ABSTRACT

The paper deals with the possibilities of utilization of the distributed power generation systems in the conditions of the Czech Republic. The influence of the dispersed generation in the medium voltage networks on voltage quality is analysed. The paper summarises problems considered of general interest in voltage fluctuations, flicker, harmonic distortion, interharmonic distortion and the effect of the dispersed generation on ripple control signals. The influence of the dispersed generation on the voltage stabilisation, line losses and short circuits impedance is also investigated. A basic analysis of the possibility and effectiveness of using a parallel active filter to compensate reactive power and terminal voltage variation for the constant speed wind turbine flicker is presented.

The modern methods of the choice of the most suitable power source for the given area are described. These sources bring new specific technical operation problems i.e. voltage level, stability in a island operation state, the quality of the power supply. The possibilities of the approaches to those tasks are mentioned in a case study.

It is necessary do develop power operation and power quality management system by a communication infrastructure and optimization tool for the distribution network operator. This device performs power quality monitoring and control and optimizes network operation through distributed generation control and demand side management. It enables integration of dispersed energy sources in distribution network at high penetration level.

The main task is to use dispersed generation with renewable energy sources with minimal impact on the environment. For optimal economical and environment friendly impact it is necessary to find a compromise solution with two conflicting objectives: the minimum of the total operating costs and the minimum of the total emissions.

1. INTRODUCTION

Increasing energy consumption, diminishing conventional sources and environmental sources and environmental aspects made people think of the utilization of the renewable sources in the conventional power systems. In the Czech Republic there are not favorable natural conditions for the construction of larger power generators based on renewable energy sources. This is the reason why the development of the distributed power generation closely relates to the renewable power system expansion. At present renewable energy facilities are mostly situated in the rural areas. With respect to the State Energy Policy the possibilities of the expansion of these power systems in urban environment are being examined, which is also stressed in special chapters of the regional energy conceptions constituted nowadays.

In the primary energy source choice process for the given area a lot of facts must be calculated. There are two basic ways how to supply a locality with the energy. One of them is to transport the needed energy by means of conventional power systems. The second one is to produce it directly in the location of its consumption. Both ways can be combined. The first method is still more frequent, but on the other hand small power generators located as near as possible to the energy consumption are more and more important. Before building such a small power generator it is necessary to analyze following problems:

- character of the demand for electricity in the given area (load curves analyses)
- availability of the chosen primary energy source
- power network accessibility
- influence of the generator on the power network environmental issues.

2. INFLUENCE OF THE GENERATOR ON THE POWER NETWORK

Within new projects in the future in supplying local areas, a Power Operation and Power Quality Management System (PO PQMS) must be developed. PQQMS will be a communication infrastructure and optimization tool for distribution grids that is expected to perform power quality monitoring and control and to optimise grid operation through distributed generation control and demand side load management. On this basis it enables and mediates integration of renewable energy sources into energy grids at high penetration level. The functionality of the PQQMS
system will cover several aspects: technical and economic optimization of the grids with high penetration of Dispersed Generation (DG) units, power quality monitoring and security/safety aspects.

A second task will be interventions in case of irregularities (stationary power quality events: under- or over-voltage etc.). Thus POPQMS may comprise long-term operation/optimization strategies mid-term prophylactic/prevention, as well as strategies for short-term reaction/intervention patterns. In the long term, with very high degrees of dispersed generation penetration, grid operators will probably need more flexibility than they have today. Finally, the management of energy flows in island grids or even black-start capability can be tackled with POPQMS.

In synthesis POPQMS is expected to collect information about topology and power quality in the network segments, local strategies for power quality improvement, schedules for economically and technically optimised operation.

A POPQMS system implementation consists of a central unit and a communication infrastructure, which connects Dispersed Generation and measurement units to POPQMS. To achieve as much flexibility and “plug & play” as possible, a strongly decentralized architecture must be chosen.

2.1 The dispersed generation in MV distribution network

Due to the recent opening of the market in EU and incidental increasing amount of Distributed Generation Systems, a need for a new type of voltage control is rising. Network automation by modern Distribution Management Systems (DMS) provides substantial benefits by improving the cost-efficiency of the network operation: customer-oriented functions and network-oriented functions.

Due to progress of liberalization, more and more customers are able to choose freely their provider. At the same time, the whole standards constituted by the regulatory authorities must be respected. However, Distribution networks have not be primarily designed for connecting a large amount of DGS, which is still increasing. For a proper VRF implemented regulation functioning, a compliance and revaluation of those regulatory standards are necessary.

On a network without DGS, HV/MV feeder is optimised by integrating downstream network states with minimal/maximal load hypothesis to avoid undervoltages that may occur at peak-load time or overvoltages that may occur at minimal-load time. Case study of 5 MW generator connected to MV line in region Central Bohemia is studied. Without distributed generation, the voltage decreases along MV feeder (see the red line). Generator has a tendency to increase the voltage at its connection node. After connection of the generator, it appears a voltage peak at node of connection. The other lines represent operation states for various power factors.

To avoid overvoltage, the generator will be commonly requested to downsize its installed power. However, if managed properly with a real-time regulation function considering current load level, DGS will be able to higher their generation capacity and also can improve voltage support capacity.

2.2 A new DMS Voltage Control Function

Voltage of HV/MV transformer is set down to avoid overvoltage in MV network with respecting connected generator voltage peak. Such type of voltage regulation requires real-time system information. Therefore it arises a need for improvement of measuring and data preprocessing by a load flow calculation function (e.g. FACE based on Back Forward Step algorithm using fuzzy logic).

The Voltage Control Function (VRF) can control several device types for real-time voltage regulation. Firstly, the VRF changes reactive power of DGS synchronous generators to improve the MV feeder voltage profile. At second step, the VRF will provide the HV/MV transformers with computed set point values. The regulation is realized by changing the transformation ratio of on-load tap changer. This is why the Voltage Regulation Strategy should coordinate all the available on line voltage setting devices and be designed at a global level.

Voltage regulation strategy by VRF is realized as following. After computation of electrical state of the network, the node voltages are compared with their target values. For each node VRF computes Node Voltage Quality Index (NVQI). Value of NVQI depends not only on difference between real voltage and target voltage, but
also on its gravity and importance of the customer it affects. To obtain a global assessment of voltage quality, Global Voltage Quality Index (GVQI) is introduced. The function optimizes GVQI, the voltage constraints are eliminated (reduced) considering their gravity. The target node voltages aim to minimize the losses and customer voltage requirements.

First VRF priority is the safety, thus at first step danger overvoltages (human life and electrical devices safety) and alert undervoltages (power system stability) have to be eliminated. Then for each node the value NQVI is assigned:

\[
(NQVI) = \sigma_{n,k}^{n,k} = \frac{(U - U_{REF})}{(U_{REF} - U)}
\]  

(1)

Once the danger overvoltages and alert undervoltages are treated, remaining constraints must be eliminated. For each node index. Main factors for \( \sigma_{n,k}^{n,k} \) determination are:

- The importance of the node from the voltage quality point of view (depending on the sum of contracted power)
- The historical voltage data of the customers
- Possible contractual specificities of the customers

The GVQI at cycle \( k \) is computed by following relation:

\[
GVQI = \frac{\sum_{i=1}^{n} \alpha_{n,k}^{n,k} (U - U_{REF})}{\sum_{i=1}^{n} \alpha_{n,k}^{n,k}}
\]  

(2)

3 ENVIRONMENTAL ASPECTS OF THE ENERGY SOURCE CHOICE

However the influence of the generator on the power network is not the only relevant issue to deal with. That is why the environmental impacts of mentioned power sources must be analysed. Environmental issues have become more and more important. The monitoring of the pollutants closely relates to the environmental problems and it is one of the most important aspects that must be respected in the process the choice of the energy source. It is evident that there are relevant differences among basic kinds of fuel.

For easier decision-making in appropriate electricity supplies various supporting tool are available. They are based on the principle of mathematical processing of the data that are relevant in the decision-making process. It is also necessary to formulate the decision-making criteria properly. The criteria are related to the economic efficiency assessment of the examined power source.

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If an effective decision-making tool based on the economic efficiency assessment of the examined variants and the methodology of the data collection is available, it is possible to choose the best option without unwanted uncertainty. The best variant is the optimal power source in this case. But it is really necessary to get all relevant inputs including evaluated environmental influences related to building-up and running the examined power source.

The approach to calculating the environmental problems is still insufficient. That is why the electricity produced by the power plants based on renewable energy is more expensive than the electricity produced by conventional sources.

4. GREEN ENERGY ON LIBERALIZED POWER MARKET

The term Green Electricity can be explained as the electric energy produced by a power plant running on a renewable energy power source. It is now more and more frequent to offer Green Electricity as a usual commodity on the power markets in many countries. With respect to its origin the Green Electricity is also considered as a product with a higher value compared to the electricity produced by conventional power plants. That is the most important reason why the Green Electricity is competitive despite of its higher price in comparison with the price of electricity produced conventionally.

Two basic possibilities how to utilize the Green Electricity, are practicable. One of them is to use potential power network interconnection and to offer the electricity to the public power market. The second possibility is to consume the energy in the location of its production directly, which can be very often considered more profitable solution. But it is necessary to analyze the structure of the consumption in the particular location, because some sectors as households or agriculture etc. are able to accept the electricity produced by renewable energy power plant more easily than others as heavy industry or transportation etc. It is depending on the reliability of the supply.

To evaluate the possible price of the green electricity on the liberalized power market, first the real costs of the green electricity production must be analysed. One of the most used tools how to determine this price is the method called “Net Present Value”. Its basic principle can be understood from the formula:
\[
\text{NPV} = \sum_{T=1}^{T_z} \frac{CF_T}{(1+r)^T} = 0 \quad (3)
\]

where NPV is the Net Present Value of the considered investment (building-up and operating the power source), \(T_z\) is the investment term, \(CF_T\) is the Cash Flow in the year \(T\) and \(r\) is the discount including the required profit. If the amount of the produced electricity is known, the price can be evaluated from \(CF_T\).

5. GENERAL DISPATCH CONTROL METHODS OF PES WITH DG

The control of PES can use the positive sides of distributed energy sources. The main part of them will be presented by renewable sources, with minimal impact on the environment. In optimal economical and environment friendly dispatching of Power System it is necessary to find a compromise solution with two conflicting objectives: the minimum of total operating cost and the minimum of total emissions. The relative importance of each criterion is given by an actual situation. It leads to the solution of more complicated multiple objective-dispatching problems:

Minimization of total operating costs:

\[
\sum_{i=1}^{n} N_i(P_i) = \min \quad (4)
\]

and minimization of total emissions:

\[
\sum_{i=1}^{n} E_i(P_i) = \min \quad (5)
\]

under conditions of demand and supply balance, power output limits, emissions limits etc, which are done simply by

\[
(P_1, P_2, P_3, \ldots, P_n) \in X \quad (6)
\]

where \(P_i\) = power output of unit \(i\), \(n\) = number of units and \(X\) = set of feasible solutions.

We can use different approaches to the solution of this problem.

Minimum cost model – Minimize total operating cost

\[
\sum_{i=1}^{n} N_i(P_i) = \min \quad (7)
\]

subject to

\[
(P_1, P_2, P_3, \ldots, P_n) \in X \quad (8)
\]

Minimum emissions model - Minimize total emissions

\[
\sum_{i=1}^{n} E_i(P_i) = \min \quad (9)
\]

subject to

\[
(P_1, P_2, P_3, \ldots, P_n) \in X \quad (10)
\]

Minimum cost with limited emissions – Minimize total operating cost

\[
\sum_{i=1}^{n} N_i(P_i) = \min \quad (11)
\]

subject to

\[
(P_1, P_2, P_3, \ldots, P_n) \in X \quad (12)
\]

and

\[
\sum_{i=1}^{n} a_{ik} E(P) \leq \varphi_k, \quad k = 1, \ldots, p \quad (13)
\]

where

\[\varphi_k\] is an emission limit for \(k\)-th pollutant

\[a_{ik}\] is a bivalent variable, \(a_{ik} = 1\) whether \(E\) is limited in \(k\)-th constraint and

\[a_{ik} = 0\] in the opposite case

6. CONCLUSION

The role of distributed power generation systems in new-planned power systems is described in this paper. Renewable energy power sources were emphasized. The process of the choice of the optimal power source for examined location was discussed. Some of the decision-making supporting tools, as NPV-method e.g., were mentioned. New approaches and tasks corresponding to the operating of the PES with high ratio of DG were explained as well.

REFERENCES

