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SGEM D 4.4.1 TSO needs and communication requirements

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Introduction

Subtask 4.6.1 Technical Potential for Virtual Power Plant (VPP) and Distribution System Operator (DSO) in SGEM aims for investigating virtual power plant from the power seller's, distribution company's and transmission system operator's point of view. In the first stage, the subtask also discusses load control possibilities for peak shifting and temporary network capacity problems. The subtask works under the task 4.6 Potential for Demand Response (SGEM WP 4, Task 4.6).

This document takes part in the subtask 4.6.1 focusing on virtual power plants. Main interests consist of different TSO needs and services that may provide a working base for VPPs. Such features cover among others spinning reserves, fast reserves and balancing power. Key issues that arise relate to the power flows established by reserve holders, reserve reaction times and reliability. These features set requirements for communication and ICT systems in use of reserves. This document aims for assessing these requirements for giving a realistic view of the possible use of VPPs as a part of TSO services. The information in this document has mainly been gathered from the Finnish TSO (Fingrid Oyj, as of now Fingrid) web pages ([1]) and an interview with Fingrid presentatives Minna Laasonen and Timo Kaukonen ([2]).

TSO system and balance services

General

The Finnish transmission system operator (TSO) Fingrid Oyj is responsible for the technical functioning of the Finnish power system and, therefore, maintains system services. These services can be listed as follows:

- Maintenance of operational reliability
- Maintenance of frequency
- Maintenance of voltage
- Data exchange

In order to attain full maintenance of the grid Fingrid maintains several power and transmission reserves. Fingrid must provide a reserve base that is sufficient enough to handle errors or faults in the Finnish power system. These reserves should also be cost-efficient and arranged by the rules of the power system operation agreement that involves all the other Nordic TSOs. The reserves are produced partly by Fingrid but mostly by other parties like electricity producers and reserve holders. Many of the reserves are used only during grid faults to avoid large disturbances. However, some are even used during normal operation conditions.

In normal operation situation Fingrid is responsible for maintaining power balance in the Finnish grid and for providing the nation-wide imbalance settlement. Each operator in the electricity market is obliged to maintain its power balance continuously. In reality, this is always achieved with the help of another party – i.e., supplier. An operator supplied by Fingrid is called as a balance responsible party. Balance responsible parties have responsibilities related to imbalance settlement and balancing power market.

Maintenance of operational reliability

TSO needs to assure that disturbances in the power system are minimised, and that restoring the power system after a fault is possible. Disturbances should be cleared as quickly as possible.

The Finnish power system has been dimensioned according to common principles agreed upon by the Nordic countries. The power system should withstand any possible single fault, such as disconnection of any generator, transmission line or power transformer, in such a way that the fault situation does not lead to a major disturbance. The worst possible fault depends always on the operational situation of the power grid and is referred to as dimensioning fault.

In order to minimise the disturbance situations in the main grid, electricity transmission should be kept within certain limits. Transmission is controlled based on operational reliability calculations that pay attention to grid faults. According to Fingrid web pages, the transmission limits are established in order to disable "loss of synchronised operation, voltage collapse, disconnection of loads, too large voltage frequency deviations, overloading of grid segments, or self-sustained electromechanical fluctuations". Sometimes the transmission in the grid is hindered by so-called bottlenecks or congestion. Usually these situations emerge when the grid experiences a fault or electricity consumption in one area is too high compared to the offered transmission capacity. From the maintenance point of view, the grid is often exposed to planned outages. Careful planning of transmission lines ensures a disturbance-free, purposeful operation.

The power system involves both power and transmission reserves. As Fingrid is in charge of and responsible for these reserves, it not only uses its own resources but purchases reserve maintenance from other reserve possessors. In case of major disturbances, Fingrid controls the restoration of the power system from its Power System Control Centre.

Fingrid is prepared for disturbances in the grid. There are a couple of ways to handle unpredicted incidents. For one, frequency controlled disturbance reserves react to changes in the grid frequency that are incurred by unpredictable faults (active power). Secondly, fast disturbance reserves include both active and reactive power reserves. These reserves are manually controlled and should contain enough capacity to cover the dimensioning fault of the grid. After activating a fast disturbance reserve, the power grid should be ready for another potential disturbance. A few of the fast disturbance reserves are equipped with a black start feature that can be used for a dead grid (zero voltage). Fingrid has a few gas turbine plants offering this feature. Black start reserves are used in case of major disturbances. However, should there be a major disturbance in the Finnish grid would the voltage be restored primarily through a Swedish 400 kV substation.

Maintenance of frequency and voltage

The nominal frequency of the inter-Nordic grid is 50 Hz. When the grid frequency drops below this figure, consumption is greater than production. In normal situation the frequency can vary between 49.9 Hz and 50.1 Hz. The grid frequency can be maintained through active power reserves – i.e., spinning reserves – and balancing power market.

The frequency controlled normal operation reserve and frequency controlled disturbance reserve react automatically to grid frequency variations. When they are not sufficient enough to maintain the grid frequency, manual up-regulation or down-regulation is implemented through the balancing power market.

The balancing power market is maintained by Fingrid, as it doesn't have its own regulating capacity for power balance. Basically, possessors of electricity production or loads submit bids to the balancing power market. Balancing bids can be comprised of any resources that can implement a power change of 10 MW in 15 minutes. As the balancing power market is hour-based market, the bids can be left no later than 45 minutes before the specific hour. Up-regulating bids are meant to increase the frequency of the grid. On the contrary, the down-regulating bids decrease the frequency – i.e., the bid contains an increase in consumption, a decrease in production or the resource holder buys electricity from the TSO.

The grid voltage also tends to change during the normal operation. Changes are incurred by load situation in the grid. Overvoltage and undervoltage may induce losses and deviation from the specified nominal transmission voltage (e.g., 110 kV). The grid voltage is controlled by reactive power reserves in connecting parties' generators, reactors and capacitors. Reactive power reserves are automatically activated in such cases where a disturbance has incurred a voltage drop in the grid. Generator reserve holders are paid compensation by Fingrid for reserving reactive power capacity from their generators.

Power balance and reserve capacity

The power system is kept in balance continuously. It doesn't always need a grid fault or disturbance to make the grid drift into a tight situation. Fingrid has three steps for keeping the power system in balance in tight situations. In a situation where forecasts tell the power production is not going to be sufficient enough for the next hours, Fingrid will notify the balance responsible parties which will prepare themselves for strained power balance. If fast disturbance reserves are used in order to maintain the power balance, the grid is said to suffer from power shortage. During a power shortage the grid is more vulnerable to failures. The most serious power balance situation is called as serious power shortage where all the power reserves are in use and Fingrid has to restrict consumption.

The three power balance situations involve grid operation without grid faults. However, grid faults exist. For minimizing disturbances each TSO in the Nordic transmission system are obligated to maintain power system reserves. Fingrid procures its reserves from the annual market (Finland), through Russian and Estonian transmission links, as well as daily from the hourly market inside the Nordic area.

Reserve providers – e.g., a Finnish power plant – can choose to provide Fingrid their services voluntarily. They don't have to serve both the annual and hourly market, thus they can decide how to participate in the reserve maintenance. Compensation paid by Fingrid to the reserve holder is similar to every participant – i.e., provider of frequency controlled normal operation reserve and frequency controlled disturbance reserve.

Table 1 introduces the maintenance of reserves in Finland (2011).

Table 1: Maintenance of reserves (source: http://www.fingrid.fi/portal/in_english/services/system_services/maintenance_of_frequency/)

Reserve	Availability	Need
Frequency controlled normal operation reserve	Power plants: - Annually contracted 71MW - Hourly market 50 MW DC-links: - Vyborg 100 MW - Estonia 50 MW	**139 MW** (The Nordic system totals 600 MW)
Frequency controlled disturbance reserve	Power plants: - Annually contracted 244 MW - Hourly market 298 MW Disconnectable loads - 40 MW	**220 – 240 MW** (The volume of the largest dimensioning fault in the Nordic grid divided to the Nordic countries weekly in proportion to the individual dimensioning faults)
Fast disturbance reserve	Gas turbines: - Fingrid 615 MW - Contracted capacity 203 MW Disconnectable loads: - 425 MW	**880 MW** (The volume of a dimensioning fault)

Frequency controlled normal operation reserve must activate fully in three (3) minutes when the grid frequency experiences a sudden change of +/- 0.1 Hz. The reserve must stay activated after three minutes if the grid frequency deviates from the nominal 50 Hz. The operation scope of frequency controlled operation reserve is thus the normal operation grid frequency 49.9 – 50.1 Hz. The dead band – that is deemed to be the minimum frequency change to which the reserve reacts so that the activated power increase is measureable – should be at maximum +/- 0.05 Hz in frequency regulation.

When the grid drifts into a situation out of the scope of normal operation, disturbance reserves are needed. Frequency controlled disturbance reserve is that part of the active power reserve which begins to activate after the grid frequency drops to under 49.9 Hz. This reserve should be fully activated when the grid frequency reaches 49.5 Hz. 50 %-implementation level is reached in 5 seconds, whereas the full utilization level is attained in 30 seconds. These time limits and utilization rates help to make a difference between frequency controlled disturbance reserve and normal operation reserve. After all, the both reserves may be provided by only one generator.

The volumes of frequency controlled reserves are case-specifically determined in the annual maintenance agreement concluded by Fingrid and the reserve holder. However, in the hourly market maintained by Fingrid there are limitations for bidding these reserves. Frequency controlled normal operation reserve are sold in blocks of minimum 0.1 MW and maximum of 5 MW, whereas frequency controlled disturbance reserves are bought in volumes of 1 to 10 MW.

Reserve holder of frequency controlled reserves is obligated to go through regulation tests that confirm the suitability of the power plant machinery for Fingrid's purposes. Regulation tests are made in coordination of Fingrid. The test is repeated every ten years or when the machinery is changed somehow.

As a result from the regulation tests – i.e., step response tests – one is able to assess statics for the machinery. Statics describes the effect of a relative change in the grid frequency to the following change in machinery output power (see the formula below). The change values are compared with the nominal values of grid frequency and machinery output power to get relative change values.

$$Statics = \frac{Relative\ change\ in\ grid\ frequency}{Relative\ change\ in\ system\ output\ power} * 100\%$$

There might be several statics used by one machinery or reserve holder. Statics should not exceed 6 %. The ability to contribute to the automatic frequency regulation is referred to as regulation power. It can be calculated from the division of changes in power output and grid frequency. The formula can be written as follows:

$$Regulation\ power = \frac{\Delta Power\ output}{\Delta Grid\ frequency}$$

The basic technical requirements for maintenance of fast disturbance reserves are rather simple. The reserve plant must have a nominal power of 10 MW minimum and it must provide the contractual power in 15 minutes. The plant should provide its service for at least 90 per cent of the time with a starting availability of minimum 90 per cent. The plant must provide Fingrid real-time measurement information on circuit breaker state and starting availability. Fingrid must also have the opportunity to give a starting command to the plant in its operation control system. Reserve holder must provide Fingrid information of all events immediately after them taking place. These incorporate failed starts and disturbances that have prevented the availability of starting the plant. Three (3) days after the event, a sufficient report must be forwarded to Fingrid. The reserve holder shall report to Fingrid also monthly and annually.

Figure 1 illustrates the fast disturbance reserve capacity used by Fingrid for emergency use in the nation-wide grid. Plants on blue background are owned by Fingrid, whereas the yellow ones are in possession of other companies. The power plant on green background in Forssa will be built in 2012.

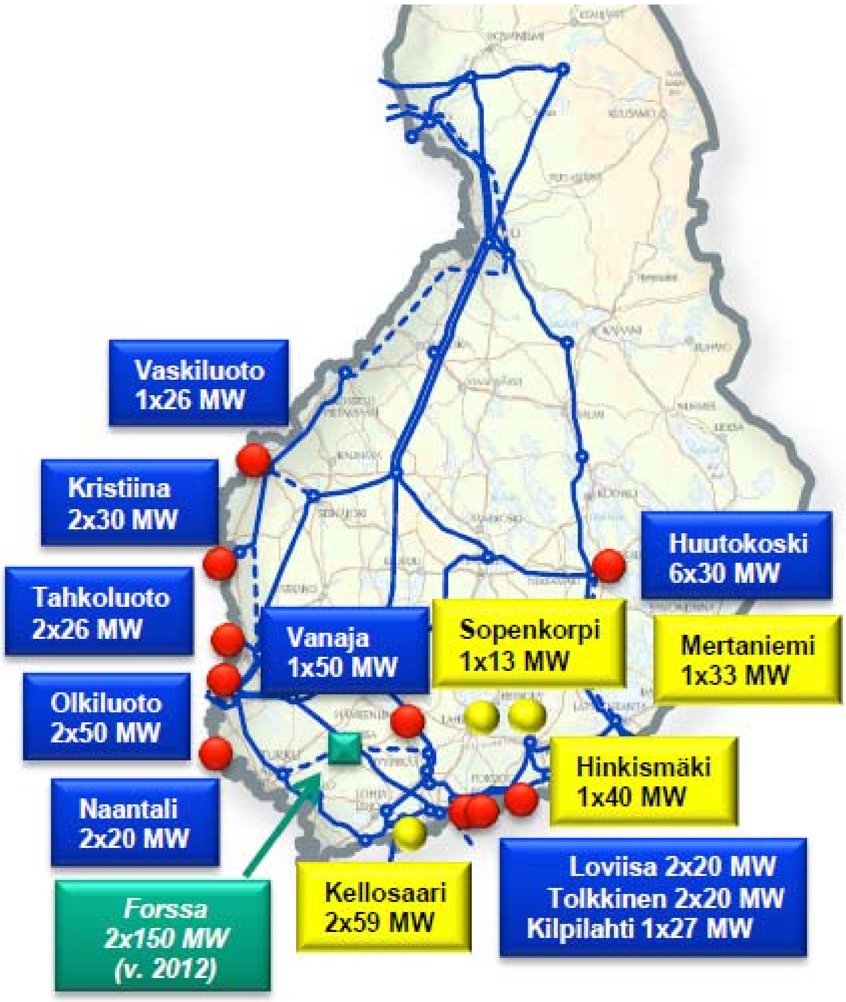

Figure 1: Fast disturbance power plants for emergency use in Finland (source: http://www.fingrid.fi/attachments/fi/yritys/varavoima/varavoima_forssa_su.pdf)

In addition to cross-border DC-link transmission and straight power plant power reserve, disturbance reserves utilize disconnectable loads. In Finland 425 MW of disconnectable loads provide maintenance of fast disturbance reserve. Only around 40 MW of disconnectable load is used for maintaining frequency controlled disturbance reserve.

For sufficient maintenance of disturbance reserves, disconnectable loads must fulfil some essential requirements. The availability of the load should exceed or match 7000 hours per year with a net effect of regular 15 MW at minimum. During a disturbance, the load should be disconnected for at least three (3) hours. To be aware of the disconnectable load situation, Fingrid must have an access to real-time load measurement information.

Disconnectable loads can function as momentary reserve, fast disturbance reserve or frequency controlled disturbance reserve. The momentary reserve – i.e., disconnectable load – is meant to subsidize Olkiluoto 3 power production in case of nuclear reactor power outage. The system protection shall be ready when the Olkiluoto 3 nuclear power plant is on trial.

Table 2 introduces the compiled information about various reserve power and balancing power specifications including the availability requirement for each option. The availability is an expectation value which is considered when checking the realized functioning of a certain reserve for a specific time period.

Table 2: Simple time and volume requirements for different types of power capacities provided as power reserves or balancing power

<table>
<tr><th>Type of power capacity</th><th>Minimum (or maximum) unit size</th><th>Activating time
(seconds, minutes)</th><th>Availability
(expectation)</th></tr>
<tr><td>Balancing power</td><td>10 MW</td><td>15 min</td><td>100 %;
Balancing power market</td></tr>
<tr><td>Frequency controlled normal operation reserve</td><td>0.1 MW (5 MW)</td><td>3 min</td><td rowspan="2">100 %;
Hourly market</td></tr>
<tr><td>Frequency controlled disturbance reserve</td><td>1 MW (10 MW)</td><td>5 sec (0...50 %);
30 sec</td></tr>
<tr><td>Fast disturbance reserve</td><td>10 MW</td><td>15 min</td><td>90 %
(with a starting availability of 90 percent)</td></tr>
<tr><td>Disconnectable load
(separate requirements)</td><td>15 MW
(for at least 3 hours)</td><td>1 Momentary reserve (Olkiluoto 3): a unique connection with “no time delay”

2 Frequency controlled disturbance reserve: 5 sec

3 Fast disturbance reserve: 15 min</td><td>7000 hours / 100 %</td></tr>
</table>

Data exchange

The maintenance of operational reliability in the power system requires adequate information practices. Planning and measurement data from the grid is exchanged between the TSO and participating reserve holders. According to Fingrid web pages such data includes "production plans, generator power measurement, and status data on generator circuit breakers and connecting stations". Fingrid has formulated data exchange principles for establishing rules for connections between the TSO itself and other parties. These principles apply to several contracts, agreements and licences – e.g., reserve maintenance agreements, reactive power agreements and balance service agreements (balancing power market). Sometimes it may be appropriate to agree upon the rules within a separate data exchange agreement.

In order to sufficiently implement system responsibility Fingrid has the right to receive necessary technical and operational information from other parties. The TSO provides information related to the system security to other parties. All the connecting parties are allowed to receive this information.

Fingrid provides the connecting party with extensive information concerning connecting party's connecting substation (i.e., busbar voltages, circuit breaker status, and line bay state), power measurements (active/reactive), control options and alarms, as well as other essential information on the connecting substation agreed upon separately.

The connecting party may be an electricity producer or another connecting party contributing to the power system. An electricity producer should provide Fingrid with the following information (real-time):

- Power measurements (active/reactive) of thermal generators of at least 30 MVA and circuit breakers' state information. The measurement information of smaller units can be presented as a sum of separate components.
- Power measurements of hydropower generators of at least 10 MVA and all machinery utilized in the maintenance of frequency controlled reserves, as well as state information of circuit breakers. The measurement information of smaller hydropower generators than 10 MVA can be summed up and provided as one measurement information.
- Information requirements set down by reserve and balance service agreements – e.g., production planning information or calculated reserve information.

A connecting party without electricity production has the obligation of providing Fingrid with the next information:

- Real-time power (active/reactive) and voltage measurements, as well as state information. This information shall be provided to Fingrid especially if the network section is in parallel operation with the main grid.
- Control options and alarms to certain extent.
- Load power measurements and state information within a reserve maintenance agreement.

There are several possible ways of exchanging information in the power system. Fingrid utilizes a few information exchange techniques presented in the following list:

- Elcom or ICCP – best suitable for transferring measurement data and state information of switchgear.
- Remote terminal units – part of operation control system for obtaining information from substations.
- EDI messages for hourly series information – i.e., information on energy measurements, balance settlement, production plans, history information, state of loads and production, electricity prices, as well as transmission confirmations.
- Web – specific individual information exchange between Fingrid and other power system participant, e.g., real-time production information.
- Internet and Extranet – open information intended for everyone in the prior, information with limited access in the latter. Extranet is a working base for balance settlement system where imbalance settlement and balance management information are presented to balance providers and other parties.

Regarding the speed of data links Fingrid has not assessed any strict values. In practice, power reserves are allowed to take time for implementation according to the agreements. This was covered before in Table 2 (see activating times). Since frequency controlled reserves are controlled locally, there is no separate connection link for initiating the reserve from the Fingrid's Power System Control Center (PSCC). On the contrary, the reserve recognizes the need for power back-up or down-regulation from the varying grid frequency in its location.

However, the fast disturbance reserves are controlled by centralized means. The PSCC in Helsinki calls for the implementation of a reserve by phone or activates the reserve through a separate, physical connection link to the reserve (e.g., gas turbine). Fast disturbance reserves are expected to activate in 15 minutes as told before.

In addition to having a right timing and functionality, reserves should be reliable. Fast disturbance reserves are expected to function with a 90 %-probability (Table 2). It can be assumed that the malfunctioning or inoperability of some fast disturbance reserves is calculated to this figure. The reliability of the frequency controlled reserves is expected to be around 100 %, and if the realized usage values differ from the expected ones, reserve holders are obliged to pay or receive sanctions agreed upon in reserve maintenance agreements.

Fingrid has been pushing through a reinforcement of physical data connections. The reliability of physical connection links usually reaches up to 95 %. For improving the overall reliability of grid-related communication, important links are made double so that the overall reliability comes close to 100 %.

Prospects for VPP use within maintenance of reserves

Little by little, the use of more variable power resources in the TSO's maintenance of operational reliability, grid frequency and voltage is getting more common. Various domestic appliances, as well as electric cars and small-scale electricity generation could benefit the power grid working as power reserves. In Finland, there is also a remarkable potential in electrical storage heating for power reserve use. To utilize the full potential of these, a party functioning as a VPP could gather together electrical capacity from various sources in order to provide it further to the TSO.

VPPs should of course fulfill the requirements of maintenance agreements etc. However, Fingrid looks at the reserve use open-minded. Whether a small-scale production or capacity constitutes a competitive alternative to other power reserve offerings, it could certainly be utilized. What comes to the physical, electrical requirements specified in Table 2 Fingrid is flexible. Reserves can be used as agreed, which means that every reserve capacity is observed separately and even half-yearly contracts etc. could be possible.

References

1. *Fingrid.* 2011. Available from: <http://www.fingrid.fi/portal/suomeksi>.

2. *Interview with Minna Laasonen and Timo Kaukonen. Fingrid Oyj*. 12 August 2011.