POSSIBILITIES OF BLACK-START WITH USING RENEWABLE SOURCES ENERGY

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ABSTRACT

The risk of a large loss of power supply (blackout) cannot be entirely excluded. Therefore the power grid has to be prepared for power restoration. One possibility of power supply restoration after blackout is a black-start of one energy source and starting up self-consumption of a larger power station.

Due to rapid increase in renewable energy sources installed power, many new large-enough power plants have been built in recent years. These power plants would be sufficient to power-up self-consumption of a larger power plant.

This paper evaluates the possibility of starting self-consumption of coal power plant Ledvice using wind farm Kryštofovy Hamry.

Key words: *Black-start, renewable energy sources, dynamic modeling*

1. INTRODUCTION

The risk of a large power grid failure (blackout) can never be completely ruled out, as experience from abroad shows [1]. Network operators must prepare recovery plans, which address situations where power is lost parts or the whole system. One of the possibilities is a black-start of the selected source, building paths between the source and drives of self-consumption of a larger classic power plant. After starting its self-consumption drives power generation can start with connecting the generator to network. Afterwards, re-connecting customers and gradually expanding the network can start.

This paper examines possibilities of starting self-consumption drives from an isolated source by simulation on a dynamic model of the electricity grid in northern Bohemia. This model allows the examination of dynamic behavior of various types of turbines (steam, water and gas) and thus the stability of the whole island. This paper deals with the start of a steam power unit Ledvice. The model allows studying time courses of and frequency of the network and verifying the success of start-up. As a computational tool network simulator MODES is used.

2. MODELED SYSTEM

For investigating the possibility of starting-up self-consumption drives of Ledvice power plant from wind farm Kryštofovy Hamry the shortest electrical route was chosen, see Fig. 2. The wind farm as a sole source for simulating black-start consists of 21 turbines (ENERCON type E 82) with output power 2MW each. Each turbine includes a synchronous generator with frequency convertor and is capable of output power control by changing the blade angle [2]. This source has been assigned a modified dynamic model of model generator ‘PMGC’ and turbine model ‘WIND’ in MODES (detailed description of the two models is in [3]).

2.1 Wind speed course

Stochastic course of output power of renewable energy sources is the biggest challenge these resources face. In case of black-start the situation is even worse because in an isolated system lacks another source that would compensate sudden powers drop of the renewable source.

For analyzing this particular system we have chosen the course of wind speed from the afternoon of 24th Nov 2010. Wind Park Kryštofovy Hamry was supplying full power to the grid until 13:00, but between 13th and 16th hour wind speed decreased and thus the power supplied to the grid dropped to 12 MW, see Fig.1. This situation is especially unfavorable for black-start.

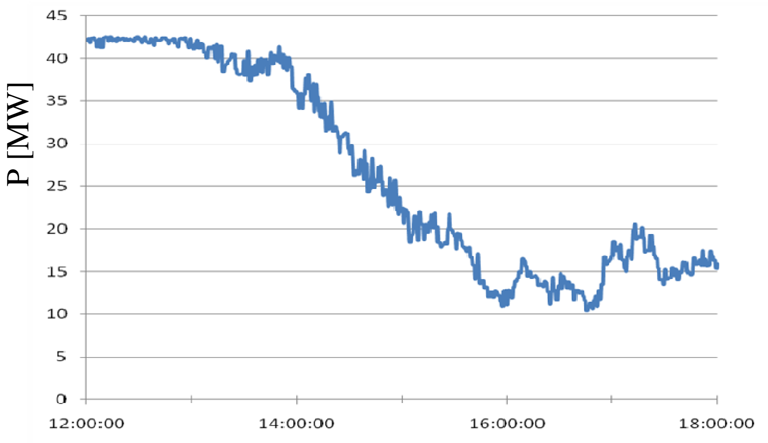

Fig.1 Progress of performance of wind park Kryštofovy Hamry 24. 11. 2011

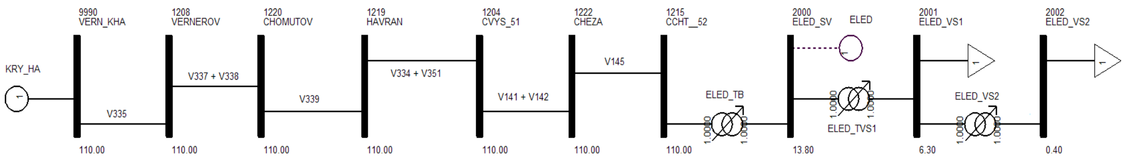

Fig. 2 Scheme of modeled system

2.2 Self-consumption model

Modeled self-consumption drives match those installed on blocks 2 and 3 of Ledvice plant. Self-consumption is linked to the secondary side of power transformers at voltage levels 6.3 kV and 0.4 kV. It consists of 15 induction motors with a total input power of 13.1 MW, for details see Tab. 1. In MODES simulation software these induction drives are modeled as asynchronous motors (model 'ELM2' – asynchronous motor with a double cage) and the corresponding model of driven equipment (fans, pumps and mills).

Tab. 1 Self-consumption drives

Self-consumption drive	Voltage level [kV]	P [MW]
Atomizer	0.4	0.5
Cooling water pump	6.3	2 x 0.57
2nd level Condensate Pump	0.4	2 x 1.6
Block smoke fan	6.3	2 x 0.86
Desulfurization smoke fan	6.3	1.2
Feeding Pump	6.3	3
Fan beater mill	6.3	4 x 0.42
Air fan	6.3	2 x 0.35

3. SIMULATION CALCULATIONS

The above-described modeled system was used for simulation of long-term dynamics, lasting over 4 hours. During that time the self-consumption drives were powered-up and wind speed was changing linearly in 12 min intervals according to Fig.1.

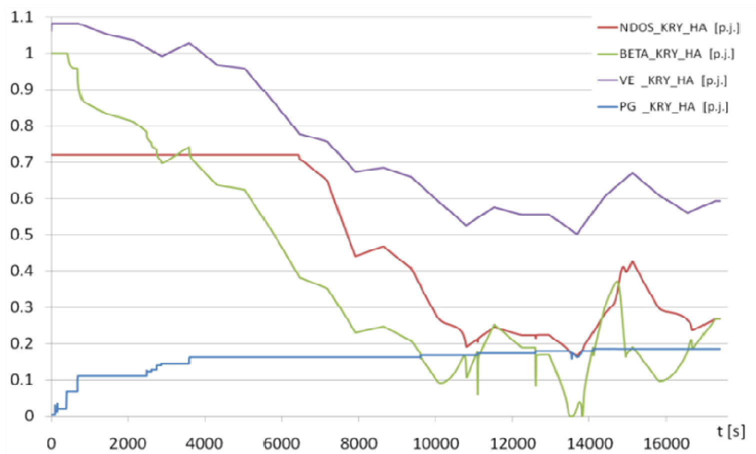

Fig. 3 Simulated waveforms variables of wind farm Kryštofovy Hamry

In Fig. 3 the following variables are plotted:

- NDOS - available output power
- BETA – pitch angle of wind turbine blades
- VE - wind speed
- PG - active power of wind generator

The Fig. 3 shows the effect of decreasing wind speed (purple) which the wind turbine compensates by reducing the blades pitch (green). With the decline in wind speed the available output power (red) decreases as well, but the active power (blue) fed to the island grid is not affected (the wind farm operates with a large-enough power reserve to cover the varying power demand during starting-up asynchronous drives). However, before 4th hour of the simulation (14,000 s) wind speed drops so low that the active power supply to the system is limited.

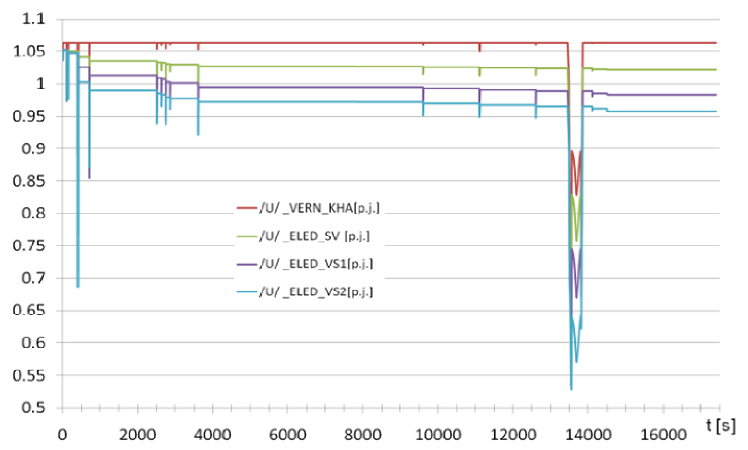

Fig. 4 Simulated voltages of selected waveforms

Fig. 4 shows the waveforms of voltage in selected nodes:

- VERN_KHA - 110kV side of the wind farm transformer
- ELED_SV - the voltage on the primary side of self-consumption transformer of Ledvice power plant
- ELED_VS1 - the voltage on the secondary side of self-consumption transformer
- ELED_VS2 - secondary voltage of self-consumption transformer 6.3/0.4 kV

The Fig. 4 shows a significant short-term dips in voltage during start-ups of large induction motors, especially when starting-up both condensate pumps (2 x 1.7 MVA) within 1 minute.

Furthermore, a big drop in voltage of down to 53% of the nominal value at the time before the 4th hour (14000s) of the simulation can be clearly seen. At the 110kV side of the wind park transformer voltage drops by 20% during 20s. This drop is too fast for it to be compensated by tap changing. As a result, the voltage on the output inverter of wind turbine drops, which causes the inverter to be turned off.

This decrease is in detail shown in Figure 5, where the following courses are rendered: active (PM, blue) and reactive (QM, orange) input power of condensate pump induction drive and its voltage (/U/, violet).

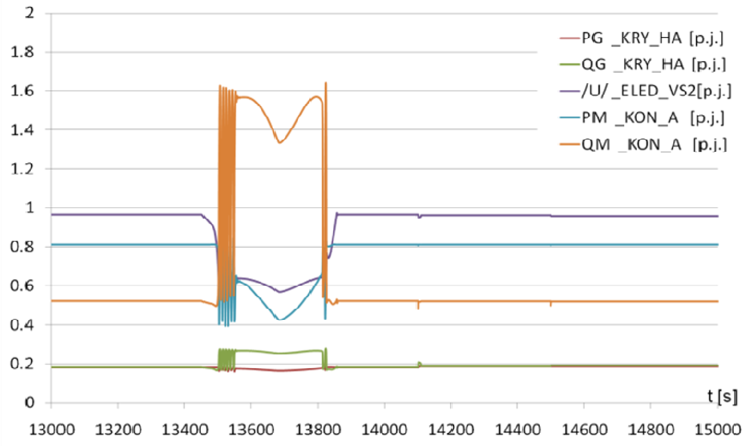

Fig. 5 Detail time period with a lack of power

In the Fig. 5 the step change in reactive power (to 160%) is alarming. A more detailed analysis shows that it is caused by the growth of slip of induction motor, which reaches up to 20%. Induction motor is hampered and therefore the reactive power consumption rises. Growth in consumption of reactive power causes further voltage drops and thus the engine power drops which are accompanied by a further increase in slip. The so-called voltage avalanche occurs, which can result in an engine stop. Simplified dependence of active and reactive power at rated motor voltage (stator resistance and magnetizing current is neglected) is shown in the following Fig. 6.

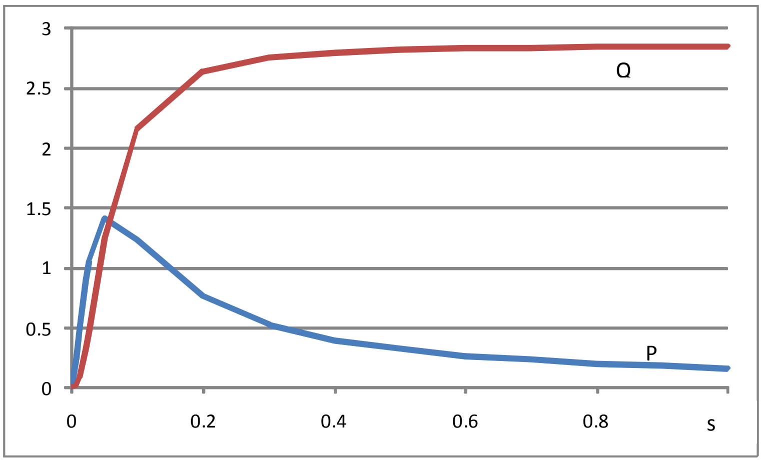

Fig. 6 Dependence of active and reactive power at rated motor voltage

It must also be noted that without a decrease in wind speed (and thus the active power) these problems would not have occurred and the system would have been stable at all times.

4. PRECONDITIONS OF A SUCCESSFUL BLACK-START

Given that the present rules of operation of distribution or transmission system do not require renewable energy sources to be capable of island operation or black-start manufacturers do not include these features in them. But because the wind is blowing and the Sun shines without additional energy supply, these sources are good candidate’s black-start operation. However, in order to operate the service these sources must gain some new abilities:

1. Black-starting itself (without support of grid voltage)
2. Maintain a constant frequency of 50Hz and power balance (adjusting by speed and power)
3. Accurately predict wind speed (choose an appropriate time to start with constant wind conditions).

4.1 Black-start

To black-start itself a wind turbine shall be equipped with backup power supply such as batteries or diesel generator [4]. This source can energize the inverter and activate the power management system. Afterwards the wind turbine can generate electric power.

4.2 Maintaining constant frequency and power balance

To successfully operate in an isolated grid, it is necessary to maintain power balance between consumption and production while keeping the nominal grid frequency 50Hz.

To ensure power balance it is necessary for turbines equipped with power converters to have accurate data on consumption in the isolated system. When black-starting self-consumption this is not an issue because size and order of drives started-up is known in advance. Moreover, the whole consumption is located in one place. Should an island operation occur, determining exact momentary consumption could be done by measuring immediate consumption of load. However, this is impossible today. In the future, once the smart household metering device (smart meter) becomes common, this will be possible.

5. CONCLUSION

This study shows that a black-start using renewable energy sources is possible under certain conditions One of the most important prerequisites is to ensure sufficient power from the wind. Otherwise a black-start using this source is impossible. Study also shows the functionality of innovated models ‘PMGC’ and ‘WIND’ when simulating wind turbine operation into an isolated load. Basic condition for a separate operation is the turbines ability to work with power reserve, from which it can cover rapid increase in load.

6. LITERATURE

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