CONNECTING OF DISTRIBUTED ELECTRICITY SOURCES TO ELECTRIC POWER SYSTEM

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ABSTRACT

Increasing share of renewable distributed electricity sources is one of possibilities how to cover growth of electricity consumption. So far, these sources have insignificant contribution in energy balance in Slovakia. Interest of investors in sources installing is very intensive and reaches some GW. Electric power system, built-up on centralised basis, is not adapted for this situation. In this article, connecting conditions for distributed electricity sources in Slovakia are analysed and the example calculation for connecting is presented.

KEYWORDS

distributed electricity sources, renewable energy sources, distributed generation, connecting conditions

1. INTRODUCTION

Renewable energy sources (RES) are often applied as distributed energy sources (DES). They exist as small and dispersed sources of electricity. These sources are connected to lower voltage levels according to their location and size. Nowadays, these sources reach an installed power almost 100 GW and number of installed units is several ten thousand. Continual growth of prices and decreasing reserves of non-renewable energy sources causes the interest in utilisation of renewable energy sources. The aim is also to clear of dependency on oil, gas and other fuels [1].

During gradual growth of installed power, problems of cooperation between these sources and the present centralised electric power system began to occur. The problems are caused by territorial configuration of network and location of distributed sources, which are situated mostly in places, where electricity consumers have existed by now.

The advantage of distributed generation (DG) is evident only if the plant is built in places with near energy source for its operation and sufficiency of close consumers. Only because of surplus or deficit of produced electricity, the cooperation with electric power system is needed. It induces an adaptation of existing network configuration at the connection point. Because of sizeable installed power of DES in near future, the solution needs also long-time accumulation of large volumes of electricity [2].

The intensive interest in installing of RES requires the optimization of connecting conditions for these sources to eliminate their negative impact on distribution system operation. These regulations have to avoid the unreasonable building-up of DES, but also to enable their installation in the suitable places.

2. CONNECTING CONDITIONS OF DISTRIBUTED ELECTRICITY SOURCES

It is necessary to observe legal procedure for connecting of DES to distribution system. Every distribution company in Slovakia determines these procedure steps in accordance with the Energy Act No. 656/2004, government regulation No. 317/2007, valid rulings of ÚRSO and technical conditions of distribution system operator.

Every regional distribution company in Slovakia asserts its defined procedure and conditions for connection of electricity source to distribution system. The most detailed procedure was elaborated by the distribution company in Eastern Slovakia VSD, a.s. [3], [4].

2.1 Impact of DES connecting on power system operation

Feedback impacts of DG on power system are shown mainly as voltage changes and harmonic effects [5], [6]. Immediate notable effects are:

- flicker – brightness variation of light sources,
- influence on remote control and signalling devices, computer techniques, protection and measurement devices,
- moment swinging of machines,
- additional warming of condensers, motors, filter circuits, transformers,
- incorrect operation of ripple control receivers and electronic control.

Feedback effects on distribution system can be manifested by:

- decline of power factor,
- increase of transmission losses,
- influence on ground faults suppression.

To evaluate feedback impacts of DES, it is necessary to determine:

- *ratio between the short-circuit power at the connection point and rated power of connected source (short check of connectivity)*
  If this ratio is more than 500, further feedback checks are not necessary. With the ratio less than 20, the connection of DES is not possible.
- *voltage increase at the connection point caused by source operation*
  During the operation of DES, voltage at the connection point can increase by $\Delta u \leq 3$ % on low voltage level, and $\Delta u \leq 2$ % on medium and high voltage levels.
- *voltage increase at the connection point caused by source switching*
  During DES switching on and switching off, the evaluation of voltage changes is similar to previous check, but with reference to switching frequency and generator type.
- *flicker factor*
  Value of flicker factor c is given by producer of used device or independent institute. Its evaluation is the most important for wind power plants. Flicker factor is calculated using measured value of long-time flicker P_{lt}, short-circuit power at the connection point S_k, source power S_{nG}, and with reference to relevant angles:

$$c = P_{lt} \frac{S_k}{S_{nG} \cdot \cos(\psi_k - \varphi_i)}$$

  If this value is less than 20, it is not necessary to test DES regarding the flicker.

- *higher harmonics amount*
  Higher harmonic components of current originate mostly in devices with invertors or frequency convertors. Information about current harmonics, generated by these devices, is given by producer. Acceptable values of higher harmonics are listed in [4].
- *influence on ripple control signal*
  Ripple control devices operate with frequency range 180-1050 Hz. Transmitted signal radius is limited by barrier gates. It is required, that DES do not generate and operate with the ripple control frequencies and do not influence on ripple control signal within network.

3. EXAMPLE OF DISTRIBUTED ELECTRICITY SOURCE CONNECTING

Solution of distributed electricity source connecting to distribution network is possible to illustrate on next example.

Electricity source with installed power $S_{\mathrm{nDES}} = 9$ MVA will be connected to the network. The network is already built, so it is necessary to find suitable common feed point (PCC) of distribution system. There were 3 possible scenarios of DES connection to the system. Existing lines are divided to line fields with various types (overhead, cable) and sections. In scenario No.1 (Fig. 1), DES will be connected to the line fed by electric substation 110/22 kV (Substation 1). Substation transformer has power 25 MVA and short-circuit power in substation is $S''_{\mathrm{kQ3}} = 206$ MVA.

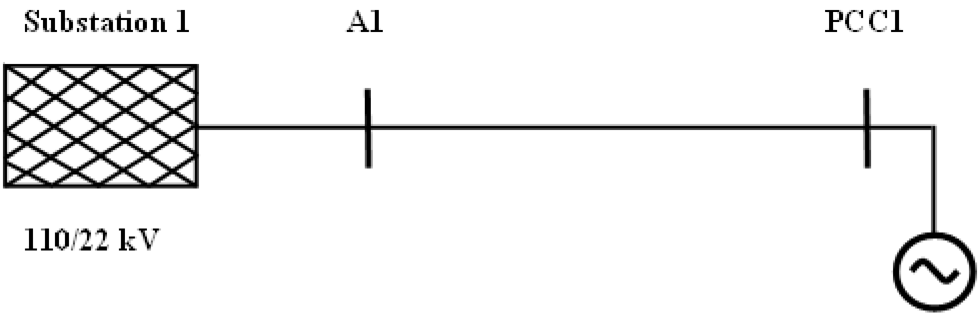

Fig. 1 Network scheme of scenario No.1

Short-circuit current and short-circuit power at the point PCC1:

$$I''_{kPCC} = \frac{c \cdot U_{nQ}}{\sqrt{3} \cdot Z_k} = \frac{1 \cdot 22 \cdot 10^3}{\sqrt{3} \cdot 4{,}971} = 2{,}555\ kA$$

$$S_{kPCC} = \frac{c \cdot U_{nQ}^2}{Z_k} = \frac{1 \cdot \left(22 \cdot 10^3\right)^2}{4{,}971} = 97{,}361\ MVA$$

Short check of connectivity:

$$\frac{S_{kPCC}}{S_{nDES}} = \frac{97{,}361 \cdot 10^6}{9 \cdot 10^6} = 10{,}818 < 20$$

This value is less than 20, so it is not possible to obtain satisfactory operation of considered source in present configuration.

To calculate the maximal joinable power of generator at the connection point with respect to voltage increase condition (max. 2 %), it is considered complex network impedance with its phase angle ψ_k:

$$\Delta S_{DES\max} = \frac{2\%\ S_{kPCC}}{\left|\cos(\psi_k - \varphi)\right|} = \frac{0{,}02 \cdot 97{,}361 \cdot 10^6}{\left|\cos(65{,}28° - 0°)\right|} = 4{,}656\ MVA$$

Calculated maximal joinable power is less than rated power of supposed DES (4,656 MVA < 9 MVA). It means that this scenario is not suitable according to voltage conditions.

This situation can be solved by several methods to fulfil the conditions for connecting of distributed electricity sources:

- change of location of PCC to the point with higher value of short-circuit power,
- increase of short-circuit power at supposed point by decreasing of circuit impedance:
  - by increasing of short-circuit power of substation (installation of transformers with higher power),
  - by rebuilding of line to decrease its impedance.

4. CONCLUSIONS

Complex solution of electric power system configuration is necessary in the course of distributed electricity sources connecting. The goal is maximal adaptation of the system for connecting of all perspective sources, including distributed ones, in Slovakia and also in conditions of interconnected electric power systems [7].

Calculations in chapter No.3 show, that in some cases the connecting of distributed electricity sources is not possible at all, or the connecting is possible only with corresponding changes in network.

At the present time, investor requirements for sources installing are over the real possibilities of our electric power system. According to long-time aspect, it is necessary to locate all perspective sources, their types and sizes. This information should be consequently included in scheduled network reconstruction and renovation to achieve the reasonable and efficient utilisation of sources [8].

Considering the global economical and ecological problems, it is necessary to focus on new energy-saving technology applications. It enables significant decreasing of electricity consumption in compliance with European Union aims [9], [10], [11].

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