NEPP
north european power perspectives

Fact sheet

September 2011

Different time scales for studies of power system performance

This short paper aims to give a conceptual understanding of the electric power system and its behavior in different time scales. The electric power system is a key component in the energy system with main function to deliver electricity to customers at minimal cost for production and losses in energy in conversion and deliver from generation points. Future developments of the electric power system involves integration of electricity generated from large scale renewable energy resources. These have a variable behaviour which further underlines the importance of understanding the power system phenomena for different time scales.

Introduction

The operation of the electric power system is performed in order to maximize the economic performance of the system considering security and reliability. Below follows a more detailed description of which types of studies that are necessary in order to obtain an efficient electric power system being able to handle future developments.

The power balance in the electric power system has to be kept with a certain security, This leads to that the consequences of different types of faults have to be studied as well as a design of the protection system. In modern power systems there is a large amount of controllable devices, which means that relevant control actions have to be designed and considered in order to obtain a cost efficient dimensioning of the system. For the dimensioning it is also important to consider the cost of operation in different power plants since distant balancing can be cheaper than local balancing but this may require more grids in order to obtain a cost efficient dimensioning of the whole system.

Figure 1 below shows the different phenomena that have to be considered and studied for development of the future when a future electric power system is to be dimensioned. As shown on the x axis, there are phenomena from micro seconds up to years that have to be considered.

Important power system different phenomena

There are many important phenomena in an electric power system which interacts in such a way that all phenomena have an impact on the other phenomena. The main challenges of the electric power system are two-fold: When a consumer pushes the on-button, then there should come power and the voltage should be on the nominal level plus/minus some per cents. When e.g. investments are performed in an electric power system all the other issues have to be considered in order to obtain a reliable system.

The electric power system constitutes of the general part of: generation, power delivery grid (here referred as grid) and customer points. The grid is typically divided into transmission and distribution depending on voltage level and complexity of the grid, with more complex system on higher voltage levels.

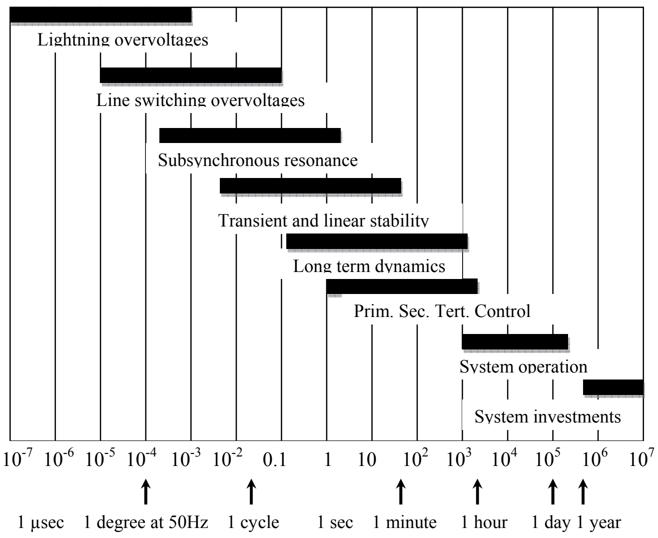

Figure 1: Frequency bands of different dynamic phenomena

Lightning over voltages are obtained when a lightning strikes a line. This happens could e.g. in Sweden happen hundreds of times per year. The consequence is a short circuit between the line and the pole (over the isolator) and the protection system then disconnects the line. A challenge is to disconnect as small part of the electric power system as possible and reconnect the system as fast as possible.

Line switching over voltages are obtained when transformers, generators or lines are connected or disconnected to the grid. The challenge is to separate the transients caused by these needed actions from transients caused by faults in the system.

Subsynchronous resonance can occur between large turbines and the grid, especially if there is series compensation in the grid in order to increase the transfer capacity. The risk is that there will be mechanical oscillations in the turbine shaft of large power plants between the turbine and the generator which can break the shaft which can cause large problems. This means that the grid structure has to be considered when a large turbine is connected.

Transient stability considers the problem of a short interruption of a transmission line from a generator. If the interruption is caused by a lightning then the line is normally reconnected after, e.g., 100 ms and the question is if the generator stays on line after this short interruption. During the time when the line does not work, the generator speeds up and it may be impossible to electrically reconnect it since the voltage deviation in each phase is too large between the grid and the generator. It is not acceptable that large generators are disconnected every time there is a lightning strike. Another cause of transient stability problems are outages in generators which may cause oscillations and a transient instability

Linear stability, or small signal stability considers the risk of oscillations between generators in different ends of a power system. In the Nordic power system there is often an oscillation between Finnish nuclear power plants and hydro power plants in southern Norway. Also Swedish generators participate in the oscillations. The frequency of this oscillation is often in the range of 0,2 Hz. If this oscillation grows too large, then it is not any longer possible to transfer power between these two regions, which mean that Sweden has to be disconnected from either Finland or Norway.

Long term dynamics, include voltage stability which is a common stability issue and line limiter in the Nordic system. Voltage stability problem implies that there is a problem to keep a voltage which is high enough in the receiving end of a transmission line, or transmission corridor. The consequence of a too high loading can be a so-called voltage collapse which means that the voltage suddenly just drops to levels that are too low in order to operate the system.

Primary, secondary and tertiary control, are used to keep a continuous production-consumption balance. Primary control is mainly power plants (could be consumption) that reacts within 30 seconds when there is a fast production change in a power plant or a load change. Secondary control replaces used margins for primary control and consists of power plants that start within some-15 minutes. Tertiary control is the next step which means replacement of used secondary reserves and acts up to around 15 minutes. Primary and secondary controls are automatic systems while tertiary control is manually operated.

System operation consists of planning of which electric power generation plants that should be used within the coming hour, day and month and in this planning it is needed to consider all the above issues, i.e., there must be enough margins in primary, secondary and tertiary control as well as the system must be stable also after possible faults.

System investments consists of planning of new electric power system components such as new lines, generators, control actions etc and when these are performed one must consider that the system can be operated and that this can be performed in a stable and reliable way.

Examples of interaction between different system phenomena in the electric power system

Intra hour variation: When future power systems are to be studied it is important that the modeling of the system is relevant so the correct conclusions can be drawn from the study. One important issues is, e.g., which time step one used in the analysis of the future power system. If one, e.g., uses a 1 hour time step, then the question is how to consider what is happening within the hour. In reality it is impossible to make micro second simulations of large power systems in order to consider all possible phenomena. The figure below shows one example of a simulation challenge.

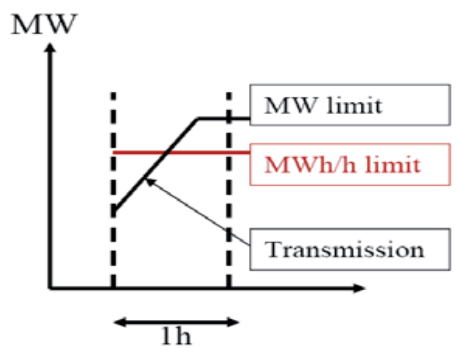

Figure 2: Interaction between different system phenomenas

Figure 2 shows the power delivery between two areas during an hour. The true power delivery increases during the hour up to the limit. It is here important to remember that the limit is set in MW. With a varying use of the grid during the hour this then means that if the limit is set in MWh/h then another limit has to be set than the available MW level.

Transmission limits: A transmission limit is normally set for a single line or for a corridor between two areas. The normal method is to say that the allowed transmission (NTC=Net Transfer Capacity) is defined in such a way that this amount of power can be transferred even if there is a large fault somewhere in the system, the so-called N-1 criterion (the system will be stable also after an outage in one important component). An issue is though that the consequence of a fault is system dependent. If there, today, is a sudden outage in O3, then the primary control will react in Northern Sweden so one have to keep enough margins on the lines from Northern Sweden. But assume that there is a situation with large amounts of wind power in Northern Sweden and the primary control is to a larger extent coming from Norway. Then one has to reconsider the consequence of the fault which also will change the transmission capacity from North to South Sweden.

Wind power and HVDC technology: Another issue is the controllability of wind power stations concerning oscillations and reactive power control. If there are controllable reactive power resources in the wind power stations then this has an impact on the voltage stability in the system which has an impact on the transmission capacities if they are set by voltage stability limits. If wind power plants can be controlled they can also damp oscillations which have an impact on the linear stability of the system, which has an impact on transmission limits if they are set by linear stability. The same possibilities (reactive power support and controlled damping) are also possible in HVDC interconnections.

Economic operation and continuous control: In the Nordic system most of the continuous control (primary etc) is performed in hydro power stations. It is also technically possible to do this in the same way in the future with larger amounts of wind power, but it may also be performed in thermal power stations in Southern Sweden. The different solutions may lead to different operation costs and transmission investments, which means that the intra-hour operation should be considered when a rational future power system is designed.

For further information:
Lennart Söder, KTH, and Lina Bertling Tjernberg, Chalmers