MODELLING OF NETWORKS FOR ASSESSING THE CONNECTIBILITY OF A LIMIT POWER OF GENERATING SOURCES INTO THE DISTRIBUTION SYSTEM

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ABSTRACT

Operators of distribution systems with suitable conditions for wind power plant (WPP) operation have to examine the requests for WPP connection to 110kV networks, often with power higher than their transmission capacity. This paper describes one of the possibilities of quick examination of connection request. It describes the examination of connectibility of dispersed production in the Czech Republic.

INTRODUCTION

Newly established conditions for purchasing electricity generated by renewable sources in the Czech Republic attract a relatively great number of investors into this field, especially into that of wind energy. Therefore, when installing a higher power of these sources, a direct supply of their power into the 110 kV networks (maybe also into the networks of the transmission system) comes into consideration for technical as well as economical reasons. As opposed to MV networks, these networks are usually operated as interconnected nodal areas. In such cases it is no longer possible to assume a relatively simple evaluation based on the ratio between the power of the source being connected and the short-circuit power of the system at the point of connection, but a complex calculation is necessary which would respect the structure of the network and the loading of its individual elements.
The distribution network operators having regions, where there are areas with favourable conditions for installing large farms of wind power plants, are confronted with the need to decide how to react on new requests for connection into the networks which, at the first sight already, exceed both the contemporary consumption and the nominal power of supply transformers in many cases, and the connection of which would lead to high costs of modifying the networks which, in turn, would worsen if not at all eliminate the return on investments into building these generating sources. It is thus necessary to be able to answer the questions what power could be connected in a certain location without any modifications or with only small modifications required in the distribution network, and/or what power could be connected by direct lines into the supply transformer station of the nodal area, etc.
When evaluating the connectibility of these sources it is also important to respect new requirements on the behaviour of wind farms at failures in the network and on the inclusion of the wind farms into the active and reactive power control systems in the respective distribution system.
As a suitable approach we found the elaboration of models of individual 110 kV nodal systems in which the impact of individual wind farms on complying with the set limits may be verified interactively and limitations of the connectibility on the side of the elements of the distribution system (DS) may be identified.

ASSESSING THE CONNECTIBILITY OF SOURCES ACCORDING TO VALID REGULATIONS AND THEIR RISKS

Currently the conditions for the connection ability examination of sources in CR are defined in Annexe 4 Distribution Code (DC) [1]. These regulations are amended each year and so they can respond on new trends of connection ability examination eventually they can be completed by new knowledge. Validity of these regulations are accepted by the Energy Regulatory Office of CR. Regulations of connection ability of dispersed production have the origin in [3,4] for LV and MV and in [5] for level HV and EHV.
According to the situation the Distribution Network Operator (DNO) can ask the applicant to elaborate a study of connectibility.
Study of connectibility of power source has to contain technical examination, especially considering the limit of reverse actions on DS mainly for sources working to 110 kV networks.

- Voltage change caused by continuous operation of power source – (limit 2% for all sources in the network)
- Voltage changes at switching – limit 2% (1,5%)
- Ripple control signal attenuation (max. 10%)
- Flicker (max. 0,46)
- Harmonic current (limits taken from [3 to 5]
- and other criteria given in [1] depending on the power source character.

Examination of connectibility in the study should respect the unique approach defined in above mentioned regulations [1].
DNO usually requests the WPP connectibility examination, warranting neutral power factor in the point of delivery.
It is necessary to submit the study of examination within 90 days from the delivery of preliminary

standpoint. During this period, the demander can ask for postponing of the delivery time (only once), but he has to prove that he has started already with connection ability study examination.

THE TOOL FOR MAXIMUM CONNECTABLE POWER EXAMINATION

In relation to too many connection requests for high power renewable sources by investors, especially wind power plants in one 110 kV node area, special algorithms have been developed. It helps to determinate the maximum of connectable power in specified node areas. This has been implemented to the standard SW for evaluation of reverse consumer impact as well as connectibility of sources to DS. The SW tool (program E-Vlivy) is used by all DNO in the Czech Republic.

These algorithms help DNO with evaluation of preliminary power value, and assessment of suitability of proposed point of connection to DS. These algorithms respect following conditions:

1. dU < 2% - voltage change caused by connecting a source into the network may not exceed 2% (DNO has the possibility to definite higher or lower change)
2. current rating of all components of the examined part of the distribution system (DNO has the possibility to define the rate of load limit of different elements)
3. taking into account other possible sources being connected into the network which participate in the resulting voltage change. Individual cases cannot be evaluated separately but, on the contrary, a summarizing evaluation of their influence on the examined network is needed
4. In case of examination of connection ability of more sources with higher power output it is necessary to simulate the examined network with supply transformer (for networks of 110kV it is a question of 400/100kV eventually 220/110kV) and supply node of superior network. In case of the simplification of the network analyzer and transfer of supply node on voltage level, where the sources are connected, eventual excess load wouldn't be respected in case of overflow of power (in case of connection of higher power output this is a quite frequent phenomenon).

The algorithms are searching using iterating process and respecting the above mentioned conditions the maximal connectable power in nodes of simulated node area, where the power is injected. Following situations can occur:

1. Examined WPP farms don't exceed defined limit values – algorithms increase connectable power in points of connection only in case the defined level of power output is reached or their values in case some limit conditions are exceeded. In these nodes the maximal level of connectable power output is reached.
2. Examined WPP farms exceed defined limit values – algorithms decrease connectable power output in points of connection till the moment, when no limit condition is exceeded. In these nodes, the maximal level of connectable power output is found.

In case of successive examination of connection ability of WPP farms and determination of maximal connectable power output into chosen nodes of simulated network, DNO can determinate, which ones from simulated sources will participate on maximal connectable power output searching. It is possible to respect and conserve formerly accepted connectable power outputs.

Algorithms have the possibility to define, which nodes will be controlled for intensity of originated voltage change in the considered node areas 110 kV, which are the subject of examination as well as considering of modeling of nodes placed on lower levels of voltage in controlled networks of examined farms of wind power plants.

Nodes, which are not the subject of examination, however they have to be simulated (for ex. nodes at changes of cross-section of simulated line 110kV) can be eliminated from results of modeling. The aim is clarity of results. Process of WPP farms modeling has two levels.

- Equivalent of simulated WPP farms at level of 110kV
- Equivalent of simulated WPP farms at level of nominal voltage of simulated sources with respect of transformation LV/MV and MV/110kV

In the first case of WPP farms modeling neither reactance of block transformers nor reactance of transformation MV/110kV are respected. Capacities of MV cables used for bringing out of power are not respected too. Sources are simulated with neutral power factor; it means that only active power is injected to the node area of 110 kV.

After improvement of acquired power output the sources are simulated with more details according to 2nd point, it means that at least the parameters of block transformers and transformation 110kV/MV have been respected. Parameters of MV cables eventually of HV lines are not used, because of the fact that in the moment of examination, applicant is at the beginning of preparatory works and neither length of lines nor internal connection of examined WPP farm are known.

Examinations of other impacts of sources to network were not included. We suppose that this examination will be a part of individual studies of connectibility. This is also the case of the detailed network model of connected WPP farm.

In case of detailed modeling, the study of connectibility can cause increase of connected power output (from the point of view of voltage change), but on other side it can involve decrease of connected power output (considering of other examined impacts).

EXAMPLE OF EXAMINED NETWORK

Application of above mentioned algorithms are shown on following examples.

Example 1

First example is a node area, where investors are supposing to build 8 WPP farms. Short circuit capacity in supply node at 110kV is c. 1240MVA; power output of supply transformer is 200 MVA. Total acquired power output for connection to distribution system 110 kV is 294 MW. At modeling of node area loads we used summer data (160 MW, 21 MVAr).

The extent of network model is shown on the scheme (see Figure 1). Point of connection of different farms WPP has been fixed by DNO.

One of the requirements for modeling of connected power was neutral power factor in points of delivery.

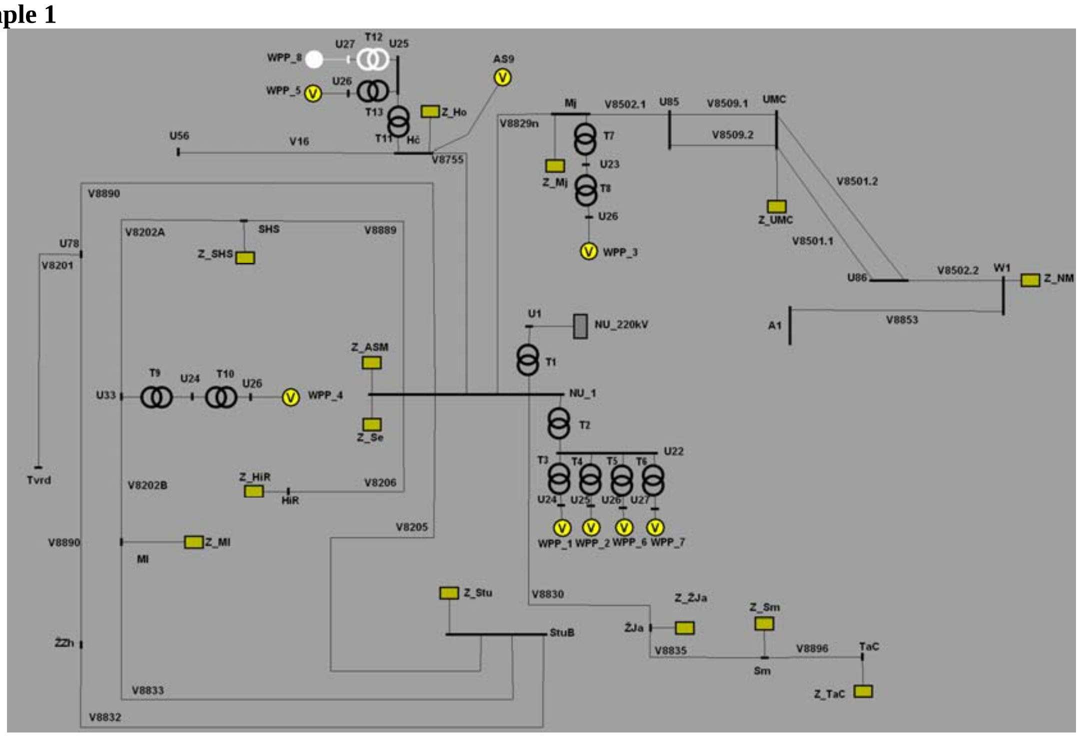

Figure 1: Scheme of modeled distribution system

On the Fig. 1 we can see that elaborated network model of node area includes also elements of the transmission system, supply transformer EHV/HV and EHV supply node, because of above mentioned reasons. Designed network models of WPP farms are corresponding to examined state of maximal connectable power output for WPP farm number 8.

Others of examined WPP farms have been verified in previous steps of modeling. Results of modeling are seen on the table bellow. Red marked values point out the elements, where it was necessary to decrease the acquired power. The column named "Max. connectable power [MW]" expresses the value of maximal connectable power in the point of connection of WPP farm defined through the above described algorithms.

Farm WPP	$P_{requested}$ [MW]	Pn source [MW]	Max. connectable Power [MW]	Limit factor
WPP 1	64	2	365,5	In transf. EHV/HV
WPP 2		2		
WPP 3	48	2	64	du
WPP 4	48	3	40	du
WPP 5	28	2	23	du
WPP 6	8	2	14	du
WPP 7	46	2	27	du
WPP 8	46	2	7	du

The table shows, that in the case of examination of connectibility of WPP farm number 8, the maximal connectable power is substantially lower then the acquired power.

In case we examine the farm in detail we will observe, that from the point of view of voltage change it is possible to connect up to 12MW. This value of power is necessary to be examined also with respect to other impacts.
In the table we can also see, that the factor, which limits the maximal connectable power is the voltage change, caused by cumulative impact of applicants.

Example 2
The second example of these algorithms application shows examination of WPP to node area 110kV supplied by two transformers 200MVA, short circuit power of supply node on the side of 110 kV is 2440 MVA.
13 applicants asked for connection into this node area. Total acquired power for connection is 546MW. Total load of this node area is approximately 103 MW, 24MVAr. From these values can be seen that extensive overflow to transmission network occurs.
Regarding relatively high value of short circuit power given by parallel operation of two supplying transformers, voltage change is not limiting factor, but the possibility of overloading of some lines in the examined node area. In case of examination of 11th and 13th applicants is to be seen an exceeding of the supply transformers ratings. In case of these applicants it is possible to connect less power, than is acquired. Especially in case of 13th applicants the decreasing is (demanded is 50MW, connectable is only 11MW).

CONCLUSION

The paper describes algorithms used by DNO to relatively rapid examination of requests for connection to node areas 110kV.
Limit conditions of algorithm is voltage change of 2% and nominal load limit of elements transporting the injected power. We consider modeling of power injection with neutral power factor in the point of delivery.
Algorithms are used especially for control of voltage changes caused by connection of WPP sources and load limit of modeled node area elements as the main limiting factor for WPP sources connection.
Examination of connectibility from the point of view of other examined impacts as for example: flicker, ripple control signal attenuation, harmonic current and voltage and short circuit power contribution will be elaborated in the detailed study of connectibility. The reason is that in case of eventual exceeding of limits of other impacts than voltage changes, technical arrangements are possible for their decreasing to acceptable limits.
The paper also shows particular applications of these algorithms on 2 examples. Limiting factor for networks with lower short circuit capacity is the voltage change caused by the activity of connected sources, while in case of networks with higher short circuit capacity the main limiting factor is nominal load limit of elements. The results refer also about possible problems in case of power overflow to transmission system.
For modeled node area is possible to definite maximal connectable power to selected node using relatively easy process.
The described tool for examination of maximal power connectibility is used by 2 DNO for 13 node areas of 110kV.

LITERATURE

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