A "SMARTGRIDS-ASSISTANT" FOR POWER GRID OPERATION AND TRAINING

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Abstract – **SmartGrids are understood as cell-wise structured, intelligent supply areas with own, distributed and renewable generators and storages. The actual intelligence is the IT-supported structure and control, especially to match fluctuating generation and load. Since there are typically a large number of options, this will not happen completely automatically. With the integration of the new components, the distribution system operators and their personnel face new tasks. The scope of operational grid control is extended with the management of fluctuating generators, loads and storage units. Possibly, the legal framework will be reason to establish new structures for the control center staff to perform the new activities beyond the regulated DSO. The individual generation situation and the transports have to be managed, the voltage to be stabilized and the grid components to be dispatched. The authors in cooperation with the German power supplier HEAG Südhessische Energie AG (HSE) are developing the electronic SmartGrids-Assistant (SGA) as an EMS function of the SCADA system. It cyclically submits proposals to the control center staff how to dispatch the grid's components and resources optimally. The SGA will be used for operational training at first to prepare the staff for the new tasks and then serve as an online decision assistant for Smart Grid component operation.**

Keywords: *smartgrids, renewable energy sources, control systems, artificial neural networks*

1. INTRODUCTION

The power supply of the future SmartCities is realised with SmartGrids as cell-wise structured, intelligent grids, which are interconnected and exchange information and energy. In each SmartGrid, control center engineers will supervise and dispatch the grid and its distributed, renewable generators (RES), the assigned power plants, the loads and the available energy storages. Some RES plants run autarkic, others are connected as virtual power plants (VPP) and controlled centrally.

Therefore, the future power supply will be a mix of conventional and renewable sources. The conventional generators are easy to plan and control and so are the biogas and hydropower plants. The major part of the future renewable energy will come from distributed, wide-area spread PV and wind units, which are volatile and subject to the weather. Deficiencies and overshoots regarding the load in the grid can appear. The 2009 amendment of the German Energy Industry Act (EnWG) allows that RES plants with a rated power greater than 100 kW can be throttled temporarily and step-wise in justified cases. The missing energy (which is not produced), however, must be refunded. This option is not economic and only feasible in exceptional cases. An alternative is to buffer the overshoot energy in storages and feed it back during high-load times. The implementation of storages, especially battery-based, has a couple of positive effects [1], e.g. voltage stabilization.

In the context of the future power supply concept, the terms MicroGrid, SmartGrid and SuperGrid emerged to describe the new grid structures. There are no binding definitions yet, so the authors use the terms as follows: MicroGrids are small grid cells, e.g. feed zones of a 110/22kV power transformer. Together with the utility partner grid, internal and distributed generation units contribute to supply residential and industrial areas, offices, heating and cooling. SmartGrids are the superior units, containing the MicroGrids to be supervised, e.g. the complete low and medium voltage grid of a utility. The existing control centers of the utilities can perform the operational control of the SmartGrid if based on modern SCADA systems. SuperGrids are new DC grids (HVDC), superior to the 400kV three-phase grid, which enable a continental energy exchange. They shall be supervised by a new UCTE control center which is yet to be realized. The energy exchange is done through the grids, bidders' and buyers' work may be executed through a trader platform.

Lately, a couple of approaches have appeared to manage these components for energy balancing on their respective levels. First, "energy butlers" as a further development of smart meters will be offered for domestic, local energy management.[4] They

allow domestic customers to control manually or automatically their household devices depending on the tariffs, which is set due to RES energy production. A communication between such energy agents and the control center allows a consumer optimisation within a MicroGrid or even an energy exchange, if the cell has own distributed generation units.
Second, the Desertec concept is oriented towards a transcontinental energy transport to bring African PV power to Europe. An European HVDC ring shall enable a low loss transport and overcome existing bottlenecks in the UCTE grid. However this project is still in a preliminary planning phase. A totally new grid needs a lot of funds and many years to be realized.
The above mentioned approaches are interesting and still have to prove in practice or actually be realized. Internal stabilization is another solution for Smart Grids, that means management of internal components, e.g. storages, to stabilize the system at first priority, giving a certain level of independence. With the integration of renewable generators and storage units, the distribution system operators and their personnel as well face new tasks of energy management and got new prospects of further grid services. Battery storages and power electronics are able to support as sudden backups for frequency regulation, which is usually a high priced energy.

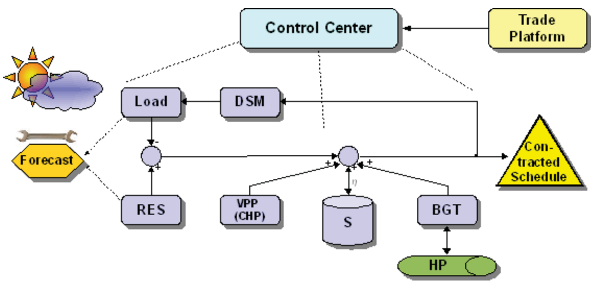

Figure 1: SmartGrid and components for energy regulation

Figure 1 illustrates the new task: The load and the generated electrical energy from renewable sources is forecasted with appropriate tools. Usually the forecasts have a certain error which increases with a wider forecast horizon. If a time span of 24 hours, for instance, is resolved in 15 minute intervals, a deviation from the contracted schedule ΔE appears for every quarter hour and has to be compensated. This can be compensated using virtual power plants (VPP), battery storage units (S), or biogas turbines with/without gas grid connection (BGT). Demand side management (DSM) are methods to influence the load side, such as switching on/off load heating or cooling groups, voltage modification and low/high tariff signals to customers or the energy butlers. Furthermore, transactions on a trade platform are placed, too, where also the internal available storage energy can be offered. Every intervention in the grid has a consequence regarding the load flow, voltages, losses, costs, contracts, the emission balance and economical consequences. Taking the amount of components and possibilities of managing them into account, the future task of Smart Grid stabilization seems to become quite complex.
The complexity of future operational control is based in the management of the fluctuating generators, loads and storages, as well as in the processing of the information content from many distributed units. Obviously the use of storage energy can only be done once. What is the best time for using and reloading? Another aspect: Once a decision has been made to, for instance, switch on/off distributed load groups or storages, this command has to be executed safely and without delay. Currently there are solutions developed based on the IEC 61850 standard. [1,2] It is yet to prove that the planned communication system can handle the enormous data traffic. The information must be bundled and processed extensively automatic. Just the tasks which cannot be solved automatically shall be presented to the control center engineers in a summarized form. New SCADA functions are currently developed to process the data accordingly and support the user with the management of the new components. One important issue is the instruction and training of control center personnel to have them prepared for the new tasks. This type of training is inevitable to master the new challenges safely and economically.

2. THE SMARTGRIDS-ASSISTANT IN THE CONTROL SYSTEM ENVIRONMENT

From this motivation, the authors together with the German power supplier HSE Energy AG are currently developing the electronic SmartGrids-Assistant (SGA) to be an EMS function of the SCADA system. It cyclically submits proposals to the control center staff how to dispatch the grid's components and resources optimally to reach the defined goals.
The SGA can be used in two modes: Real-time mode (grid operation) and simulation mode. In real-time mode, the SG-Assistant polls the values in the system and checks them cyclically, typically every 15 minutes. Using the refreshed dynamic data, a forecast and optimization algorithm is run through. The result is a proposal list in the visualization of the SCADA system. The user gets proposals of how to use virtual power plants (VPP), turbines in CHP operation, storages, biogas turbines, demand side management etc. Also proposals for external orders at a trade platform are possible. Depending on the situation the

list can contain none, one or several proposals (see application example).
Furthermore, the SmartGrids-Assistant can be operated in training mode, which is interesting especially for grid planning, instruction and training. The real process is replaces by a dynamic power system simulation to calculate a scenario in time-lapse. Training sequences which actually represent a time span of several days or weeks can be run through in a short time.

3. METHODIC APPROACH

The calculation base for the SmartGrids-Assistent is the data model of the grid, containing the internal renewable generators, storages, gas turbines, virtual power plants, the options of demand side management and the access to a trade platform. Based on this data and the dynamic values of the components, measured values and forecast deviations, an optimization is launched. The result of this calculation is a proposal list to state which intervention is most suitable in the current situation. The optimization follows pre-defined goals, such as an cost-optimized or a CO2-optimal solution. Boundary conditions such as transport capacities can be taken into account.

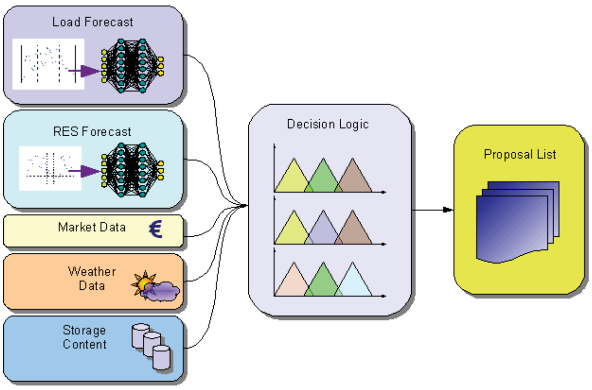

Figure 2: Structure of the decision system

The methodic approach to solve the optimisation problem is a hybrid decision system, illustrated in figure 2. Artificial Neural Networks are used for the forecast of loads and renewable generators. The forecasted values together with market and weather data and information about storage contents are loaded into a decision logic. There a proposal list is calculated with fixed rules.

4. APPLICATION EXAMPLE

An example illustrates the optimization of energy acquisition costs, see figure 3. For the upcoming quarter hour, the assistant has forecasted a deficiency of 80 MWh electrical energy. The goal is to compensate using internal own generation or by ordering from a trade platform. First, an analysis of the available (reserves of) components or possible interventions and of boundary conditions is made. All suitable proposals are then sorted by their specific costs in descending order.

	Max	Current	Reserve	Purchase price	Selling price		Use when	
	MWh	MWh	MWh	€/MWh	€/MWh	Blocked	Overshoot	Deficiency
E-Storage 2	4	2,5	1,5	12	14	0	1	1
E-Storage 1	4	2,5	1,5	17	19	0	1	1
Tariffs + and -	7,5	0	7,5	51	51	0	1	1
GT1	25	20	5	52	52	0	1	1
GT2	15	5	10	52	52	0	1	1
GT3	5	0	5	52	52	0	1	1
Grid	80	33	47	55	53	0	1	1
VPP2 only gen.	3	0	3	78	78	0	0	1
VPP1 only gen.	3	0	3	78	78	0	0	1
Cooling 1	1	0	1	65	65	0	1	0
Cooling 3	3	0	3	65	65	0	1	0
Heating 1	8	0	8	75	75	0	1	0
Heating 2	7	0	7	75	75	0	1	0
VPP3 only gen.	3	0	3	78	78	1	0	1
Cooling 2	2	0	2	65	65	1	1	0
Heating 3	6	0	6	75	75	1	1	0

Delta E [MWh]=	80

Proposal list		
Acquire [MWh]	Rest [MWh]	Costs [€]
1,5	78,5	18
1,5	77	25,5
7,5	69,5	382,5
5	64,5	260
10	54,5	520
5	49,5	260
47	2,5	2585
2,5	0	195
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

Total costs €	4246
Specif €/MWh	53,08

Figure 3: Optimisation of energy acquisition costs for a quarter hour

In the example shown in fig. 3, the energy stored in batteries is cheapest with 12 €/MWh and 14€/MWh, followed by a possible tariff change to high tariff, the start of a gas turbine for 52€/MWh, the acquisition of external energy (55€/MWh) and the remote-controlled activation of virtual power-plants (78€/MWh).

The SGA proposes to exploit the available reserves in the above mentioned order, till the deficiency is covered. The specific generation costs for the example scenario amount to 53,08 €/MWh which is cheaper than the acquisition of regulation energy.
The SmartGrids optimization tool is a prototype. In real future SmartGrids the task will be more complex than the above shown example. More controllable generation and load groups and more gas turbines will be available. Obviously, the forecasts for load and RES play a significant role, so do the market development and weather data. Eventually, a total optimum for the usage of storages and other components shall be found, considering a variable time span, e.g. 24 hours. This requires another algorithmic approach based on artificial intelligence which is currently developed at the University of Applied Sciences Darmstadt.

5. CONCLUSION AND PERSPECTIVES FOR POWER SYSTEM OPERATION AND OPERATIONAL TRAINING

The authors work in cooperation with the regional power supplier in Darmstadt, HSE Energy AG, to develop a SmartGrids-Assistant. As HSE company intents to transfer the distribution grid (20-kV and low voltage) into a Smart Grid within the next years, it is important to train the staff regarding the new tasks to be executed. This will be done by a training system using a standard SCADA system, a power system simulation and the electronic assistant SGA. The SGA is designed as an EMS function. It is smoothly integrated in the dynamic power system simulator of the University of Applied Sciences Darmstadt. In a dynamic simulation, the operation of SmartGrids, the management of storages and further operational tasks can be learned and trained risk-free. Students in lectures as well as engineers from industry are educated in a practically oriented manner to be prepared for the operation of the future power grids. In a further step the SGA will support control center engineers online, presenting proposals for switching operations and grid management.

References

[1] Metz, D.; Fiedler, Th.; *"Integration of Distributed Battery Storages in Modern Power Grids",* Energetica Conference Ohrid, Macedonia, Conference Proceedings, 2010

[2] Project "Web2Energy", http://www.web2energy.com

[3] Research Project "SmartGrids" at the University of Applied Sciences Darmstadt, http://smartgrids.eit.h-da.de

[4] MVV Energie AG; http://www.mvv-energie.de

[5] Fenn, B.; Metz, D., Fiedler, T., Röglin, A.: *"Einsatzmöglichkeiten stationärer und mobiler Stromspeicher in Verteilnetzen",* 11. Symposium Energieinnovation der TU Graz, 10.-12.2.2010, Conference Proceedings, ISBN978-3-85125-082-4