GRID SECURITY MANAGEMENT – BASIS FOR SECURE OPERATION OF THE DISTRIBUTION GRID OF ENVIAM

Wolfgang GALLAS
envia Verteilnetz GmbH
Wolfgang.gallas@envia-netz.de

Dirk HOLLMACH
envia Netzservice GmbH
dirk.hollmach@envia-nsg.de

Hans ROMAN
envia Verteilnetz GmbH
hans.roman@web.de

Adolf SCHWEER
envia Netzservice GmbH – Germany
Adolf.schweer@envia-nsg.de

ABSTRACT

The political promotion of renewable energy in Germany has led to a strong increase in the generation capacity especially by wind energy conversion. Therefore, the capacity of MV and HV grids in windy regions of Germany will have run out in a few years. In case of strong wind and low load some distribution networks are overloaded. Then even the amount of energy fed back into the transmission grid may overcome the limits for the transmission system. This critical situation can only be mastered by reduction of feeding power. This paper describes the network and system security system of enviaM (NSM) and reports on operation experiences over 5 Years with more than 50 security-events.

INTRODUCTION

The development of renewable energy has been promoted since 1990 in Germany. This was done by a guaranteed level compensation for the feed-in of electricity, and grid operators are obligated to use this electricity. This led to a strong growth of power plants based on renewable energy, in particular wind energy. EnviaM is one of the largest utilities in Eastern Germany.

Figure 1: The EnviaM – area in Eastern Germany

Therefore the grid of enviaM is strongly affected by this development (figure 2). The maximum feed-in from dispersed generation especially during windy periods exceeds the maximal load already today; the minimal load is already during normal weather conditions lower than the infeed. Looking forward to 2025, with a prognosis of 10.000 to 12.000 MW of infeed the distribution grid will gain a new function: from a retail grid to a collection grid.

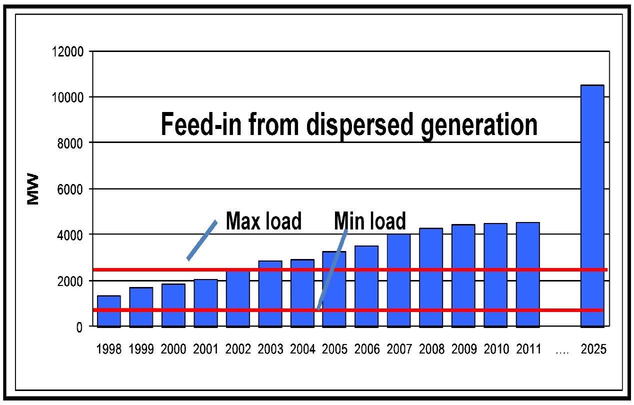

Figure 2: Development and forecast of power generation in the supply network of enviaM until 2025.

Whereas the power from renewable wind (3058 MW), Solar (379 MW), other (CHP, Water, Biomass (325 MW) summed up to 3725 MW at the end of 2009 with another strong increase in 2010, the energy delivered from these sources summed up to 39% of the total energy delivered in the enviaM area. In the Renewable Energy Act (EEG-2004/[1]), the obligation of immediate and higher priority connection to the grid, regardless of grid capacity, was established. With this, the **distribution grid situation became even more critical**. In the meantime, in some sections of supply grids, power is being generated at levels many times higher than the maximum load. Therefore some sections of the power grid quickly reach the limits of their capacity. Because of protracted approval procedures, the extension of the grid which is required by law in these cases could not and can still not be accomplished quickly enough, particularly in the high voltage grid. Of this development, so grid bottlenecks are occurring ever more frequently. When load is low and winds are strong, the risk of grid overload increases, which can practically only be managed through reductions of power at the power plants. In response to pressure from grid operators, the legislator determined measures in EEG-2009 [2] to ensure grid security. Power plants with a capacity beginning at 100 kW have to be equipped with a mechanism to reduce power, which can be used by remote control by the grid operator in case of overload.

Furthermore, **system security in the transmission system** is also increasingly **endangered** in cases where the load is light and winds are strong, because the load balance in the system can only still be achieved when power generation from renewable energy sources is correspondingly reduced. The Transmission grid links are overloaded. In such cases, according to EnWG [3], the distribution grid operator is required to provide support to the system manager by reducing feed-in.

The **"Network and System Security Management"** (NSM) system developed by enviaM to guarantee grid and system security is described as follows.

REQUIREMENTS ON THE NSM

In respect to the power plants, NSM must fulfil two control tasks which differ in terms of content: "**feed-in management"** according to §11 EEG-2009, to keep regional grid bottlenecks under control, and "**system security management"** according to §13 EnWG, to equalize the power balance in the transmission system. Since both tasks can primarily only be assured through power reduction measures at the power plants. Therefore it makes sense that the solution developed for this should follow a standardized technical approach. However, the requirements on the NSM are not purely of a technical nature, but are also determined by specifications given in government energy policy.

Order of precedence

One important requirement is determined by the fact that in Germany, power generation plants with **renewable energy or combined heat and power** are given higher priority. This means that the power which is generated in plants that do not have higher priority (e.g. coal-fired power plants) must be reduced first, and as a rule fully, before the **privileged plants**. An exception to full reduction is made for base load power plants. Moreover, according to EnWG, in cases of risk to system security, further aspects (economic effects, controllability in terms of technology and time, environmental effects, etc.) must be taken into consideration. This means that power generation plants must be prioritized in terms of intervention; in other words, if there are different types of power generation to choose from when a bottleneck occurs, then these are to be utilized in a predetermined **order of precedence**. Three priority levels were derived from the result of this evaluation which takes both the statutory requirements as well as the economic effects into account.

Controllability of low capacity power plants

For cost reasons low capacity (dispersed) generators are not connected to the grid control system via remote control. The need to achieve a reaction from multiple plants simultaneously, quickly and with little effort because of a critical grid situation, requires new solutions. At enviaM there are already over 1000 power plants connected in the NSM.

An extremely economical solution available, which provides sufficient performance, is the use of modern **radio ripple control**, which has demonstrated an ample amount of positive operation's experience together with the operator EFR (Europäische Funkrundsteuerung). This solution makes it possible to reach a **large number of power plants**, with a sufficient degree of **differentiation** and also **speed**. The apparent disadvantage of this solution is the lack of a direct "reply" from the controlled plants. However, this is not a problem because the effectiveness of the control measures is measured in the bottleneck current, captured by remote control online, and not in the behaviour of a single plant, which may possibly even be disrupted. Because of the significance of NSM to technical security, and the central nature of the control channel, a backup method has been planned for the case of a malfunction of the radio transmission channel. This consists of direct control of high capacity power plants, connected to the grid control system by a "classic" remote control system.

Grid conditions

EEG-2009 [2] requires that when grid bottlenecks are relieved, a maximum of privileged power is to be retained in the grid. But in an intermeshed grid this is not easy to do, because the influence of the power plant depends on its distance to the bottleneck and its place in the grid. Added to that is the fact that at enviaM the high voltage overhead lines (typical bottlenecks) are operated depending on the weather conditions [4]. Their current carrying capacity increases in colder weather or when the wind is strong, as far as line protection or other factors in the path of the current do not restrict this. This means that the influence of each power plant on the bottleneck current and the current carrying capacity must be evaluated online. Because of the number of power plants which must be simultaneously controlled, and the complexity of the control tasks, these can only be carried out automatically.

Ultimately, all that remains for the personnel managing the grid is to decide on the plausibility of the measures and to make the final decision.

STRUCTURE OF THE NSM OF enviaM

In the NSM of enviaM only the **high voltage grid** is directly **monitored**, because it is only on this voltage level that the extension of the grid cannot be realized quickly enough. However, **all power plants** with an installed power **above 100 kW are controlled**.

How "feed-in management" operates

The **NSM** evaluates the existing load situation, the existing switching status and the variable current carrying capacity in the high voltage grid.

This is done by an **online grid security calculation** that runs cyclically in the background. This acts on the basis of a **process model**, formed from the actual switching status, and "measured values" for the calculation of power flow, made available by a **state estimation** module, and the existing current carrying capacities. Figure 3 shows the structure of control, monitoring and calculation components working in the NSM.

With this structure and the relations between the components is ensured that the **n-1-criteria** for defined bottleneck elements can be constantly monitored in a way appropriate to the situation. Here, the existing quantitative influence of the power plants that have an effect on the grid bottleneck is simultaneously determined.

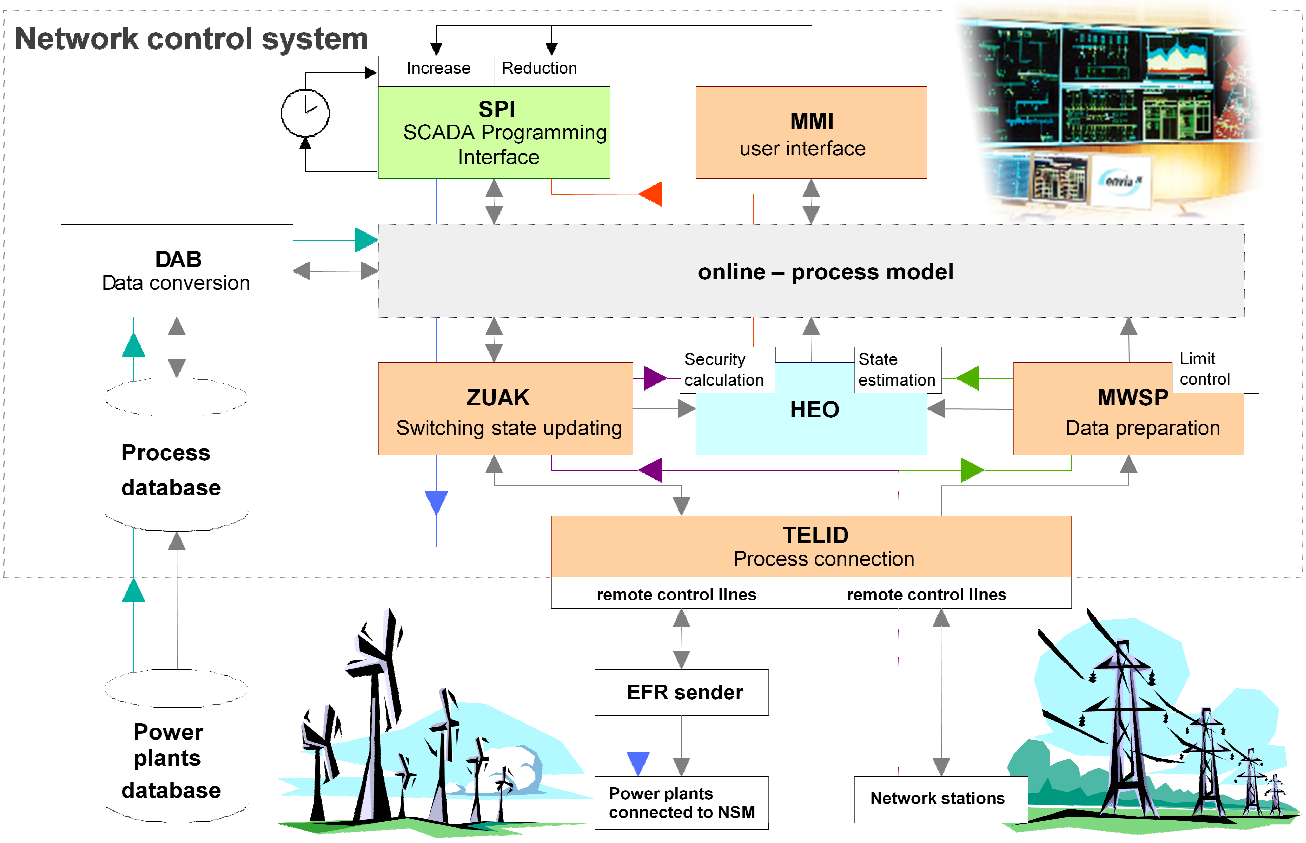

Figure 3: Structure of NSM

In a case that it is detected that a permissible current carrying capacity has been exceeded, the dispatching personal is alarmed and must carry out an evaluation of the situation, based on automatically generated overviews (Figure 4).

When the situation detected by the NSM and the degree of power reduction are deemed as plausible, the control procedure is manually triggered.

First, the power plant sources known and quantified in the grid security calculation (usually cumulative value of multiple generators) are automatically itemized in the power plants which technically belong to the grid area and can be controlled. This is based on the measured capacity values of the major plants and the respective, forecast feeding power from the installed power of the small plants (estimate based on weather data).

In conclusion, originating from the grid bottleneck follows the summation of the available reduction capacity according to the plants available to choose from in order of precedence, until the capacity to be reduced at the bottleneck has been achieved. The information used as basis for this is the database "power plants" whose data is regularly updated.

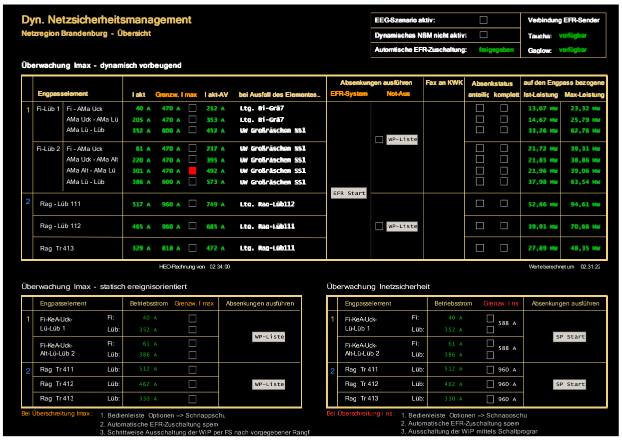

Figure 4: Operations' window of the NSM in the control system

In conclusion the generation of the control commands takes place **for radio ripple control**, and their transmission via redundant dedicated lines to the EFR transmitter (figure 5).

The effects of the control commands are automatically checked after approx. 5 minutes. If the current is still too high at the bottleneck, further plants are automatically required to make reductions. If, after a defined period, the current at the bottleneck drops under the permissible level, then generation capacity is granted again according to the same procedure.

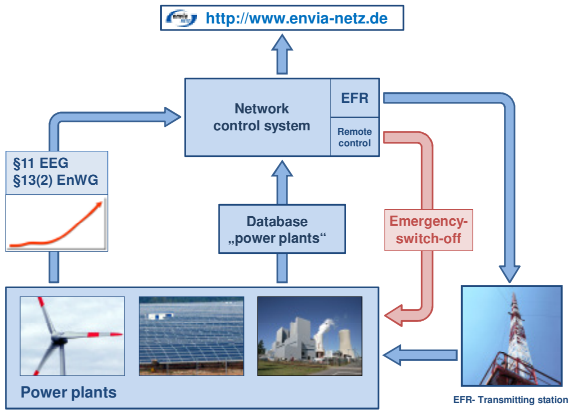

Figure 5: Information channels of the NSM

How "system security management" operates

Contrarily to the DSO the TSO is not only responsible for the secure operation of the Transmission grid, but he takes the duty for the system security in total. This means that he has to secure the frequency and the stability of the system In the case of enviaM the transmission system operator is 50Hz Transmission GmbH. He is controlling the total power system in his region, consisting of the plants connected to the transmission system, the connections to the neighbouring TSOs and the connections to all DSOs in this region (figure 6).

In case of strong wind feed-in and outages in the grid this may lead to critical situations in the total transmission grid.

This procedure is activated when the system operator detects a **risk to system security** which can only **be mastered through a reduction of generation** in the distribution grid. Here, differentiation can be made in the call for reduced generation, as either a reduction requirement for the entire supply network or for one or more coupling points between the transmission and distribution grid.

Depending on the requirement, based on the selection criteria named above, and if applicable taking the process model into consideration, the power plants are automatically chosen and totalled until the required capacity has been achieved.

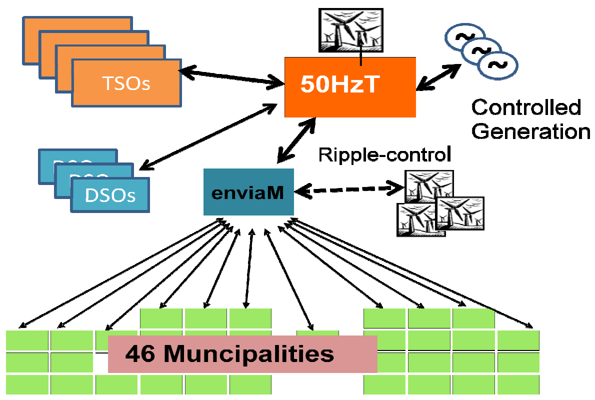

Figure 6: enviaM – connections to TSO, dispersed generation and municipalities

The rest of the procedure is largely identical to feed-in management. All the DSO's and Municipals shown in figure 6 have to follow the call for reduction, depending on area where power reduction is needed - whole area or part of that. The call of the TSO is organized as cascade, e.g. the DSO's as enviaM transmit the call to the Municipals according to their installed plant capacity.

Technical implementation in the power plant

The interface between the grid control system and the power plant is the EFR receiver. In the model currently in use there are 4 switching contacts activated in the receiver. Depending on the incoming radio telegram, a **power reduction to**

- **60%**
- **30%**
- **or 0%**

of the installed capacity is to be carried out, or 100% of the capacity can be feed into the grid. The switching contacts of the receiver are to be connected to the controls of the (dispersed) power plant in such a way that the called-for capacity reduction is initiated immediately. The radio telegram is structured in such a way that for the time reasons already mentioned, as a rule several power plants can be addressed simultaneously. By forming the groups in specific ways it is possible to achieve relatively fine control of feeding power. The parameters of the receivers are set by the grid operator and are checked for proper operation at the time of starting the operation.

OPERATIONAL EXPERIENCE

The NSM of enviaM has been **in operation since 2005**, and since August 2009 in the configuration described here.

Operational experience has been consistently positive. The functionality achieved, the proper functioning of "addressing" in the detection of critical situations, the precise selection and treatment of the power plants to be controlled, and the efficient visualization of the respective situations all fully satisfy expectations. Since the system is very complex and many of the influencing factors are chiefly of a random nature, operation of the NSM is subjected to constant evaluation. An analysis is made after each use as to whether all activities ran according to the rules and whether improvements to the system are necessary and achievable.

Until now, **measures to maintain system security** have been necessary **three times**, with a mean feed-in reduction of 350 MW. Figure 7 shows such an incident.

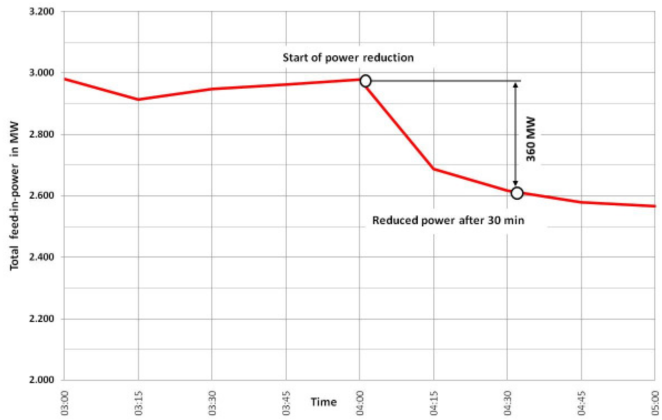

Figure 7: Feed-in power following a call for system security measures

Here, a further constant increase in incidents is to be expected because the balance of capacity in the system is increasingly at risk due to growth in generation capacity, and network extension in the distribution grid.

Until now, **feed-in management** has been utilized **more than 50 times**. On average, capacity reductions of 40 MW with a mean duration of 2.5 h have been called for. In the medium term, depending on grid extension, the calls will drop in number.

The public information required by the legislator is realized via the Internet.

Each time an NSM measure is invoked, in addition to date and time, the affected supply network is displayed in the Internet in a matter of minutes, and after the measure has been concluded, the duration and degree of power reduction is added (Figure 8).

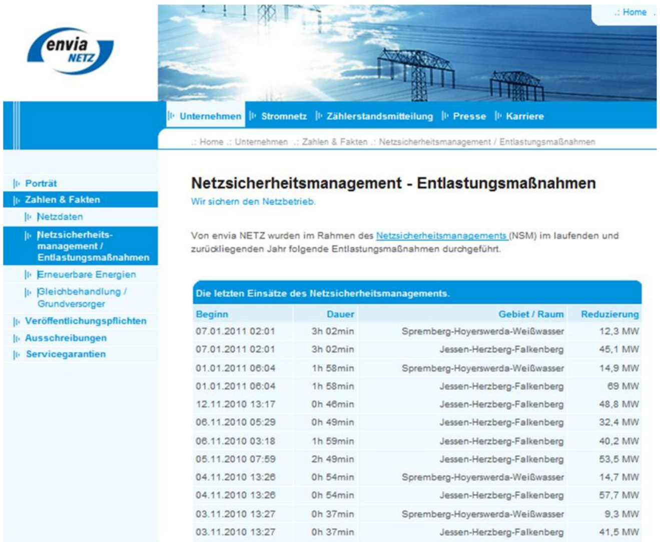

Figure 8: NSM information overview in the Internet

SUMMARY

For a few years now, the annexing of EEG power plant capacity has lead in the grid of enviaM to a considerable excess of power generation capacity relative to local demand. Because of approval conditions, the extension of the grid prescribed by law, and necessary for the sake of capacity, cannot take place quickly enough. In certain situations this leads to a risk to grid and system security which in terms of operation can only be kept under control by intervention in power generation. The network and system security management (NSM) developed for this controls any intervention in power generation, as well as any measures to maintain grid and system security. The measures in the grid control system are executed to a high degree automatically, based on a grid security calculation running continuously in the background, which detects risks to grid security (n-1-incidents), determines the necessary measures, and transmits the corresponding control commands via radio ripple control to the power plants.

Over 1000 power plants are linked to the NSM operated by enviaM since 2005, and **over 50 control measure** incidents have been properly and safely executed.

Reference

[1] EEG 2004 – Gesetz zur Neuregelung des Rechts der Erneuerbaren Energien im Strombereich; Bundesgesetzblatt Teil I Nr. 40, 31. Juli 2004

[2] EEG 2009 – Gesetz zur Neuregelung des Rechts der Erneuerbaren Energien im Strombereich…..; Bundesgesetzblatt Teil I, Nr. 49, 31.Oktober 2008

[3] EnWG – Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz) Bundesgesetzblatt Teil I Nr. 42, 12. Juli 2005

[4] Roman, H.; Dangrieß, G.; Dorendorf, S.; Struck, T.; 2009; Freileitungsmonitoring in Hochspannungsnetzen. Elektrizitätswirtschaft, H.13, S.60-63