Abstract

The world-wide high power requirement requires a constant availability of the power stations. In order to ensure this high availability, an efficient outage management process is necessary. Effective outage performance requires the optimized planning of all outage activities as well as modern nondestructive examination methods, in order to examine the highly stressed components (turbine, valves, generator) reliably and in short periods of access. This paper describes, under which criteria nondestructive inspection techniques are developed for service examinations and when they should be applied.

In addition, it is also described how the technical ability of the personnel to operate modern NDT equipment under onsite conditions is optimized by a systematic qualification and training process.

Keywords: Turbine Inspection, Phased Array Inspection, Blade Root Inspection, Training

1. Introduction

Nondestructive testing is a very important aid to assuring the safety and availability of steam and gas turbines. That is why nondestructive examinations are a standard feature in schedules for turbine and generator maintenance-inspections and overhauls. The focus here is on testing particularly highly stressed components whose proper functioning is essential to the operation of the turbine generator unit.

To be able to perform nondestructive testing in the context of servicing turbines and generators, numerous technical, organizational and personnel qualification requirements need to be fulfilled to ensure high-quality performance of testing and proper analysis and documentation of test results. EN ISO 17025/2005 is internationally recognized as the state-of-the-art standard for defining quality criteria in the context of nondestructive testing.

While there are a number of commonly used nondestructive examination techniques such as visual inspection (VT), magnetic particle testing (MT), liquid penetrant testing (PT), ultrasonic testing (UT), radiographic testing (RT) and eddy current testing (ET), modern, component-specific techniques may also be used, for example phased-array applications, and mechanized UT or ET testing. Testing is performed in accordance with test procedures which must be approved and released by a suitably qualified test supervisor. The persons actually performing the tests must meet certain minimum requirements in order to cope with the specific demands made by the individual techniques.

This paper describes the processes for
- developing component-specific examination techniques,
- introducing such techniques to turbine servicing,
- implementing experience feedback, and
- training and qualifying test personnel.

2. Development of component-specific test techniques

In view of the loads they are subjected to under operational conditions and especially the potential damage that can occur in the event of failure, turbine components are tested at regular intervals. Testing needs to be systematically planned, as usually the only time turbines and electrical generators are available for testing is during unit outages and scheduled maintenance-inspections.

In practice, “in situ” tests have proven their worth, i.e. when the component does not have to be removed for nondestructive examination, and testing can be performed without major dismantling.

In the following, the procedure for developing NDT techniques for turbine servicing will be described taking the example of a phased-array ultrasonic inspection procedure for turbine blade roots.

In particular the rotating components of turbine-generator sets are subject to very high stressing during operation. For that reason, turbine and generator shafts and the turbine blades (both vanes and roots) must be inspected periodically during the course of their service life.

Once the blades exposed to the most stressful loads have been identified, the next step is to pinpoint the areas in components where the highest stressing occurs during operation (and where cracks are most likely to originate under adverse conditions). This is facilitated by calculating the stress histories in the components. Once the stress distribution within the component is known, it is possible to define the postulated location of any flaws, the anticipated flaw orientation, and criteria for the size of flaws that need to be detected.

This information is essential for tailoring a nondestructive examination technique.

A test block that represents both the geometric and the material properties of the test object is an indispensable prerequisite when developing an ultrasonic inspection technique for steam turbine blade roots. For instance, a test block can be used to devise an ultrasonic phased-array test technique for turbine blade roots that is tailored to detecting flaws with individually specified locations and orientations. Ideally, parts with real flaws in the region where discontinuities are to expected should be used as the test block, as the reflection behavior of artificially made flaws (grooves) may differ from that of natural flaws (e.g. cracks). It should be taken into account that, depending on the design of the turbine blade, even natural cracks in blade roots that have been removed from their seats may produce a different reflection than when the blade is inserted because insertion may induce stresses in the component (blade) that cause any cracks present to open wider, making them easier to detect in the ultrasonic inspection.

Such phenomena have been observed especially in the context of developing ultrasonic examination techniques for radial entry pinned blade roots.

The location and size of the artificially made test flaws depends on the size of flaw required to be detected under actual on-site conditions. For instance, if there are machine tool/score marks in the test region whose geometries could cause reflections (which could be misinterpreted as discontinuity indications), these must be taken into account when deciding on the size of the test flaws.
To achieve the most reliable test technique possible, the test flaws introduced should as far as possible cover all flaw orientations potentially encountered under real-life in-service stress conditions.

Examinations performed on test blocks during development of the ultrasonic inspection technique must be documented in a validation report. This report is essential especially with regard to quality assurance and ensuring the traceability of data for a test technique for application in turbine servicing.

The test procedure must contain all the information required for testing, i.e. both instructions on the test technique and information on the equipment to be used.

3. **Qualification and authorization of test personnel**

Application of modern nondestructive examination techniques calls not only reliable technologies but also for well-trained and qualified operators. Qualification of personnel for nondestructive testing is governed by the international standards EN 473 and SNT-TC 1A. Both contain requirements for training in various test techniques and also with regard to the practical experience needed for certification. Whether the techniques in question are liquid penetrant inspection of welds or special examination methods for specific components (such as phased-array UT inspection of turbine blade roots), responsibility for authorizing operators to carry out the specific test technique always rests with the employer.

How can we ensure that test personnel performing various nondestructive testing tasks in power plants around the world are trained and authorized for their assigned duties? It is important to make sure that the test operators have not only the technical qualifications but also enough practical experience to be able to carry out special test jobs on their own and under complicated conditions.

To meet the above requirements, Siemens Energy Sector’s Fossil Power Generation Service unit has devised a system for authorizing test personnel, taking into account not only their formal qualifications as called for in EN 473 but also their personal experience in applying selected inspection techniques. This system calls for training in individual examination techniques on specific components and also precise documentation of all inspection jobs carried out using the test techniques for which the personnel are to be authorized.

One area of special importance is the authorization of test personnel for globally operating NDT service providers that employ nondestructive testing contractors in various regions around the world. To ensure a consistent high quality of testing, such efforts call for regular review of personnel skills in using selected specialized inspection techniques.
It is advantageous to deploy NDT specialists who have attended a number of training activities to work on turbine or generator inspections together with experienced colleagues so as to ensure that personnel share and learn from their practical experience. After several assignments (in which trainee skills are assessed by the experienced mentors), trainees can be authorized for selected test techniques. A written authorization by the employer is valid for a limited period and contains details on component-specific techniques. In addition, the trainee is assigned to one of 9 categories that reflect their performance and capabilities. This in-house classification of NDT personnel into categories (Basic, Advanced and Expert, each divided into levels 1; 2 or 3) in line with their skills facilitates efficient deployment to turbine and generator inspections. Test personnel for each assignment are chosen on the basis of the scope of work to be performed and their in-house qualifications and classification.

4. Experience feedback

Before new nondestructive test techniques can be used to service turbines, such methods must pass through a validation process to demonstrate that the technique is properly suited for its intended purpose (i.e. capable of detecting defined discontinuities). The final outcome of efforts to develop a test technique is a validation report containing all relevant technical data and a test procedure.

When special nondestructive test techniques are applied in turbine servicing under on-site conditions, phenomena sometimes occur that could not have been anticipated in the development phase. For that reason it is essential to ensure experience feedback from the actual tests performed during a defined period.

How experience feedback assures the quality of testing is explained below taking the test technique for phased-array ultrasonic inspection of steam turbine blade roots (fir-tree design) as an example.
Turbine blades are among the most highly stressed components of turbine-generator units. In view of the high damage potential in the event of a blade fracturing in service, turbine blade roots must be inspected by nondestructive testing at regular intervals. In this context, particular attention is paid to the final-stage blades. As the most highly stressed regions of the blade roots are not accessible after they have been inserted in the shaft, phased-array ultrasonic inspection is used to inspect the roots in situ. This test technique calls for extensive experience in ultrasonic inspection of forgings as well as complete familiarity with the phased-array equipment. This is necessary because past experience has shown that unforeseen phenomena can occur that impede testing. To be able to distinguish indications possibly originating from geometric discrepancies, or machine tool or score marks (caused e.g. during insertion of the blades) from relevant crack-induced indications, experience transfer is essential to enable test personnel to recognize and understand the aforesaid phenomena and so to ensure the quality of their interpretation of the findings.

After more than 50 ultrasonic phased-array tests on final-stage blade roots had been carried out by Siemens Energy Sector in turbine servicing, a round-robin test was organized not only to discuss the accumulated experience but also to review and confirm the practical skills of the test operators.

In this test, 12 blade roots (with natural or artificial flaws or without flaws) were arranged in positions representing as realistically as possible the conditions when inserted in a real turbine. A written task description was formulated. All 12 blades were inspected using a phased-array ultrasonic inspection technique in accordance with a defined test procedure. The test was documented in accordance with defined guidelines. Ten experienced test engineers from the Siemens NDT organizations in Pittsburgh (USA); Newcastle (UK) and Mülheim an der Ruhr (Germany) took part in the round-robin test.

Figure 2: Round-robin test for phased-array ultrasonic inspection of turbine blade roots

Evaluation of the round-robin test findings yielded valuable conclusions as regards:
- the standard of training of test operators
- the reliability of test techniques
- the information content of the test procedure and interpretation of indications, and
- potential for improving test operator training.
The results of the round-robin test showed that the test personnel from Pittsburgh, Newcastle and Mülheim had been trained to a very high standard. The review revealed potential for improving the formulation of the test procedure. In general terms, the round-robin test proved to be an expedient means of identifying potential for improvement at various levels as the basis for introducing actual improvements.

5. Summary

Training and qualification of nondestructive test personnel for turbine servicing is subject to particularly stringent requirements. In view of the fact that test techniques are used worldwide by test operators on different continents, particular stringent requirements apply to the standard of training of test personnel and the content of test procedures, and as regards the availability of suitable equipment and test blocks.

Modern test techniques call for a high standard of training and experience in testing similar components and a high level of skills in using the associated equipment. For this reason, it is expedient to establish a small, dedicated crew of test engineers and technicians who are always assigned to tasks involving these selected test techniques. Before authorization is given, the test operators must have demonstrated in both in-house training and trial assignments to turbine overhauls (under the guidance of an experienced mentor) that they are capable of performing inspections in accordance with the specified test procedure under real-life conditions.

Siemens Energy Sector has been successfully operating a system for qualification and authorization of test personnel since 2001. The procedure for authorization of test personnel is not only specified in the applicable standards (EN 473/SNT-TC 1A), but its use is also mandatory to ensure that testing is performed to the required high quality. This approach has proven effective especially in the context of testing of components that can potentially impact safety (with which turbine servicing is primarily concerned). In addition, unannounced on-site audits are carried out to ensure that this quality standard is complied with at all times.

Against the background of stiff international competition in turbine servicing, the standard of training of Service personnel and effective quality assurance are essential prerequisites to ensuring the success of our business.
References


[5] Dr. Stefan Frank, Hans Rauschenbach (Siemens Energy Sector Mülheim, Germany) Qualification and Training of NDT Field- Service Personnel, 6th International Conference on Certification and Standardisation in NDT; Valencia, June 2011 [conference]