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White paper

Experiences with grid connection guidelines and the certification of Howden/KK&K-Steam turbines

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Abstract

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The ongoing energy transition is shifting power generation from a small number of large power plants to numerous decentralized plants. To ensure that grid stability continues to be guaranteed, uniform regulations have been established throughout Europe via Regulation EU2016 / 631. With the subsequent implementation of German national standards (VDE4110 and 4120) three different ways of proving the grid conformity of plants have been indicated: firstly, via a unit certificate for standard machines, secondly via a prototype process that also leads to a unit certificate and thirdly, individual machine verification procedures. Typically, certification is carried out by a third party. With these certification procedures, manufacturers and plant operators as well as network operators are confronted with new tasks. Additionally, especially with regard to customer-optimized, smaller steam turbines, the certification process also poses a commercial challenge.

Howden / KK&K steam turbines are often used for residual steam generation, as reducing stations in district heating networks or in a biomass plant. In order to generate a maximum return from the existing process parameters such as steam quantity and steam pressure, the machines are designed and optimized according to the customer's specific requirements. For customized machines, the only reasonable certification route is the individual machine verification procedure. The resulting additional costs, which do not add any value, amount to up to one third of the total machine costs and thus represent an enormous economic burden.

Two major challenges exist in the context of plant certification by itemization: the technical interaction of all components and the process-related coordination of the numerous parties involved. Technical requirements are usually met by two or more components, which often come from different manufacturers. Thus, the consideration of the interaction of the plant components is essential, especially in the evaluation of dynamic ptrocesses. In the process-related interaction, it is shown how all parties involved – from network operator, plant user, manufacturer, numerous suppliers, test facility to accredited certifier – are coordinated in order to conclude the process.

By mastering the complex process, plant certification is also possible for individual customer-optimized steam turbines.

Global trend of energy transition and its challenges for the grid infrastructure

The widely-discussed topic of climate change poses hitherto unknown difficulties for almost all areas of life. Thus, energy production is also being converted from fossil-fuelled large-scale power plants to sustainable energy production. CO_2 emissions are usually used as a measure of environmental damage.

In Germany, the largest percentage of CO_2 emissions stem from public electricity and heat supply, with a share of 41% [1]. Although CO_2 emissions per kWh decreased by 36% from 1990 to 2018, only 30% of CO_2 is being saved in total due to the increasing demand for electricity. The targets of the European Union specify a reduction in CO_2 emissions of 55% by 2030 compared to 1990.

In the future, electricity demand will continue to rise, due to, for example, increasing electromobility, automation and digitalization. Thus, increasing efforts will be necessary to switch power generation to sustainable sources, especially wind power and photovoltaics. Both wind power and photovoltaics are characterized by significantly smaller generation plants compared to fossil power plants. Characteristic of these two main sustainable energy sources is their natural fluctuation, which occurs regionally and over time. Photovoltaics fluctuate seasonally, as well as in the day-night cycle and additionally due to cloud cover. Wind power is also subject to significant fluctuations due to local weather patterns.

Thus, local and temporal fluctuations in energy supply will still exist in the future, leading to either undersupply or oversupply. In order to keep power grids stable, these increasing differences will have to be equalized in the future as well.

Grid connection guidelines in Europe

To ensure future grid stability, the European Union issued Regulation EU2016/631 for the European interconnected grid in 2016 [2]. In this regulation, rules are issued for the five European grid interconnections: Continental Europe, Great Britain, Northern Europe, Ireland and Northern Ireland and the Baltic States. Basic requirements for power generation plants indicate how long they must continue to operate even at frequencies deviating from 50Hz. In addition, the plants must adapt their active power output to the grid frequency and thus stabilize the grid.

A key requirement that applies to larger plants is the ride through of grid faults, the so-called fault ride through or low voltage ride through. This is defined by a sudden drop in voltage down to 0% of the nominal voltage. For synchronous generators, requirements apply with regard to the possible range of reactive power output or absorption. Further requirements are specified, for example, in the synchronization or the tripping values of the protection devices [2].

Due to different European network associations, country-specific regulations and non-uniform verification, certification within the European framework is very complex. In addition, network operators are entitled to impose deviating requirements.

Implementation of the European Grid Code in Germany and the certification process

In Germany, the EU regulation is implemented via three national regulations: VDE4105, VDE4110 and VDE4120. VDE 4105 is the authoritative standard for small low-voltage systems up to 135kW [3]. The grid connection directive that is usually applied to Howden steam turbines is VDE4110 [4] for medium-voltage systems. VDE4120 specifies the regulations for high-voltage systems [5]. Within the technical guidelines of the VDE, specific requirements are imposed on plants. A generating plant is defined as one that is connected at a grid connection point. A generation plant may consist of several generation units, for example, several turbine-generator sets. Verification is designed as a third-party procedure. This means that an accredited certification institute checks and confirms the verification. The measurement must in turn be carried out by another independent testing laboratory. An appropriate simulation model must also be provided and validated.

In the VDE rules, three possibilities for proving the electrical properties are listed. The most practical way for series units and smaller units, such as photovoltaic modules, is the unit certificate. In this, proof is provided for a unit on a test bed. Subsequently, a plant certificate must be provided, in which the local characteristics of a plant are taken into account. For plants with lower outputs that can be certified on a test bed, a unit certificate is economical. Thus, for serial products with higher quantities, the certification costs only insignificantly drive the product costs.

If the units are too large to be measured on a test bed, but are still series machines, the prototype method can be used, in which a unit is measured for wind power units, for example. In this process, a machine is evaluated and measured individually and a unit certificate is created. Subsequently, a plant certificate is created taking into account plant-specific parameters. For additional plants, this standard procedure can be used.

For individually-designed plants, an individual certificate procedure is provided. In this procedure, each individual plant is separately tested, measured and validated. In particular, plants with high outputs from approx. 10 MW are often specifically planned and designed. This can be evaluated most sensibly with the individual verification procedure. There are no LVRT test containers for this and the costs of the individual verification disappear in the costs of the overall plant. For individual steam turbine plants in the range of 1–10 MW, on the other hand, the relative costs of certification are at the limit of economic viability.

European Verification Method

Overall, European grid requirements refer to EU Directive EU2016/631 [2]. However, both the exact formulation of grid connection guidelines and verification procedures are different in all European countries. Thus, both the technical requirements as well as the supplied documents, models and data differ in the verification procedure.

This wide range of potential verifications to be provided can be seen clearly in the G99 from Great Britain. In this, depending on the machine type, the verification is available via manufacturer's information as well as witness test [6]. Thus, for each individual machine, it must be checked which requirements have to be met. Due to the different verification procedures, a check is also necessary before the machine is designed and purchased.

In other European countries, which do not have or do not yet have a clearly defined verification process, the German verification procedure is often used by plant operators and network operators. Howden, for example, is currently applying the German verification procedure in several European projects, supplemented by additional local requirements. For manufacturers of grid-connected machines, it is necessary to keep track of all the exact requirements and the verification process.

Challenge: certification for small, individually-designed steam turbines

Steam turbines in the Howden-KK&K series have a relatively small output of up to 15 MWel. They are often used to increase steam utilization and thus directly increase energy efficiency. Applications include pressure reduction in steam and (district) heating processes and the utilization of residual steam for power generation. Often the actual steam process already exists and the turbine is added. To ensure the best possible utilization, each Howden steam turbine is individually designed, as the processes are very specifically designed as well. Howden turbines are designed based on customer operating points, so no two turbines are alike. Howden turbines can be single- or multi-stage, and one or more steam extraction units are possible. Condensing turbines are often used for residual steam recovery. Howden's own power and process controller allows one or more process variables, such as live steam pressure or exhaust steam temperature, to be individually controlled in parallel with mains operation [7]. This high degree of optimization and customization for each individual customer means, of course, that there is no standard product.

The only possible way to obtain plant certification for individual turbines is the individual verification procedure. In this procedure, the machine is designed, the simulation model is created and then, during commissioning, the machine is tested and validated in its facility over several days for its electrical properties. Particularly for turbines with a connected load of less than 1 MW, the costs of certification in the individual verification procedure can amount to up to 30% of the machine costs. This is of course an economic barrier for many customers. In addition to the pure costs, the complexity of certification is another difficult point to clarify. The certification process introduced in Germany leads to an economic obstacle and thus to a slowed-down energy turnaround, as the energy feed-in becomes uneconomical due to residual steam generation.

In addition to the commercial aspects, two other major problem areas in particular can arise during certification: on the one hand, the technical design of the machine and on the other hand, the process of certification itself.

Technical challenges

The effects of these grid connection directives have a fundamental impact on the overall design of the machine. On the technical side, the main challenge is that many of the requirements are not fulfilled by one component alone. The machine consists of numerous components that influence the electrical properties (Figure 1). The main energy-converting unit is the turbine with a gearbox and a generator. These are controlled by a turbine power and process controller and a generator governor, respectively, and are supplied by numerous auxiliary units such as an oil system, valves and control cabinet. The control cabinet accommodates all essential electrical equipment, such as a synchronizer unit or protective devices.

All of these components comprise the overall plant and must reflect the electrical requirements. The characteristics of individual components sometimes influence each other in a very complex way. Thus, the statement that a component, for example the generator or the turbine, fulfills a requirement is only possible with limitations.

Example: Low Voltage Ride Through

The interaction of components can best be illustrated by the most-discussed example of LVRT (Low Voltage Ride Through). This is a short-term voltage drop on the grid side. In normal operation, the turbine generates rotational energy, which is then converted into electrical energy in the generator. During LVRT, the grid collapses and the resulting energy can no longer be released into the grid and thus remains in the entire string of the unit. This energy is absorbed both on the electrical side in the generator and mechanically in the drive train of the turbine. Thus, both the generator and the mechanical part of the turbine, the gearbox and the train must be designed for this. Thus, the mass moment of inertia of the entire train is decisive for the LVRT. Based on the interaction of the components, neither the generator manufacturer nor the turbine manufacturer can commit to an LVRT of the entire system.

The turbine must therefore be designed accordingly to withstand the mechanical effects. Thus, if technically required by the machine, the use of overrunning clutches is necessary to limit the torque in the train [8].

In addition to the main line, all auxiliary units such as oil pumps, valves or the LVRT control cabinet must also be safe. For example, they must be electrically buffered sufficiently. Verification for each individual component is necessary. Failure of a single component will result in the entire plant being unable to pass an LVRT.

This example shows that the electrical requirements can only be satisfied by the interaction of all components. The task of ensuring and verifying this is one of the central tasks in certification [9].

Figure 1: MONO AFA6 turbine (Howden / KK&K type) with LVRT relevant components such as generator, valves and oil supply

Example: Power control

In addition, when choosing power and generator controllers, it is important to ensure that measurements are possible. The parameters to be measured, such as static grid support, must be measured in the normal power grid at a specified frequency without jeopardizing grid stability. Thus, since no test bed is available, the frequency-dependent power reduction at grid frequencies higher than 50Hz is also measured at a constant grid frequency by giving the controller a grid frequency that is too high. In the measurement, the power reduction of the turbine can be seen in Figure 2 on the left. In Figure 2 on the right, the evaluation can be seen, together with the setpoint value of the power at the respective specified frequency.

Since many of the components are from different manufacturers, the other major challenge is to coordinate the certification process.

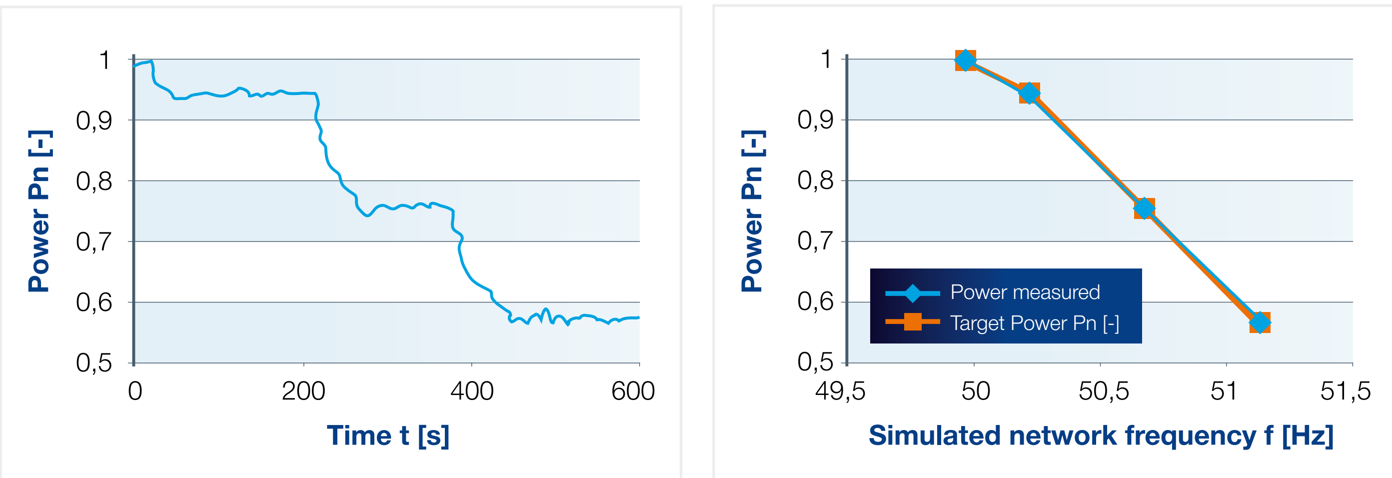

Figure 2: Measurement of the frequency-dependent power reduction at constant mains frequency (left) and the evaluation (right).

Challenges in the verification process (process)

Once the technology of the machine has been clarified, the challenge is to make the certification process economical. The design of the certification process together with the interaction of the many components and suppliers makes certification difficult. This results in a network of numerous participants. On the machine manufacturing side, in addition to Howden as the turbine manufacturer, there are also sub-suppliers such as control cabinet manufacturers, generator suppliers, producers of the generator governor, the power controller and the process controller. Furthermore, the certifier, the test laboratory and the grid operator have to be considered. Of course, the customer, who provides not only the machine but also the rest of the plant, has a significant part to play. The different, sometimes conflicting requirements of all parties involved must be taken into account at every step of the process, from the sale of the plant to manufacture, commissioning, measurement and certification. An exemplary network of different stakeholders is shown in Figure 3.

Methodology for solving the issue

The solution of technical and procedural challenges begins well prior to the actual commissioning. Already during the sales phase, the certification has to be considered intensively and an appropriate generator, corresponding mechanical components, as well as auxiliary aggregates have to be selected. In addition, customer sensitivity must be created so that the customer addresses this difficult issue and coordinates with his grid operator already in this early phase in order to clarify any special requirements. In practice, two methods have proved to be promising in the last few projects.

The first method is when the machine manufacturer takes over the certification as the lead company. In this case, all disciplines are coordinated centrally by a single body. This ensures that everything runs smoothly from the design stage to the final certificate. For example, as early as the design phase, a joint meeting is coordinated

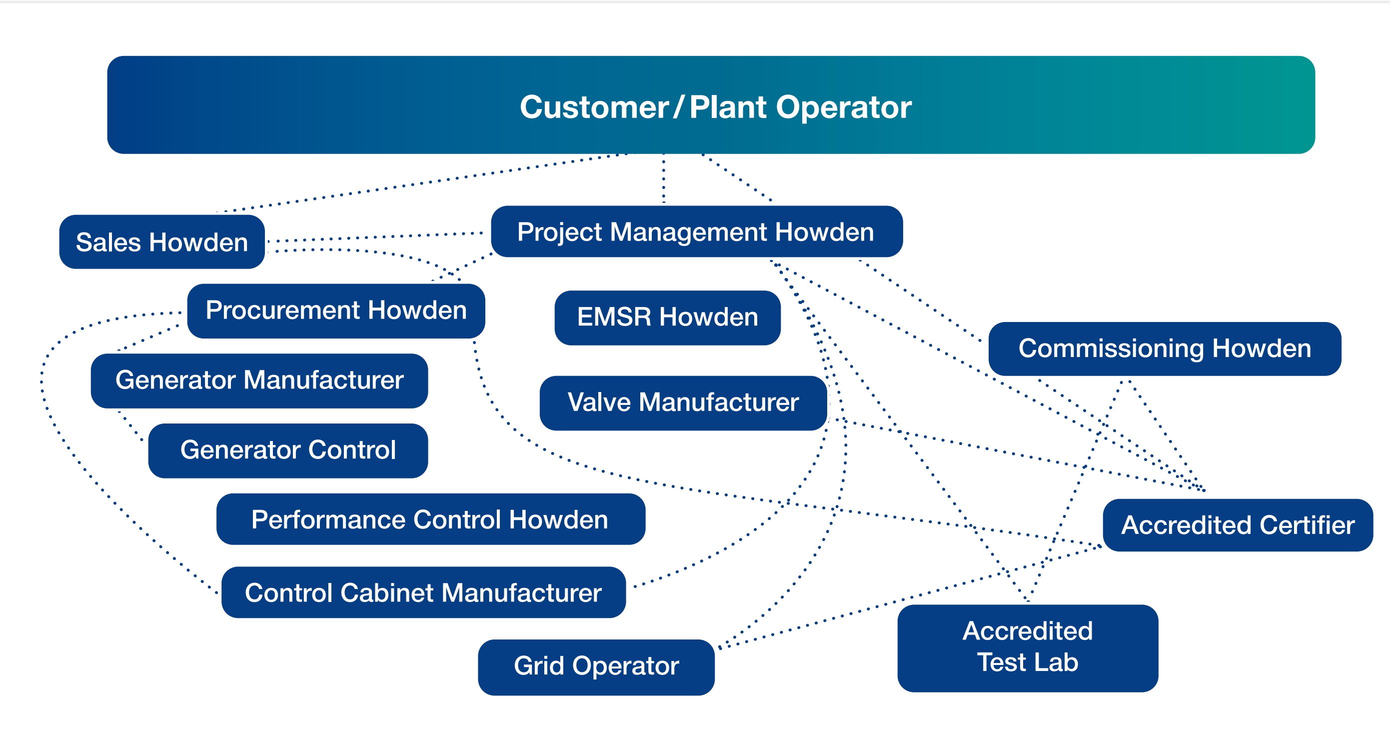

Figure 3: Emerging network of stakeholders in the certification process

with the network operator, plant operator, certifier and Howden to discuss the upcoming certification. All relevant parties have one central contact person who can resolve any conflicting requirements. For plant operators whose core business is different from power generation, for example, in the residual steam utilization of other processes, this method has proven to be effective.

The second successful method is when the customer, as the plant operator, is responsible for coordination. The customer takes care of certification as well as contact with the certifier and the testing laboratory. In this arrangement, we as Howden play the essential role of supplying a grid-code-compliant machine and providing intensive advice based on our accumulated knowledge. This second method has proven to be particularly successful with plant operators who are intensively involved with the topic of certification. Examples include municipal utilities that also act as energy suppliers or operators of multiple plants.

Outlook

In summary, plant certification according to VDE4110 and VDE4120 is a major challenge for the plant certification of individually-designed steam turbines. This is solved by a very clear structure and interaction of all parties involved with a central contact person.

Plant certification will continue to be a challenge in the future, although some simplifications are in sight. For example, component-certified parts will make it easier to prove that the technical requirements have been met. This is a first step in the direction of checking the interaction of the components more economically. The increasing experience of all those involved will ensure that the necessary knowledge is available and, for example, that the necessary data is available to those involved.

From a European perspective, further standardization of grid connection rules and the certification process would be desirable; the optimum would be the same rules and a uniform process throughout Europe.

With the concept developed, Howden is in a position to carry out plant certification economically even for turbines that have been individually designed and optimized for operation. All that then remains is the additional cost of certification, which must be taken into account when planning the overall plant.

It is to be hoped that the certification procedure introduced in Germany will not lead to an economic obstacle and thus to a slowed-down energy turnaround.

References

[1] Drosihn, Detlef Umweltbundesamt: Übersicht zur Entwicklung der energiebedingten Emissionen und Brennstoffeinsätze in Deutschland 1990–2018 unter Verwendung von Berechnungsergebnissen der Nationalen Koordinierungsstelle Emissionsberichterstattung. Dessau-Roßlau, 2020, ISSN 1862-4359

[2] Die Europäische Kommission: Verordnung 2016/631 DER KOMMISSION zur Festlegung eines Netzkodex mit Netzanschlussbestimmungen für Stromerzeuger. Brüssel, 2016

[3] Verband der Elektrotechnik, Elektronik und Informationstechnik e.V.: Erzeugungsanlagen am Niederspannungsnetz – Technische Mindestanforderungen für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Niederspannungsnetz, Berlin, 2018

[4] Verband der Elektrotechnik, Elektronik und Informationstechnik e.V.: Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb (TAR Mittelspannung), Berlin, 2018

[5] Verband der Elektrotechnik, Elektronik und Informationstechnik e.V.: Technische Regeln für den Anschluss von Kundenanlagen an das Hochspannungsnetz und deren Betrieb (TAR Hochspannung), Berlin, 2018

[6] Energy Networks Association: Engineering Recommendation G99 – Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019. London, 2018

[7] Howden Turbo GmbH: ST Brochure: www.howden.com/en-gb/products/steam-turbines; Frankenthal, 2020

[8] Mehlich, Andreas; Drubel, Oliver; Bohler, Axel: Einsatz von drehmomentbegrenzenden Kupplungen zur Auslegung von Wellensträngen von Stromerzeugern bei Energiewendespezifischen Netzanforderungen. In VGB PowerTech, 2018, 1/2, Seite 78-82

[9] Haller, Jens: Anforderungen aus dem Entwurf der VDE Mittelspannungsrichtlinie an die schutztechnische Ausstattung von Generatoren in Dampfturbinenanlagen. Mannheim, 2017

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