A1 - 00

SPECIAL REPORT FOR SC A1
ROTATING ELECTRICAL MACHINES

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Special Reporters

1. Introduction

Study Committee A1 is responsible for the area of Rotating Electrical Machines within CIGRE and includes in its scope all such machines for power generation, motors for power stations, and synchronous compensators for power system support. Also included in the scope are materials technology and superconducting technology relevant to rotating machines.

The range of activities and interests of Study Committee A1 includes research, design and development, manufacture and test, site assembly, commissioning, operation and maintenance, asset management and the de-commissioning of the machines within its scope. The assessment of the current condition of machines and their components, the refurbishment, power upgrade, conversion to synchronous compensator duty, long-term health assessment of the machines, and proper storage of strategic spares are all included under the asset management aspect.

In recent years Study Committee A1 has seen an increasing interest in the use of rotating electrical machines alongside the newer power generation technologies and in machines for dispersed generation. The role of large machines in supporting grid reliability in the face of power fluctuations and unpredictability from renewable generation sources has become increasingly important with the focus on new plant changing from primarily power output towards the available contribution to system inertia, short circuit power and the ability to ride through grid disturbances. The increased demand on the flexibility of operation of both new and existing plant is presenting real challenges to the application of standard designs.

The high level of introduction of wind turbines has meant that there is a huge installed base that continues to develop quickly both on- and off-shore. This again raises the importance of monitoring, reliability, availability, and maintenance strategies particularly with regard to locations with difficult access, limited availability of suitable handling equipment, and weather constraints dictating the timing of maintenance activities.

Study Committee A1 is adapting its scope to encompass all of these challenges.

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2. Group Discussion Meeting in Paris Session 2021

The Study Committee invited written contributions to provide discussion material for the Group Meeting in Paris Session 2021. A total of 27 abstracts were accepted from those submitted for approval under three Preferential Subjects. One paper was subsequently withdrawn. The submitted 26 papers are summarised below under the following three Preferential Subjects chosen for the 2021 Session. Please note that these contributions were presented at the 2020 virtual Session.

PS1 Generation mix of the future

- Effect and risk of an increasing renewable power mix on existing legacy generators, generator auxiliaries, and motors of renewable energy and variable load demand.
- Improvement in designs and maintenance practices to comply with new and future grid requirements.
- Evolution and trends in designs of machines for renewable generation.

PS2 Asset Management of Electrical Machines

- Experience with refurbishment, replacement, power up-rating and efficiency improvement of aged generators and motors.
- Optimised condition monitoring, diagnosis, prognosis, and maintenance practices to improve reliability and extend operational life.
- Operational and project experience: installations, failure analysis; robotic inspections; recovery options; cost and time reduction initiatives; and effects of torsional electromechanical oscillations for synchronous compensators, wind turbine generators, turbogenerators, hydro-generators, and motors.

PS3 Developments of rotating electrical machines and operational experience

- Designs, specifications, materials, manufacturing, maintenance and performance and efficiency improvements of electrical machines.
- Condition monitoring techniques and equipment.

3. Preferential Subject 1: Generation mix of the future

Two papers were accepted under PS1 and are summarised below.

Paper A1-101 (Australia): Is reliance on synchronous machines holding back the evolution of the power grid to facilitate renewables?

The paper brings an interesting discussion which should be in focus not only by engineers specialized in synchronous machine design and operation, but by engineers involved in the operation of the power system, mainly in protection and control aspects, as well as design. In terms of the 20th century definition and thinking of the power system, which is based on the flexibility of the AC generation and transmission plants, it is pointed out that old trade-offs are bringing difficulties and holding back the development of renewables. According to the author, fault level and inertia are the main concepts dealt with by energy systems engineers. This leads to difficulties in an environment in which the power sources are connected to the system by inverters. On the other hand, the types of load that are more tolerant of voltage and frequency variations are now much more common and widespread. Thus, the author warns that it is necessary to change the way of thinking about stability and continuity of energy supply. He also poses important questions to operators and designers, which could be summed up in a single direction: to value not what is obsolete, but what is being presented as a solution for a world increasingly reluctant to accept environmentally impacting technologies.

Question 1.1: Aside from water sources, renewable energies inexorably have the characteristic of intermittency. Thus, the presence of synchronous generators is, in almost all power systems, essential. Is it possible to build the mentioned system with zero inertia, without considering any type of storage? In this case, are there systems of this type in operation in the world today, even on a small-scale?

Paper A1-102 (Switzerland & France): The benefits of implementing Synchronous Compensators in grids with high penetration of Renewables

The paper mainly points out that the synchronous compensator (SC) will have a fundamental role in the scenario of system operation in an environment of energy production by renewable sources in the near future. This is due to SC energy performance characteristics and the spread of operating techniques. It is demonstrated that SC technical and economical performances are superior to that of new technologies, such as SVC or STATCOM. In view of the great focus on cost reduction in systems based on non-dispatchable renewable sources, the authors remind of the possibility of using present energy production facilities, such as hydro, pumping, and thermal plants, as lower cost plants to be converted to SC.

Question 1.2: In the simulated system, Battery Energy Storage Systems (BESS) were used. Consider a certain system where the use of non-dispatchable energies requires the installation of SC. In a practical scenario, what directions should be taken to dimension the power of BESS's and their location to be installed?

4. Preferential Subject 2: Asset Management of Electrical Machines

Thirteen papers were accepted under PS2 and are summarized below.

Paper A1-201 (USA): Experimental Study of Vibration Sparking Erosion on Stator Bars

Paper A1-202 describes an experimental study into vibration sparking erosion on generator stator bars and identifies three stages of vibration sparking and its action upon the stator winding semi-conductive layer. The study involved setting up vibration sparking on samples within the laboratory and electrical measurements made during the testing and physical damage clearly visible after the tests were concluded.

The paper reports the increase in surface resistivity of the semi-conductive layer after erosion has taken place and that the area of damage initially widens with increasing vibration levels before it starts to decrease when the erosion products limits the intensity of sparking, by breaking the current path. The paper suggests a circuit model of the semi-conductive layer of a stator bar to describe the parameters of VS generation and the distribution of the parasitic current along the semi-conductive layer.

Question 2.1: The paper discusses the impact of the residual carbon from the erosion products, in an operating machine with cooling gas. What is the anticipated impact of the erosion products and the propensity for vibration sparking to occur? Will these products be redistributed by cooling gas flows with the potential to cause issues elsewhere in the generator?

Paper A1-202 (Brazil): Supervised and Unsupervised Machine Learning Techniques Applied to SCADA and Vibration Data for Diagnostics and Prognostics of Two Wind Turbines' Drivetrains

Paper A1-202 describes application of a number of Machine Learning (ML) methods to not only diagnose vibration issues associated with the drivetrain of wind turbines but also provide the capability to determine when maintenance intervention is required. The study focusses on two wind turbines, presumably of identical or similar design, adjacent to one another in a wind farm. One of the wind turbines had recently been refurbished while no maintenance had been performed on the other which had experienced long service hours. The paper identifies the common failure modes of drivetrains and their means of detection. Brief descriptions are provided on the ML algorithms used. The criteria used to provide prognosis of the drivetrain based on the results of analysis of the vibration data are based on limits described in ISO 10816-21. Vibration data was acquired over a six-month period and analysed using the ML techniques described in the paper. This analysis concluded that there were significant differences in the vibration results as well as other monitored parameters between the two wind turbines. The wind turbine that had been in-service longer with no maintenance exhibited degraded performance. This information was used to prioritize maintenance actions on this machine as well as other similar wind turbines on the farm. Using an extrapolation algorithm indicated that the other wind turbine in the study would require inspection and maintenance with a period of a few months.

Question 2.2: Using the methods described in the paper, the recommendation was made to operations and maintenance staff in the utility to consider taking some form of action to address the increasing vibration levels in the drivetrain of one of the wind turbines. Were such actions taken and, if so, what were the results? Can other organizations comment on their experience with applying AI techniques to identify defects and plan maintenance?

Paper A1-203 (Brazil): Evaluation of the Behavior of Partial Discharges in Generator Heating and Operating Range Tests

This contribution documents a series of on-line partial discharge (PD) tests made on a new hydrogenerator stator winding operating over a range of controlled loads and temperatures during commissioning. The purpose of these tests was to explore the effect on PD behaviour of variations in thermal and mechanical stress. Further, the authors examined the influence of rotor temperature on PD activity. This latter parameter is interesting because of the increasing need for VAR support to maintain power system stability due to the increasing penetration of wind and solar generating assets. Operating under increased reactive power tends to increase rotor temperature. Consistent with previous studies in the literature, these tests showed that the reliability of PD data is correlated with testing being performed on thermally stable stator windings. A finding that confirms the tolerances for operating conditions defined in IEEE 1434 and IEC 60034-27-2 in order to confidently trend PD data.

Question 2.3: The authors conclude that the PD magnitudes observed during the commissioning tests will probably decrease over a six-month period due to final curing of the impregnating resins. Has such a reduction in PD activity been observed over the period since the stator winding was commissioned and has this expectation been confirmed by other manufacturers?

Paper A1-204 (Brazil): The evolution of the maintenance processes increases the operational availability and contribute to the operational efficiency of the Itaipu Power Plant

The Itaipu Binacional hydroelectric power plant, with a 14000 MW of installed capacity, has constantly been improving its processes to ensure increasingly higher indicators of availability of the generating units. Over the last six years, these indicators have always been above 96%; in 2017, 2018, and 2019 the availability exceeded 97%. Hence, combined with operational effectiveness, this fact made possible excellent energy efficiencies such as 98.09%, 99.30%, and 99.55%, respectively.
Although Itaipu has not the largest installed capacity in the world, they have beaten their own world record on energy generation. The authors describe their efforts to reach and preserve this valuable achievement, which, as explained, was thanks to the convergence of four essential factors: i) energy consumption in Brazil (472,242 GWh); ii) the availability of the transmission system under FURNAS responsibility; iii) hydrologic availability in Itaipu (107,176 GWh), and iv) mainly the generating units availability optimization (96.30%). These factors led to a production performance of 96.20%.
As can be seen, from the four factors presented above, the only one which can be managed directly by Itaipu is the generation availability. This paper portrays the experience of the Maintenance Supervision of Itaipu Binacional on the strategic maintenance management to reach such a vital energy generation ranking.

Question 2.4: It is stated that the balance between availability, reliability, and costs involved in the equipment maintenance and operation processes is a constant management concern. Would it be possible for the authors to explain their experience in how these conflicting factors are assessed and the challenges faced in establishing such a change in the corporation's mindset?

Paper A1-205 (NO): Partial Discharge Characterization of Stator Windings Taken from a Hydro Generator After 50 Years Service

Paper A1-212 (CH): Potential of VLF PD Measurements for Diagnosis of Stator Insulation of Large Hydro Generators

Very low frequency high voltage testing of stator winding insulation has been investigated since the late 1950s by Bhimani and colleagues at General Electric. An IEEE standard (IEEE 433) that governs VLF testing has been available since 1974. Despite the advantages afforded by VLF power supplies, i.e., size and cost, widespread application to rotating machines has not occurred. Likely one reason preventing more common adoption is the relative lack, compared to power frequency, of PD results necessary to build confidence in the method. Two contributions from Norway and Switzerland, taking somewhat different approaches, provide much needed data to address some of these issues.

Paper A1-205 examines PD behaviour under power frequency (50 Hz) and very low frequency (VLF) (0.1 Hz) voltage application. The study, on a 50-year-old stator winding, includes results obtained from on-line PD measurements as well as off-line testing on-site and in the laboratory. Principle findings from this work included: phase-resolved PD (PRPD) patterns are similar for VLF and 50 Hz PD characterization; PD inception voltage (PDIV) is found to be independent of frequency and similar for single stator bars and measurements on-site. The maximum PD amplitude and repetition rate increases with the frequency of the applied voltage. These results indicate that VLF PD testing is promising for condition assessment regarding PDIV and PRPD patterns, but great care should be taken when comparing other parameters at VLF to conventional 50 Hz PD measurements.

Paper A1-212 also studies the similarities and differences between PD data obtained at 50 Hz and 0.1 Hz. In addition, PD characteristics at 10 Hz and 1Hz were examined. This work involved experiments on small samples of stator bar and modelling using a circuit-based approach. In addition to considerations of the role of frequency on void discharge, the authors also examined the influence of the frequency of the applied voltage on the conductive and stress grading systems that are applied to high voltage windings. The results in the paper showed that as the frequency decreased the electrical stress in the slot cell and the endwinding corona protection also decreased thus reducing the probability of PD occurring and being detected. Based on these results, the authors concluded that despite the cost and size advantage of VLF power supplies, diagnostic testing of stator windings at, or near, power frequency was still preferred.

Question 2.5: The conclusions of papers A1-205 and A1-212 offer different perspectives on the effectiveness of insulation diagnosis under VLF conditions. Have the authors carried out further research in this area and have other organizations performed work on the comparability, or otherwise, of power frequency and VLF testing?

Paper A1-206 (Russia): Features of the design and operating modes of the asynchronized turbogenerator T3FSU-320

This paper portrays design features and operation modes of a turbogenerator design with two explicit coils in the rotor, one in the direct (d) axis and the other in the quadrature (q) axis. Some constructive details are described, with more emphasis on the excitation system details and unconventional operation modes.

Question 2.6: The authors have mentioned "operating modes of the asynchronized turbogenerator" but this term is not explained nor defined in this contribution. Would it be possible to clarify the specific operational mode described and to present an insightful

explanation of the advantages of the transverse rotor winding? Would this novel design have other advantages in other aspects of grid support with relation to the increasingly high penetration of intermittent renewable energy sources?

Paper A1-207 (Republic of Korea): A Study on the Resonance Problems and Anti-Vibration Design of Large Vertical Motor-Pump set.

The case introduced in this paper is very unusual resultant from the primary torsional resonance frequency of a large vertical motor-pump structure. The possible origin of the torsional resonance is explained through FEM analysis. As one way to overcome the problem, a beam stiffener was successfully introduced.

Question 2.7: The authors have mentioned reed, torsional, and vertical vibration modes; finally, the torsional vibration mode was identified as the resonant one. Would it be possible to offer more detail about the mechanisms that would excite those resonant processes? Have others experienced similar vibration problems on large vertical pump motor sets?

Paper A1-208 (Thailand): Motor Maintenance Management for Power Plant Operation Reliability with Work Optimization by On-Line Condition Based Monitoring

Paper A1-208 considers the experience and example of condition-based monitoring of motors attached to a pump set. The paper discusses the case study of a once per revolution vibration imbalance and provides before and after current signature analysis, thermal imaging and spectral frequency analysis. Spare bearings were procured in advance to enable faster return to service during the outage. The authors have also provided a reference section with a short description of the vibration spectral analysis and current signature analysis for benefit of the reader.

Question 2.8: The paper advises that spare bearing parts were ordered due to the condition-based assessment. The imbalance measured with the vibration probes was corroborated by the current signature and spectral analysis. For the thermal imaging was there a baseline temperature assessment for comparison with the as found condition used? Have other users/manufacturers experience with the application of current signature analysis, thermal imaging and spectral frequency analysis have been used to diagnose operating issues.

Paper A1-209R (India): PD Measurement of Rotating Machine for Condition Monitoring

Paper A1-209R presents case studies of the use of 80pF and 2nF capacitors for online PD measurements. The use of offline monitoring is discussed as less favourable to the utility due to outage requirements and that whilst online temperature, vibration and other influencing factors are not present.

The various case studies discuss a number of different failures and the ability of PD to detect certain defects. The authors describe the difficulty in detecting a fault in the transposition of a Roebel bar which had been operating for 13 years although previous PD tests did not raise any concerns. The insulation between the cross over Roebel turn failed leading to an eventual earth fault to the stator core. No obvious external contributing factors were found. Five identical generators of the same type were tested, and a large variation of Tan delta was found between 9 – 0.5% however, the capacitance was found to be similar across the units. PD magnitudes and patterns were found to be different across the five units making direct comparisons difficult.

The paper concludes that industry guidance and standards for PD testing on rotating machines is less prevalent than for other static equipment, such as transformers. Lack of alignment of the

PD monitoring equipment for coupling capacitors is highlighted. These deficiencies in the authors' experience is causing unpopularity of PD as a condition monitoring tool.

Question 2.9: With the difficulty in detecting faults in the transposition area using PD, is other testing being considered such as surge testing or high potential testing on the generators?

Paper A1-210 (Russia): Optimization of turbogenerator's core suspension system reconstruction methods for life time extension in the power plant conditions

The paper examines the experience of Elektrotyazhmash TGV series generators in particular core vibration. A theoretical study is discussed and a practical approach to mitigating high core vibration at twice fundamental frequency.

The paper presents historical operating experience of TGV series generator with 23%-26% defects relating to the core fastening, being first and second highest reported defect for the 200MW and 300MW units respectively. The amplitude of the vibration is stated as being over 100µm and has resulted in fatigue cracking of the keybar to the core inner frame and stiffening ribs on numerous machines and is one of the key concerns over the life of the units.

The authors discuss a theoretical model produced to access the design, which indicated that stiffening in the radial and tangential planes would provide the most effective attenuation of vibration amplitudes. A case study where an additional bracing was installed to a unit with a measured reduction of 30% on the core vibration of 30% and 70% on core frame were realised.

Question 2.10: Has the machine been reassessed since being installed, and, how effective has this procedure been at reducing fatigue cracking previously experienced? A number of designs installed in the world have had core vibration issues historically and various methods of reducing this problem has been carried out, for example belly bands. What are other users experience in resolving such issues that could be shared?

Paper A1-211 (France): A study of the drop test to detect damper faults and sensitivity analysis in order to identify the parameters that have an impact on the test results

The article presents analysis of the effects of different anomalies on the results of the drop test in hydro-generators. The analysis is performed using Finite Elements. It is shown how shorted turns, broken bars in the damper winding and stator joints interfere with the drop test results.

Question 2.11: Although it would require a failed machine, it would be interesting if actual test results of performed tests could be shown. In a hypothetical case, if there were shorted turns and a broken bar on the same pole in one machine, would it be possible to identify the defects in a single test?

Paper A1-213 (Brazil): Evaluation of High Voltage Isolation Systems Electrodynamic Meaning of Typically Specified Tests

The authors of Paper A1-213 offer an alternative approach, based on fundamental considerations of dielectric process, to understanding the function of many tests that are applied to the diagnostic and qualification testing of stator winding insulation systems especially those concerned with large hydro generators. This view of the insulation ageing process due to thermal and electrical stresses provides valuable insight into the basis for a number of the more common tests. Among the tests examined using this approach are dielectric dissipation factor, thermal cycling, voltage endurance and the insulation breakdown test. The latter two tests are

considered as methods to assess whether, or not, the stator winding insulation system is deemed to have passed the thermal cycling test as described in IEEE 1310 or, alternatively, IEC 60034-18-34.

Question 2.12: The authors of paper A1-213 raise the valid, and sometimes controversial, point regarding pass/fail criteria for the thermal cycling test. In this contribution, mention is made of using either voltage endurance or insulation breakdown testing to assess acceptability. Do the authors, or any other organizations, have any data or opinion as to which of these two tests, if either, are superior?

5. Preferential Subject 3: Latest Developments

Eleven papers were accepted under PS3 and are summarized below.

Paper A1- 301 (Germany & Brazil): Modern Approaches for the Thermal Design of High Rotational Speed, Air-Cooled Hydro Motor-Generators.

The rotor excitation winding's thermal performance was investigated for two high rotational speed air-cooled salient pole synchronous motor-generators with different cooling and ventilation system designs. The two studied designs differ in the cooling air's flow orientation close to the excitation winding, one with a radial and one with an axial flow direction relative to the machine's rotational axis.

Detailed 3D conjugate heat transfer (CHT) simulations were conducted to investigate the rotor pole excitation winding's cooling efficiency. For both researched motor-generator designs, the applied simulation approach is presented in this paper, including different calculation strategies. The obtained results were evaluated with a focus on local temperature distributions and averaged rotor winding temperatures. A comparison with plant measurements conducted during the investigated motor-generators commissioning showed good agreement with both machines' presented simulation model results.

Question 3.1: Volume flow measurements were made according to traditional procedures that have shown an excellent theoretical to measured correlation. Yet, there is the question of how would it be possible to correlate mean winding temperature rise (measured by resistance variation) with the distributed temperatures calculated by the 3D CHT method?

Paper A1-302 (Croatia): Static Eccentricity Fault Detection Method For Electrical Rotating Machines Based on the Magnetic Field Analysis in the Air Gap by Measuring Coils.

The machine fault detection technique presented in this paper is based on measuring the air gap's magnetic field. The proposed method of positioning and installing measuring coils on an induction motor stator bore within the machine's air gap region enables various faults to be identified. Furthermore, different faults can be detected if measuring-coils are placed on the stator teeth. The paper presents a method for analysing and processing the measured voltages acquired from measuring coils placed within the machine, especially in the case of rotor static eccentricity detection.

Question 3.2: The idea of allocating search coils in the stator bore is not new. The challenge was always to identify a safe mode to insert the sensors. It seems that the authors have found a secure way to install such coils. Is the manufacturer's intention to offer this monitoring device together with a new motor or would it possible to install in motors that are already in operation?

Paper A1-303 (Sweden): Magnetic Balancing System for Synchronous Machines– A Full-Scale Demonstration of Unbalanced Pull Mitigation.

The working principle and performance data of a magnetic balancing system for an 11 MVA synchronous machine are presented. The system is a special type of magnetization system that can practically eliminate unbalanced magnetic pull (UMP). It was made possible by dividing the rotor poles into separate groups of poles in which the current could be controlled independently using modern power electronics. Each segment was fed via a dedicated slip ring and brush. Magnetic flux density sensors mounted equidistantly on the stator inside the air-gap, and an encoder provided the needed information for the control system to apply the appropriate compensation currents. This system eliminates the forces due to the UMP even though the

mechanical imperfections remain. Also, results from long-term tests of system stability are presented and discussed.

Question 3.3: The authors' creativity should be commented on since there are UMP cases where this solution certainly will be welcomed. In the paper it is not stated if the multi-excitation control system can modulate cases where a dynamic eccentricity is installed. Would the authors comment on this kind of application?

Paper A1-304 (Italy): Technical challenges and solutions for the new Terna's standardized synchronous condensers/flywheel systems

The paper presents the standardization of new Synchronous Compensator Flywheel (SCF) power plants to be installed in Italy. The standardization is under the Italian Transmission System Operator. The size of the SCF units mainly follows the criteria of keeping under safe limits the rate of change of frequency of selected areas of the power system. The authors show numerical results of simulations on frequency versus time response of the system, as well as operating speed, thermal behaviour, and ventilation performance during breaking of flywheel. The work shows one installation of SCF under construction and describes the developed monitoring system.

Question 3.4: In graphical results concerning torsional mode and thermal performance, what are the criteria to approve simulation results and what are the criteria used by TERNA in defining the aspects to be assessed in defining the location of the SCF stations?

Paper A1-305 (Macedonia): How To Choose Electric Drive According IEC 60034-1?

The paper brings to light the definitions of duty cycles of motor drive systems, according to IEC 60034-1: *Rotating electrical machines - Part 1: Rating and performance*. Duty cycles definitions are shown and classified according to the type of supply device. It is emphasized that only S8, S9 and S10 duty cycles refer to motors driven by variable speed drives – VSD. In view of the increasing popularity of the use of VSD, the paper proposes a wider discussion of the duty cycles of IEC 60034-1. Specifically, the authors suggest two ideas: (i) to increase the number of duty cycles, or (ii) to include VSD in other existing duty cycles, so that the Standard keeps up to date with current uses in industry.

Question 3.5: In Case study 1, the authors state that the power converter corrects cos (ø) of the plant, because of the energy costs. Usually, Power Distribution Companies charge for active power and assess fines for reactive energy exchange with the system. Could the authors clarify the statement "the price of reactive power is lower than price of active, approximately in relation 1:3", and what is the relation of case study 2 with IEC 60034-1? Have others come across a perceived deficiency in IEC duty definitions for VSD applications?

Paper A1-306 (Brazil): Considerations on IEEE 1310-2012, Numbers of Start-Stops and Life Time of Stator Windings in Hydro-Generators

Thermal cycling testing, as per IEEE 1310 and IEC 60034-18-34, has been specified by many end users of principally, hydro generators since the mid-1990s. The development of this test, that is based on an OEM protocol, was driven by North American experience with premature failures caused by delamination at the ground wall-to-copper interface. Paper A1-306 presents a comprehensive study, based on laboratory testing, destructive testing of service-aged stator insulation and a review of industry surveys to critically examine some aspects of IEEE 1310. Among the aspects examined are whether starts-stops affect stator winding life and whether,

even if this assumption is correct, do accelerated ageing tests like thermal cycling accurately represent this type of ageing or do they introduce extraneous artefacts. Essentially, the authors conclude that, based on their work, starts-stops do not affect winding longevity and that the thermal cycling test may, in some cases, introduce artefacts that do not relate to actual stator winding ageing.

Question 3.6: This thorough study by the authors of paper A1-306 raises some important questions about IEEE 1310 that warrant consideration by those responsible for maintaining and developing this standard. What are the views of the community of OEMs, end users and test organizations on IEEE 1310?

Paper A1-308: Development of Reliable Stator Coil End Design of Large Turbine Generator

Changes in operational regime for generators, due to higher renewable penetration, from base load to cyclic operation have resulted in an increase in faults. This paper discusses how these issues have been addressed through design improvements, in particular, in the stator coil ends and phase connection rings on 1,000MVA generators and above.

3D electromagnetic force analysis carried out on the endwindings showed the positive effect of increasing mass in conjunction with stiffness has on vibration levels. The connection rings of the original design and a large number of other OEMs do not cover the full circumference of the endwindings due to the location of the phase ends and the HV bushings. By adding dummy sections where they are not present, the uniformity, mass and stiffness of the structure is increased.

In addition, the results from the analysis were used to model stress on copper elbows in the water circuit and an improved design was produce incorporating stainless steel and copper. The paper concludes with verification of the new design with modal testing and rotating performance test with vibration transducers. Load tests on site report a 23 percent reduction in vibration amplitude on the non-connection end and 75 percent on the connection end with the new connection ring arrangement when compared to the original design.

Question 3.7: The report describes the issues and concern that are exacerbated by cyclic operation. The paper focuses on large 1000MVA plant, noting that this could also be applied to large-capacity Combined Cycle Gas Turbine (CCGT) generators. What size generators, in the authors view. would this encompass? What are other users experience of generator faults due to the impact from higher renewables penetration and associated cyclic operation?

Paper A1-309 (Spain): Impact of the Q-Axis Sub-Transient Reactance on the Rotor Oscillations of a Hydro Generator.

The paper presents a typical case where some of the hydro-generator electrical parameters cannot be fulfilled. This time was the q-axis sub-transient reactance X" q. The impact of fulfilling that requirement would be a significant cost increase. Therefore, simulation studies were made aiming to identify the impact of the new X" q on the system. It was observed that a proper setting on the Power System Stabilizer would successfully overcome the apparent limitation.

Question 3.8: How many times have hydro generator designers faced such kind of dilemma? It is a question that only designers may answer, but certainly, in retrofitting processes, that is nothing new and almost frequent. What are the constructive limitations transformed as a cost concern in such cases related to q-axis sub-transient reactance?

Paper A1-310 (China): The Design and Application of New Fast-response, Large-scaled Rotary Condensers in UHV Power Grid

The paper presents one proposal of design philosophy for Synchronous Compensators. The historical scenario of operation of SC in China power system is presented. Typical failures in UHVDC and UHVAC supplied power systems in China are also described. Specifications of new SCs put into commission are shown. Simulations of system connected SC are performed, showing that the performance of the system in face of commutation and overvoltage disturbances is improved. In addition, SC offer better voltage stability.

Question 3.9: Is it possible for the authors to show a figure of the proposed SC design cost compared to a traditional SC design cost? In addition, what would be the response of the system, or the simulation results if a traditional SC were used? Are the benefits worth the additional cost of one technology in comparison to the other?
It would be nice if the authors could show and comment on possible measured results, showing the enhancement of the system operation.

Paper A1-311 (China): Design, Implementation and Field Application of a New Generation Flexible Excitation System for High-Power Synchronous Generators

The paper presents a new flexible excitation system with multilevel topology for high-power synchronous generators. The developed system uses the flexibility of switching and control of IGBT-based converters. The main goal is to improve transient stability and reduce frequency fluctuations. Topology, control strategy and test results of the application of the system in a generator are presented. The great contribution of the system is the ability to absorb reactive power oscillations, improving generator operation during faults.

Question 3.10: For the generator used in the tests, could the authors show the value of the field time constant? Is it relevant for the control system?
When there are two generators connected to one busbar or in the same power generation plant, what should be the design philosophy of the controller?

Paper A1-312 (India): Failures of Large Turbo-Generators on Prolonged Site Storage - Case Studies of Indian Power Utility

Paper A1-312 describes the experience of the authors to failures of generators following prolonged storage. Highlighting that poor storage of generator can substantially reduce the equipment life and stator failures have been experienced during commissioning of installed spares. Three case studies are examined 1) stator stored for 4 years; failing after 10 months operation; 2) stator stored for 4 years; failing on initial run up to full load, and 3) stator stored for 4 years; failed on HV testing prior to being run up. All of which highlight a concern for the utility and the financial ramifications of extended outages.

In case 1 there was a significant number of issues reported after 10 months operation such as, migrated top ripple springs and side packers, fretting of the semi conductive layer of th bars at the slot exits, missing blocking in the endwinding, abraded and cut bar insulation. Exposed copper was also visible on a number of bars at the slot exit.

Further to the failures the authors examined the insulation resistance of the stored machines and found that these had deteriorated on the stored units to below acceptable levels. Investigation was carried out on the endwinding support ties which had failed during high potential tests in one of the case studies. The conclusion was that moisture and dirt allowed electrical tracking over these components. In conclusion the authors draw design considerations in the paper to

the required specification for the electrical insulation and endwinding support ties for future machines.

Question 3.11: The paper highlights the improper storage of the stators as the cause of the issues. Can the authors elaborate on the storage conditions on site: ambient conditions, location, foreign material exclusion measures etc. Can other organisations in high temperature / humidity areas of the world provide their experience and controls to store generators for use as spares on site?

6. Important dates and instructions

Registered delegates can prepare one or several contributions to the Study Committee Group Discussion Meeting related to the questions raised in this report.

A template as well as a guide for contributions are made available to intended contributors on the Session website. Contributions are required to be uploaded through the Session registration platform before the communicated deadline. In addition to the presentation, a text version should also be prepared. The Special Reporters will review and manage the contributions through the Session Papers management platform.

The draft presentations will be checked for readability and technical/scientific content (no commercial information is allowed) and will give recommendations to the experts and inform them whether the prepared contribution will be accepted for presentation. Prepared contributions which are received after the deadline will not be considered for presentation at the Session. During the Session, for each prepared contribution a time slot of three to four minutes will be available, so that the number of slides essentially has to be less than four.

The SC A1 Session is scheduled for Wednesday 25th August 2021, in the hall Havana, situated on level 3 of the Palais des Congrès.

On Tuesday 24th August 2021, all experts with prepared contributions need to meet the Chairman, the Secretary and Special Reporters of SC A1. The room name and location will be confirmed nearer the time (a banner in front of these rooms will indicate the specific meeting room for SC A1). Please note that the Special Reporters will only be available from **9AM to 2PM** for receiving and reviewing final contributions.

During the Session the Chairman may call for spontaneous contributions. Attendees, who provide a spontaneous contribution, are allowed to deliver a written contribution which will be included in the Session Proceedings. This text is required to be forwarded within a maximum delay of two weeks after the SC A1 Session (i.e. by Wednesday September 8th, 2021) to kevin.mayor@ge.com.

The authors of the SC A1 Session Papers present the results of their studies during the Poster Session on Tuesday afternoon, August 24th, 2021, in Hall Ternes situated on Level 1 of the Palais des Congrès. If the author(s) cannot attend the Poster Session the respective National Committee is requested to send a substitute.

Draft Posters need to be sent in the required format, on the allocated templates, according to the published details and schedule. The received posters will be reviewed and any required changes communicated to the Authors.

Any changes to the above information due to the COVID situation will be communicated via the Session website.