Consultative Advisory Council of Romanian Energy Regulatory Authority (1999-2004).



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