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Investigation of Wind Power Parks Islanding Conditions in Small Parts of Smart Power System

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Introduction

Wind power stations which are working with power converters have control chain to measure the frequency and voltage in connection point and according these measurements the converters output values are operated. During emergencies of power system when frequency and voltage in network are dropped down, the converters of wind station do not can to work and wind stations are disconnected from system (Fig. 1).

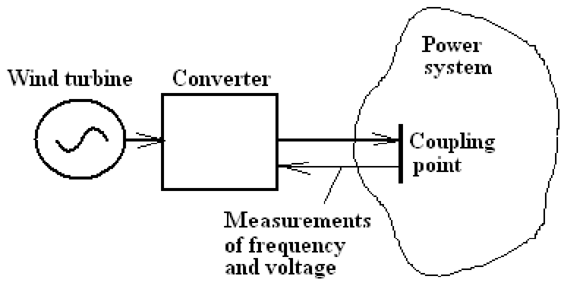

Fig. 1. Measurements of frequency and voltage in coupling point

If wind powers stations parks are tangible parts of system generations' capacity, unexpected lost of uncorrupted generators are heavily governed situation [1]. One of possible solution of this problem can be creating of small power systems, sometimes named as microgrids in conjunction with concepts of smart power system's information system [2]. The microgrids were developed to involve the renewable energy sources and considerable number of experiments was performed in many universities of European countries and US [3, 4].

The necessity part of small power system is local synchronous generator which can be for example renewal thermal or hydraulic generator and which can be guide for strike and regulate local frequency ant voltage. The key role of this generator is balancing of active power in small power system, because wind station parks production has very changeable character [5].

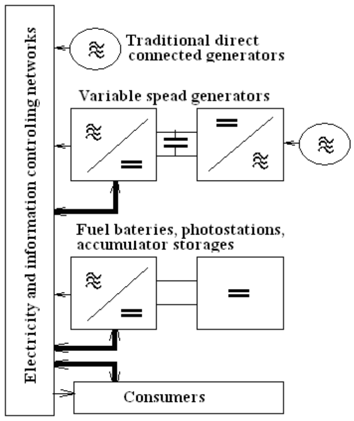

Fig. 2. Scheme of small power system's elements

Small power system architecture

Idea and research of small power system are targeted to wide-ranging renewable energy sources utilization [6]. In place of low voltage microgrid the small part of electricity power system, whish consist from several high voltage (110 kV) lines and its generators' and consumers' substations (Fig. 3).

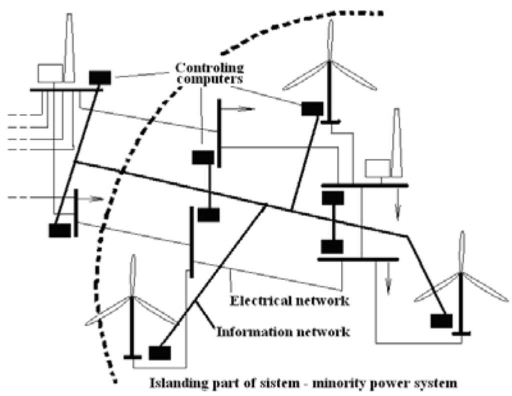

Fig. 3. Small energy system as an islanding part of system

The small power system can be named as midisystem. The control system of small power system must to work independently and to operate power balancing, frequency, voltage and its quality by information network and consist from controlling units.

Researches show that small power system can not work without continuous leading synchronous generator, which is worked as frequency etalon. Wind power parks and solar photovoltaic power stations can to work together in small power system when power storages units or accumulators batteries are worked together. These storages are smoothed out the peaks of generated energy and consumers demands maximums. Smooth operation of future electrical energy system is possible by having developed network of various models of storage system.

Small power systems can start to work only during emergencies time of big power system or it can be continuously working part of big system. In this case new smart control and management tasks can be realized (Fig. 4).

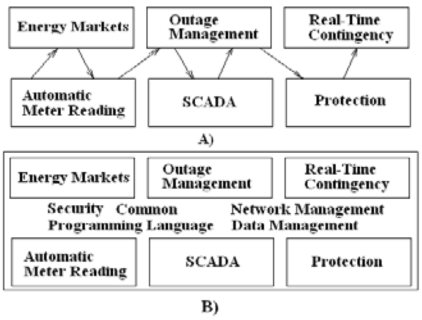

Fig. 4. Small power system's control and management systems

Overload, fault and disconnection possibility is increasing due to limited power line capacity. Possibility The creation of small power systems and its working in island regime is one of methods to increasing power supply reliability overall. Proper preparation for island regime, preparation of local power generation for autonomous control and further operation in island regime are essential objectives of new control and management system.

Other purpose of small power systems is involvement of energy consumers in active power balancing. Smart control device, for example, smart meter should track momentary electricity price and control consumer‘s electric equipments which may standby for cheaper energy.

In further future the extension of electrical car park will became new part of small power system, because it will be powerful energy storage factor.

Model of small power system

Small system model consists from one 110 kV line sector with its consumers and thermal power station with two generators and two wind parks on the strength (Fig. 5).

The basic regimes of small power system were simulated. At firstly the moment of disconnection from big system and creation of islanded conditions was investigated.

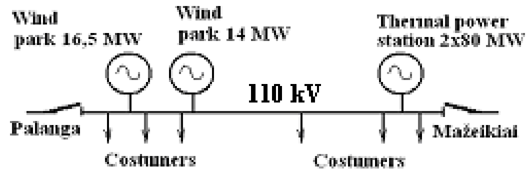

Fig. 5. Example of small power system

Steady – state regime of SES describes nodal voltage and power flow in lines. Simulation is performed by changing 110 kV line voltage, changing the WPP generation at minimum, average and maximum powers according to summer and winter seasons. WPP generates reactive power for its own use.

System balance between generation power and consumption power at different frequencies maintenance is based on

$$P_{\mathrm{Gf}} - P_{Af} = 0. \tag{1}$$

Program. The "Mustang" program which can to calculate transients in power systems was used for simulation. If fault happened in electrical energy system, the 110 kV transmission line would be disconnected from system by opening of ties circuit breakers. The consumers of small power system are essential (Mažeikių nafta, Klaipėda port, Būtingė oil terminal and villages or small towns (Židikai, Skuodas, Lenkimai, Šventoji, Palanga, Tauraukis and other)).

The basic modelling conditions. The main generator is Mažeikių PS maintaining frequency, voltage, active and reactive power balance. Voltage must not exceed ± 10 % of the nominal voltage. Different regimes of minimum, average and maximum in summer and winter mode of wind power generation is performed.

Regime is simulated when WPPs are generated maximum, average and minimum power. Generator voltage range is form 10 kV to 11.5 kV. Voltage change while WPPs generate nominal power and generator voltage on generator terminal is 10.5 kV. Voltage change is in 10 % range. Reactive power varies from 9 Mvar to 13 Mvar in different regimes.

Mažeikių thermal station consists from two 100 MW generators. However generators are limited to 80 MW by turbine. Presently generators load is at level of 20 % of power, which is 16 MW. Generators of Mažeikių stations are main part of small power system, because its frequency and output voltage are etalons for all in small power systems incoming wind power generators.

The main consumer is oil refinery plant with 55 MW of active power and 3.5 Mvar of reactive power demand. Mažeikių station had generators with instantaneous change 7 % of 80 MW power, or totally 2x5.6 MW.

Minimal power generation of one generator is 2 % per minute of 80 MW power, both – 3.2 MW/min. Reactive power generations limits is from 20 Mvar to 85 Mvar at 80 MW power generations.

Simulation. Simulations of the transient processes have been performed, when a small system separates from the electrical energy system, for example, most of the system in the event of an accident. Short circuit occurred in the substation of Varduva of 110 kV line near Mažeikiai station

The changes of voltage and frequency are described in Fig. 6, Fig. 7.

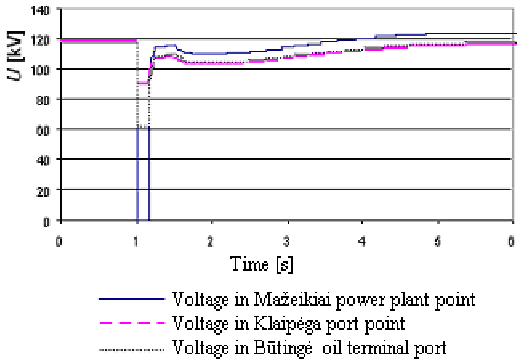

Fig. 6. Voltage change during disconnection while system generates 17 MW and wind power generation is according to area average wind

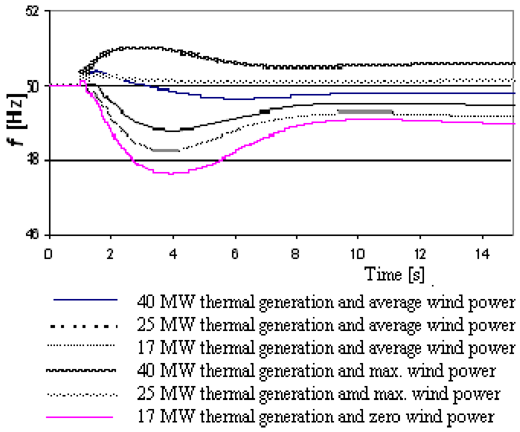

Fig. 7. Small system frequency change after disconnection

The transient process of generator power is as maximum continued for 10 s – 15 s and finished when stabile regimes were achieved. The transient regime of voltage continued 4 s only. The results of short circuit simulating are described in Fig. 8.

Small power system power fluctuates during disconnection moment and in short circuit regime was investigated. Active power and reactive power change in 14 MW wind power park point during disconnection are given in Fig. 9.

The wind parks power changes were measured every 2 minutes in real time. From the point of view of simulation the most complicated operation moment was in 2200 minute cycle, when wind power fluctuation up to 10 MW per 2 min is presented in Fig. 10.

The capability of thermal generators to change its output power is only 6.4 MW/min or 12.8 MW per 2 min. The regulation of frequency in small power system is complicated task and only common efforts by thermal and wind generation units it can by solving.

These limits put forward requirements to control equipment and programmes of small power system.

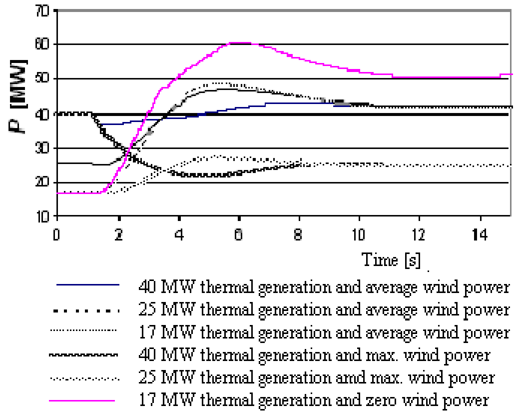

Fig. 8. Generator power change at different regimes in small system where short circuit location is on 110 kV line (Mažeikių station – Varduva substation)

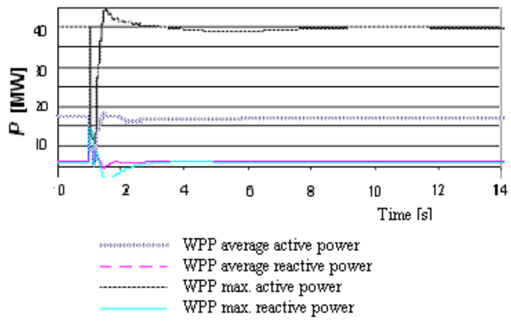

Fig. 9. Active and reactive power change in 14 MW wind park point during disconnection from network system while thermal generators generates 2x40 MW

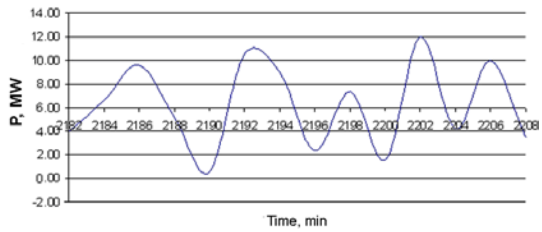

Fig. 10. Wind power park's generated power during the period

Load forecast model must be applied for this region after disconnection. Mažeikių station generators are loaded based on load forecast model.

Disconnected small power system must to balance and to regulate voltage rapidly, in order to ensure the quality of system operation real-time control system must be installed. The investigation shoes that to this control 5 s periods are suffice.

It is essential to forecast wind power parks generated power that small power system's generators and consumers might prepare for disconnection and control and management system could calculate the future price of electricity.

Detection when small power system can to disconnect and start to work separately is described in [7].

Electric engineers are very interested in electric car development and widespread usage. Firstly, electric cars are environmental friendly using electricity instead of gasoline. Secondly, electric car park is a powerful electricity consumer capable of variable power consumption of excessive electrical energy system generated power.

Decentralized electrical energy system development would provide competitive energy supply to the market besides the expected direct economic benefits. Electrical energy system development is faster and more efficient because of open market conditions which priority is the most efficient market solutions.

However, there is no experience how operates small power systems and if there is impact to energy cost and expenditure [8]. It is essential to accumulate as much as possible reliable and practically tested solutions while small power system's operational standards are being created. In the future the power storage units must to play important role too.

Conclusions

Small electrical system can be created with the installation of complex control and management system, in advance to forecast power balance between generators and consumer, control and regulation devices which are necessary to supply power in the grid. If the source is generating too much power excessive power is allocated to energy storage or wind power parks have to be disconnected.

Small power system would shut down if the main generator was disconnected during the short circuit, but a small system could to start work if wind parks have emergency diesel generator that can start as small system again.

Small power system's dynamic and static stability tests identify that disconnected systems can operate independently, generators reaction speed is sufficient to compensate the changeability of wind power generation and the balancing of small power system is capable to implement.

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The work of wind stations is analyzed in condition of small power system, which is established in complicated moments of large energy system, when breakdown or other bottleneck regimes are occurred. The switching of wind power parks to islanding regime as small power system can by one of means to keep wind station in work state, because now in emergencies of system wind stations are disconnected and stopped. An analyzing transients of islanding moment and transients of short circuit where can be took place in small power system is performed in this paper. The requirements to smart control of small system are formed. Several directions for the future research were offered. Ill. 10, bibl. 8 (in English; abstracts in English and Lithuanian).

T. Deveikis, E. Nevardauskas. Vėjo elektros parkų darbo salos režimu mažose išmaniosios elektros sistemos dalyse tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 1(107). – P. 99–102.

Analizuojamas vėjo elektrinių darbas yra mažosios elektros sistemos sudėtyje. Ši sistema sukuriama sudėtingais didžiosios elektros sistemos darbo momentais, kai įvyksta avarinis atjungis arba kai pasunkėja darbo sąlygos. Vėjo parkų perjungimas dirbti mažosios elektros sistemos sudėtyje gali būti vienas iš būdų išlaikyti vėjo elektrinių darbinę būklę, nes dabar per sistemos avarijas vėjo elektrinės atjungiamos ir stabdomos. Šiame straipsnyje pateikiama pereinamųjų vyksmų, atsiskiriant nuo sistemos į salos režimą ir trumpojo jungimo akimirksniu, analizė. Pateikiami mažosios sistemos išmaniajai valdymo sistemai keliami reikalavimai. Aptariamos tolesnio tyrimo kryptys. Il. 10, bibl. 8 (anglų kalba; santraukos anglų ir lietuvių k.).