THE CHALLENGE OF RETROFITTING OLD DECENTRALIZED POWER PLANTS IN GERMANY IN TERMS OF POWER SYSTEM STABILITY

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ABSTRACT

In order to counter the danger of instabilities caused by old decentralized power plants, the Ordinance on System Stability (Systemstabilitätsverordnung, SysStabV) was implemented in Germany in June 2012.
This paper describes the process including tasks and responsibilities of all relevant stakeholders within the second stage of implementing the SysStabV. In contrast to its first stage, power plant operators have the option to apply for proportional reimbursement as well as for exemption from the obligation of retrofitting measures for their power generation plants.
Strangely it has been stated that the actual number of applied exemptions is much lower than the expected one. Furthermore, also the number of confirmed retrofitting is lower than expected.
In conclusion a considerable divergence between the forecast and the actual state data indicates the importance for an on-site inspection at power plants as part of an important follow-up process.

INTRODUCTION

In normal operation the system-wide frequency of the interconnected European grid should be close to the nominal value of 50.0 Hz. For a stable operation it is necessary that generation and load are in balance. In the first moment of a frequency deviation the instantaneous reserve – provided by conventional power plants – is an important contribution to frequency stability via damping frequency changes and limiting frequency gradients before other stabilizing measures can be started. Though, system events can lead to frequency deviations. The increasing share of decentralized power generation with a high degree of volatility as wind turbines or PV power plants can endanger the equilibrium between generation and load. Several severe events can be found in the recent past, as for example the incident of November 4th 2006 [5]. But even the enlarged ENTSO-E grid with its frequency oscillations between the outer borders demonstrates considerable threats. For the future, ENTSO-E prepares for frequency gradients up to 2 Hz/s [1].
However, until 2009 technical guidelines and directives in Germany required an operating range only from 49.5 Hz to 50.2 Hz for decentralized power generation units (PGU). Therefor the high amount of old PGUs with narrow frequency operating ranges represents a risk for power stability by simultaneously switching off.
The European Union – urged by the European Network of Transmission System Operators for Electricity (ENTSO-E) – adopted a two-stage approach in terms of technical instructions in order to retrofit old PGUs.
The national implementation of this instruction in Germany was published in June 2012, the so-called SysStabV. Power plant operators (PPO) are obliged to ensure PGU's operation within an extended frequency range of 47.5 Hz to 51.5 Hz. If PGU do not operate as mandatory, measures for retrofitting need to be conducted by the PPO. In the first stage of the retrofit program about 27 GW of installed power of PV plants were affected to adjust the frequency settings in accordance with the SysStabV [5]. Total estimated costs for the first retrofit program range from 4m € up to 28m €. The second stage of the SysStabV, valid since March 2015, strikes further technologies as wind, biomass, combined heat and power (CHP) and hydro.

IMPLEMENTATION PROCESS

In the first step of the process the German Transmission System Operators (TSOs) determined on which frequency levels the power plants must be adjusted. The lower frequency value has been defined on 47.5 Hz for all power plants concerned by SysStabV. The upper frequency value is defined between 50.2 Hz and 51.5 Hz in order to get a stepwise reduction of active power. The determined frequency range was transmitted via the Distribution Grid Operators (DSOs) to the PPO who had to confirm the receipt within a deadline of six weeks [2]. The PPOs need to take care that their plants are retrofitted within a period of 12 month. This has to be verified by sending a retrofitting confirmation after completion. DSOs surveil the deadlines and report to TSOs.
In the last step of the process TSO perform an inspection of the retrofitting measures on a sample basis. DSOs have to support TSOs within this step, which is planned in the time frame between 2017 and 2019.

TECHNICAL RESTRICTIONS AND ECONOMICAL EXPENDITURES

1. EXEMPTION APPLICATION

The PPOs have the possibility for partly or full exemption from this obligation in case they can prove one of the following reasons [2]:

1. The retrofitting measures include the replacement of the generator, the drivetrain or the power electronics in reference to DIN IEC

60050-551:1999.

2. The expenses for retrofitting measures are equal or higher than the replacement of the generator, the drivetrain or the power electronics in reference to DIN IEC 60050-551:1999.
3. The expenses for the retrofitting measures are not lower than retrofitting measures to fulfil the generally recognised codes of practice.
4. The PGU is used as an emergency power generating unit.

To verify one of these reasons for exemption the PPOs must submit an official application including all evidences to the appropriate DSO within the first nine month after the retrofitting request. The DSO checks the applications for formal completeness [3] and forwards the applications to the relevant TSO. TSOs check the applications in regard to their technical content within a timeframe of 9 months. In this context FGH supports three out of four German TSOs. While inquiring the applications the PPO´s deadline to retrofit the power plant is stemmed and extended up to 18 month. The necessary preconditions for exemptions are explained below.

To prove an exemption concerning ***reason 1*** the PPO has to provide technical datasheets, manufacturer declarations or scientific studies which are able to demonstrate the technical limits of the operating ranges.
Once the PPO could prove the reason for an exemption and that his PGU is operating at its limits, there is no further obligation to retrofit (full exemption). However, even a constricted performance in the required frequency ranges is accepted if the technical restrictions are proved transparently (partly exemption).
An exemption in regard to ***reason 2*** must be proven through a cost estimation of retrofitting the PGU onto the determined operating range. The calculation needs to be checked for plausibility, appropriate pricing and its SysStabV-context. Even applications with reason 2 could lead to full and partly exemptions.
An exemption with ***reason 3*** has to be proved via an economical comparison between retrofitting and the fulfillment of generally recognised codes of practice. If the measures listed in the SysStabV cost estimation are plausible, appropriate in pricing and in total lower than the costs for measures to fulfil the most recent recognised codes of practice, the application is approved. In that case the PPO needs to retrofit his PGU to fulfil the recent recognised codes of practice.
To prove an exemption in regard to ***reason 4*** the PPO has to declare that the power plant is only used as an emergency power generating unit regarding the requirements in [4].

2. PROPORTIONATE REIMBURSEMENT

Next to exemptions from the obligation of retrofitting measures for their PGU, the PPO has the option to apply for proportional reimbursement if the costs for retrofitting exceed 7.5 € per kW. In this case the PPO has to submit cost estimation to the appropriate TSO before commissioning the retrofitting measures. The TSO checks the cost estimation in the same way like for the exemption process, i.e. for plausibility, appropriate pricing and SysStabV-context. If the examination of the cost estimation is negative, the PPO has the opportunity to improve the cost estimation or submit the application to the German regulatory authority called "*Bundesnetzagentur*" for separable inspection.
If the result of the examination is positive, 75 % of the costs exceeding 7.5 € per kW are refundable. After the execution of the retrofitting measures the PPO has to submit the bill. A proportional reimbursement is only possible for the previously approved costs and measures. If other measures are necessary or it becomes likely that the costs exceed the previously approved costs, the PPO can submit a new cost estimation before the measures are executed.

3. CHALLENGES

Some PPOs have difficulties to submit proofs for exemptions because several of the original manufacturers either had stopped their business or had been sold. Hence, technical support is no longer available. If in addition the original technical documentation of the power plant is missing, it becomes complex and expensive to prove the exemption through expert reports including necessary measurements.
Moreover, there have been different approaches for the adaption of frequency ranges. Thus, there are service providers with different retrofitting concepts for equal types of PGUs. For instance, service provider A could retrofit the PGU just by updating the power electronic's firmware, however, another service provider B has no access to the firmware and needs to replace the entire power electronics. Therefor not only submitted retrofitting concepts with different efficiency-levels exist but also more efficient concepts need to be considered within the inquiry.
At the beginning the applications for exemptions as well as reimbursement mostly did not include explanations for the listed items. If e.g. components could not operate in the determined frequency range and had to be exchanged, no technical information about the installed component was submitted. Consequently, it was impossible to perform plausibility checks for this item and the application had to be revised.
In this context, one of the most restricted requirements is the monthly operating duration. According to [4] PGUs that are used as emergency power generating units are not allowed to operate in parallel to the public grid more than

15 hours monthly. A lot of submitted applications for PGUs did not fulfill this criterion. Consequently, the applications had to be dismissed.

STATUS QUO OF RETROFITTING

Figure 1 shows the reported PGUs for two TSOs. In October 2016 a number of 10,370 PGUs with an installed power of 18,228 MW were announced in the two considered control areas. For 8,977 PGUs with an installed power of 13,533 MW a confirmation of complete retrofitting already has been received. This leads to a quote of 87 % based on the number of power plants and to a quote of 74 % based on the installed power. Meanwhile, the deadline for most of the PGUs is reached. Missing confirmations can partially be explained by bottlenecks in the provision of retrofitting services.

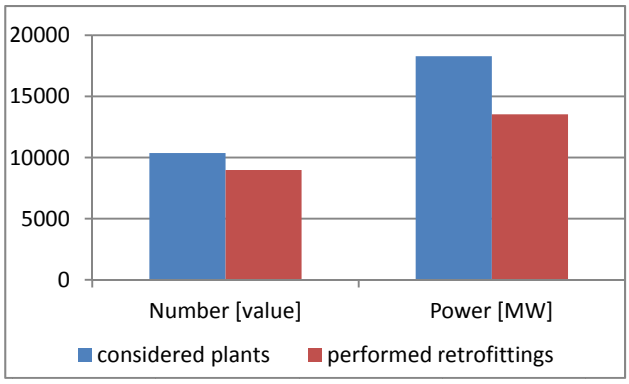

Figure 1: Number and installed power of reported power plants for two TSOs in Germany

According to [5] the number of exemptions was expected by 10 % of all affected PGUs. Figure 2 shows that in october 2016 the actual number of exemption is much lower. A total of 263 applications for exemptions have been submitted whereas only 84 with an installed power of 146 MW have been approved. This leads to a quote of 3 % based on the number of PGUs and to a quote of 5 % based on the installed power. Due to approaching deadlines a considerable increase of the number of exemptions is not expected.

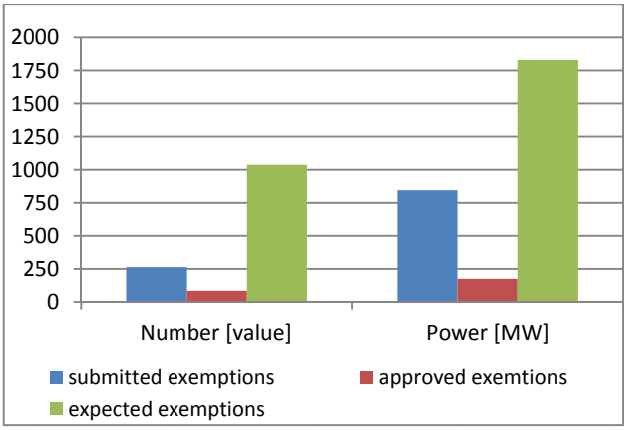

Figure 2: Exemption applications for power plants of two TSOs in Germany

The expected costs for reimbursement for all of the German TSOs have been 33 m € [6]. The actual expenditures for the TSOs considered in this paper for submitted applications amount to 1.75 m € with an approved part of 0.29 m €.

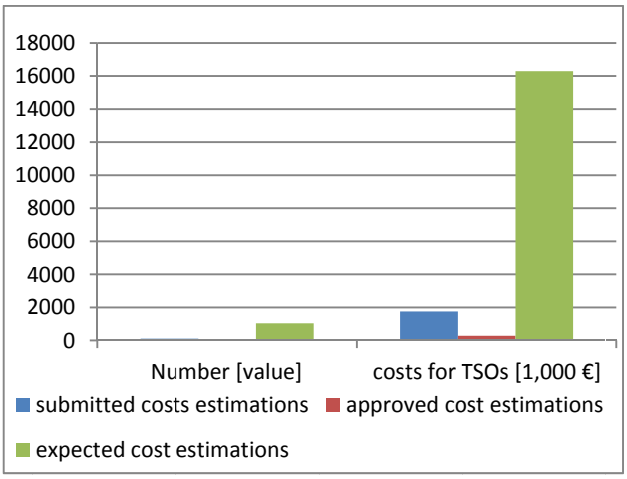

Figure 3: Cost estimations for power plants of two TSOs in Germany

QUALITY CONTROL

Subsequent to the implementation of the retrofitting requirements, the ordinance SysStabV postulates quality controls performed by the TSO, DSO and/or further service provider as FGH. It has to be proved randomly if retrofitting measures had been conducted successfully.
Thereby the sampling procedure is carried out based on the reported PGUs. In this context the lack of a central PGU-register in Germany is quite problematic. There are different facilitations implemented in diverse laws concerning all types of technologies. Furthermore, there are PGUs without any facilitation, e.g. hydroelectric power stations that are nevertheless affected by the ordinance. Hence, first of all it is necessary to obtain a consolidated population as a base for the random sample. The random itself is effected according to standard DIN ISO 2859 [7], inspection level II, containing twelve

categories depending on technology and voltage level.

It is possible to get disburdened from quality control if a protection testing protocol appropriate to German certification guideline FGW-TR8, rev. 6 [8], has been conducted. Hence, it can be deducted implicitly, that the German legislator stipulates protection tests at PGUs without correspondent protocols. A verification of parameters inside of the protection relays or inverter controls is not sufficient and would contradict to protection engineers' principals. This approach underlines the need of protection tests for new installed PGUs, e.g. single wind turbines, which have not yet become international standard. In Germany it has just started in 2011.
In addition, contrary to the verification of parameters, dependencies between protection relays and auxiliary components using protections can be checked using protection tests. However, there are limits. Thus, in case of higher influences of subordinated components further examinations concerning the operation in postulated frequency ranges have to be performed within the PGU.
The recommendation how to carry out and document protection tests according to FGW-TR8, rev. 6, was significantly developed by FGH.

CONCLUSION

Retrofitting targets in Germany are closely complete. After PV even other technologies had to implement wider frequency ranges. Quality control just has started and probably will be performed within the next two years. Its crucial importance can be deducted by the current scandals in car business. Type tests in laboratories as well as manufacturer declarations themselves are not sufficient to guarantee proper behavior under real conditions.

In this paper it was shown that the actual number of applied exemptions is much lower than the expected one. Supplementary, received confirmations on complete retrofitting are lower than its forecast. This leads to uncertainties concerning the available data base of the PGU-registers. In the future, it is highly recommended to implement overall registers by the national regulatory authorities.

Furthermore the paper shows that for system operators the expected costs for reimbursement has not reached its forecast at all. The divergences can be seen as an indicator for the importance of an on-site inspection within the quality control as part of a follow-up process to ensure a reliable operation according to the required frequency ranges. If the onsite inspections show a correct execution, the retrofitting measures are much less sophisticated than expected.

The big efforts that have to be performed within these retrofitting programs should be an important lesson learned for the future concerning the national implementations based on RFG (*"Requirements for Generators"*). Technical requirements and reliable verification schemes have to be introduced at the very beginning and before the amount of decentralized PGU reaches an uncontrollable level.

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