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Review of the doctoral thesis by Ing. Sven Künkel entitled "Design and Implementation of a Method of Monitoring the Interaction Between Turbine-Generator and the Electrical Network"

Evaluation of the significance of the doctoral thesis for the given field

The doctoral thesis was focused on the research and development of methods, software and the necessary components of the measuring chain for the purpose of analysis and subsequent monitoring of the torsional interaction of the turbine-generator with the events in the electricity network. The indisputable importance of this work for given field is in achieving the method of automatic detection of the occurrence of torsional vibrations of the rotor, which is currently a burning problem of a number of turbine-generators. Current power plants are not equipped with torsional vibration monitoring systems as standard. Typically, only the lateral and axial vibrations of the rotor are monitored. The application of the developed method in practice on 14 turbine-generators is a significant contribution of the doctoral thesis.

Comment on the approach to solving the problem, methods used, and fulfilment of the objectives

The goals of the work are defined in its introduction, three goals are mentioned here: 1. monitoring of the interaction between the turbine-generator unit and the electrical grid; 2. measurement and evaluation of the torsional vibration signals and 3. practical evaluation on data measured in power plants. These goals and their fulfilment are gradually described in the following chapters of the thesis.

The primary focus of this thesis lies in the third chapter, wherein a detailed explanation and step-by-step documentation of a torsional vibration measurement method based on incremental sensor data is presented. The chapter delves into the design of the method, particularly the intricacies of estimating encoder geometry. A comprehensive discussion is included, encompassing an analysis of potential parasitic effects and their impact on measurement accuracy.

Practical examples of potential interpretations of the measured data are reliably illustrated in the fourth chapter, where the contribution and potential of the proposed method for detecting torsional vibrations in turbogenerators, originating from the power grid, are simultaneously demonstrated.

I don't quite understand table 3.1 in chapter 3.4.3. It appears to be incorrectly laid out, lacking combinations of generator frequency slip during operation and frequency of torsional vibrations. Variants such as non-zero slip synchronous vibration and zero-slip non-synchronous vibration are missing.

Nevertheless, I am confident that the approach the author has adopted for attaining the final results in describing torsional vibrations is accurate and well-conceived.

The set goals of the work were met, the methods used correspond to the current state of knowledge, the solution procedure used the analysis of real signals from turbines, modelling and experiments.

Opinion on the results of the thesis and specification of the student´s original contribution to the given area of knowledge

The doctoral thesis concludes with an in-depth survey of the torsional vibration measurement method. The original contribution of the work is new knowledge and a method of evaluating torsional oscillations of turbogenerator rotors and procedures for their automated evaluation. The main contribution of the author is the creation of a robust mathematical model for the measuring technique and subsequent confirmation of its effectiveness through practical implementations. The author's insightful analysis of the measured data is worth mentioning, which highlights not only the effectiveness of the method in condition monitoring, but also emphasizes its diagnostic capabilities. Moreover, I appreciate that the results were applied in industrial practice.

Systematic approach, clarity, appropriateness of form and language

From a formal point of view, I rate the presented work as good. It has a logical structure and gradually introduces the reader to a whole range of implemented activities. Individual steps are systematically described and partial conclusions are sufficiently explained and derived. The work has an excellent formal and linguistic level.

Student´s publications

The student is the author of 3 articles in significant international journals, the main author or co-author of many publications at relevant international conferences. The Scopus database lists 12 publications in which he is an author or co-author with 22 citations. The publication activity of the student demonstrates his ability to produce scientific research results in an international context.

Conclusion

The doctoral thesis is a very high-quality work demonstrating Ing. Künkel's ability to conduct independent and creative scientific research. It presents radically new insights and has highly important practical implications; therefore, I strongly recommend the doctoral thesis for defense without reservations.

Questions for discussion

1) In the text, you most often use radians as the unit of amplitude of oscillations. Do you have any idea what the vibration amplitude values are in the circumferential deflection? What benefit do you see in the evaluation of specific torsional vibration amplitude values? Do you have set limits for each machine?
2) Torsional excitation of the generator rotor at twice the rotational frequency (2X) is a consequence of many typical generator/grid fault conditions. How then do you approach the limitation of your proposed method of not being able to detect torsional vibrations at 1X and multiples?
3) The figures in your doctoral thesis illustrate the large variability of the relative damping of torsional vibrations. Do you have any idea what affects the torsional vibration damping?

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FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
department of control and instrumentation

Review of Doctoral Thesis

Candidate: **Ing. Sven Künkel, Faculty of Applied Science, University of West Bohemia**

Thesis title: **Design and implementation of a method of monitoring the interaction between the turbine-generator and the electrical network**

Supervisor: **doc. Ing. Eduard Janeček, CSc.**

Evaluation of the significance of the dissertation for the scientific community

The aim of the presented thesis is to research and develop methods for monitoring and analysing torsional vibrations of a turbine-generator caused by events in the power system, and their practical verification in real conditions. This is a very interesting and promising topic, which is gaining importance in the context of the development of alternative energy sources. Increasingly, there are rapid changes in the conditions of the power system that cause transient excitation of torsional vibrations of the turbine generator rotor, thus shortening its lifetime.

Comment on the approach to the problem, the methods used and the achievement of the objectives

The thesis is divided into four main chapters. In the first two, the mechanical model of the rotor torsional vibration, the electrical model of the synchronous generator and the possible mechanisms of interaction of the electromechanical turbine-generator system with the electrical grid are described in detail.

The main contribution of the thesis is in the following third chapter, where the design of a torsional vibration measurement method based on incremental sensor data is explained and documented step by step. A thorough discussion of the method design for estimating the encoder geometry is provided, including an analysis of possible parasitic effects and their significance in terms of measurement accuracy.

In the fourth chapter, practical examples are used to demonstrate the possible interpretation of the measured data and to credibly demonstrate the contribution of the proposed method and its potential for the detection of torsional vibrations induced by faults in the power system.

I consider that the procedure chosen by the author to arrive at the final relation 3.54 for the determination of the instantaneous angular velocity is correct and well thought out. My only comment is that, in an almost complete analysis, the author failed to discuss the effect of the accuracy of the time interval measurement, in particular its limited resolution due to the sampling frequency of the A/D converter.

It is a pity that the author did not use the detailed analysis of individual measurement errors to determine the uncertainty budget of the instantaneous angular velocity measurement. This would have significantly increased the credibility of the method for safety critical applications.

The paper also lacks a more detailed description of the technical design of the monitoring system, only the sensors used are listed in the appendix, but there is no discussion of the HW and SW requirements for the rest of the diagnostic system, or at least a brief description of the solution used.

However, despite these comments, I consider the objectives of the thesis to have been fully met.

Opinion on the results of the thesis and the author's contribution

The result of the dissertation is a detailed analysis of the torsional vibration measurement method using a common incremental encoder. The main contribution of the author is in the design of the mathematical model of the measurement method and subsequently in the practical verification of the method. In particular, his interpretation of the measured data demonstrates the possibilities of using the method not only for condition monitoring but also for diagnostic purposes.

Statement on the systematics, clarity, formality and quality of the thesis

From a formal and linguistic point of view, I do not have any major comments to make, except for a few typographical errors in the text. On the contrary, I must praise the author's pedagogical skills. The thesis is well and clearly written, it is readable and the chapters are logically linked. It is a pity that the appendix of the thesis does not contain the developed software, because I would probably find an Easter egg there too.

Statement on the student's publications

The WoS database lists five publications with UWB affiliation, with a total of 8 citations for which he is listed as co-author. The dissertation appendix lists a total of 18 publications in which he is an author or co-author. Although these are mostly conference papers, I consider the publication activity to be sufficient and indicative of the ability to present the results of his work to the professional community.

Final opinion

Based on the work submitted, I conclude that Ing. Sven Künkel has fulfilled the requirements for a doctoral thesis in a technical field in the sense of the conditions specified in §47 of Act No. 111/1998. I recommend that the thesis be defended and, if it is successfully defended, that the degree of Doctor of Science be conferred.

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department of control and instrumentation

Questions for discussion

1) On page 37 you state 0.004 rad.s^{-1} as the limiting angular velocity of torsional vibrations. On what basis was this value determined?

2) On page 37 you also state that the error of the measurement result must be within specified limits. What do you assume to be the expanded uncertainty of the instantaneous angular velocity measurement? For the specific case chosen, can you quantify the uncertainty for at least the three most important sources? Which are these?

3) From a practical point of view, how important is the limitation that the proposed method cannot measure synchronous torsional vibrations in synchronous machines?

V Brně, 20.11.2023

doc. Ing. Petr Beneš, Ph.D.

FEKT, VUT v Brně