GENERATOR MAINTENANCE UPDATE

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ABSTRACT

Generator operations, generator designs and generator maintenance technology have all changed significantly over the past 10 years or so. Most generator owner / operators have generator maintenance programs in place. However, a close review of those programs will likely find that they are not tightly aligned with current day generator operational scenarios and new machine or upgraded generator designs. The review may also find that recent technology advances of equipment, and procedures are not fully utilized or even applied at all.

This paper and presentation will help owners and users understand changes and advancements of generator operations, design, and maintenance technology and how they should be addressed in an effective maintenance program. Given the objective of ensuring long term reliable operation of generators, the discussion will be applicable to a broad spectrum of manufacturers, ratings, design characteristics, and operational scenarios.

A basic review of key generator maintenance elements will be shared as a foundation. Current market operational scenarios will be discussed relative to generator maintenance and impact on generator reliability. Generator design trends and characteristics will also be explored in the same way. Recent advances in generator maintenance technologies will be identified and discussed relative to their maintenance value, capabilities, limitations, design applicability, and how to best incorporate them into an effective maintenance program.

INTRODUCTION

It is undeniable that the electric power generation industry has experienced exceptional change during the past few decades. There has been an unprecedented change in the makeup of electric power generation assets. Coal fired plants, once the primary producers, have now been significantly reduced in numbers with the remaining having little hope of surviving let alone regaining prominence. Solar and Wind assets have come of age, hydro assets have enjoyed renewed interest, and combined cycle and simple cycle gas assets have attained a position of prominence. Operationally, the strong leadership from Engineering and Maintenance functions has diminished and become more relegated to supporting commercial priorities seeking to enhance profits by slashing budgets, extending run times between maintenance, and cycling assets.

These changes have raised tremendous challenges regarding the effective maintenance of electric generation assets. Fortunately, there have been corollary improvements with maintenance technologies, methodologies, and practices. This paper will strive to update both new and old maintenance professionals to help them meet market challenges through effective electric generator maintenance.

KEY MAINTENANCE ELEMENTS

A key maintenance element of most successful maintenance programs is the basic need to inspect and test. One thing that has not changed over time is the value of trained and experienced personnel performing maintenance inspection and testing activities. The power generation industry, like many other industries, has struggled to keep and attract new personnel resources necessary to carry out essential maintenance functions. While there does not appear to be a simple solution to the personnel challenge, there have been

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technology advancements that make maintenance professionals more effective and productive in performing their inspection and testing responsibilities.

Visual inspection has long been referred to as the most cost effective maintenance tool. Traditionally to gain appropriate access to perform visual inspection, the generator was disassembled and the rotor removed. Figure 1 is a pictorial progression of a generator rotor being removed.

Generator Rotor Removal
Figure 1

Without a doubt, the access granted by removing the rotor provides the best overall access for visual inspection, but along with that access comes a significant cost in both money and time. Some circumstances justify the monetary cost and time due to known issues or urgently needed modifications. However, current day pressures to decrease maintenance cost and outage durations mandate other maintenance options be chosen when possible to conserve time and money without completely sacrificing insight gathered from inspection and testing.

Tremendous advances have been made with borescope technology. These devices have become smaller, with improved manipulation to access areas that were previously not possible to access, even with complete generator disassembly. Optics have improved dramatically too. The “Fish Eye” appearance displayed by early borescope instruments is thankfully a thing of the past. Newer instruments have a much higher degree of clarity with more realistic coloration. Many new instruments also have the ability to accurately measure observed conditions to further enhance insight gathered, and of course also digitally document findings. For standard planned maintenance outages, borescope inspections have become an invaluable option to decrease the level of disassembly needed, reducing cost and time with little if any sacrifice to inspecting areas of greatest concern. Figure 2 and Figure 3 below contain good examples illustrating this point.

Generator Stator Borescope Inspection
Figure 2

The generator pictured in figure 2a is an AEROPAC model generator. This model along with a few other models from other OEM’s, were not manufactured utilizing side slot ripple filler to secure the coil in the slot. Without compression and constant tension, coils can become loose in the slot and as coils move, a very aggressive deterioration condition called Spark Erosion (also referred to as Vibration Sparking) can develop and quickly progress to failure. The condition develops in the stator slot areas adjacent to the laminations.

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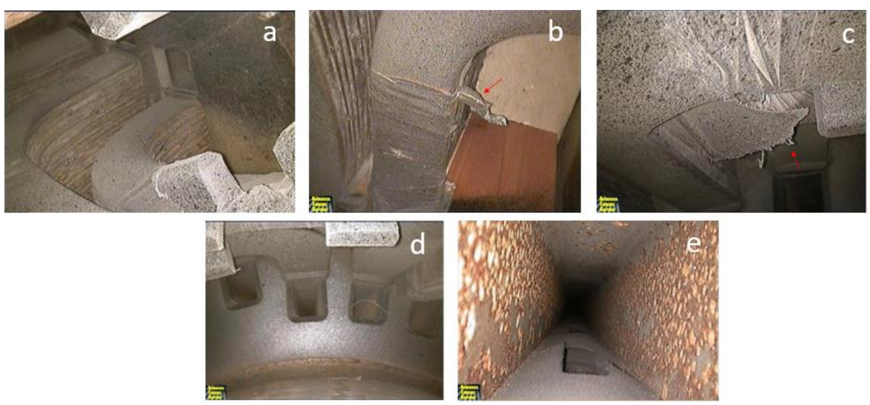
Small borescopes can enter the stator core vents to observe the coil surface. Figure 2b shows the discovery of severe spark erosion activity. Without swift action to rewind using slot side ripple filler, to prevent future reoccurrence, the unit would most likely experience an in service failure. Figure 2c shows a classic Partial Discharge (PD) finding. PD is a well know deterioration mechanism that is much less damaging and progresses slower than Spark Erosion. Nevertheless, it is still important to identify, document, and trend the progression of PD deterioration. Areas having PD activity outside the slot can often be addressed remedially to arrest and help prevent further PD activity from occurring.

The access necessary to best use borescopes varies by model, but typically inspection covers on the stator frame sides or on the stator end bells will allow the access needed. Inner shrouds on the ends can sometimes be challenging. A quick study of cross sectional and end view generator drawings and also perhaps stator air flow diagrams can be most helpful to establishing the plan to deploy and inspect with a borescope. Specific access to perform an AEROPC model generator borescope core inspection is only the removal of an access covers on the lower side of the stator frame. Having a small nimble individual to shimmy into the inner area of the generator is most helpful too. See the shoes of the person inside the access way above the white arrow in Figure 2a. Generally speaking, this inspection takes about one shift to perform and is an excellent tool to track and trend Spark Erosion deterioration.

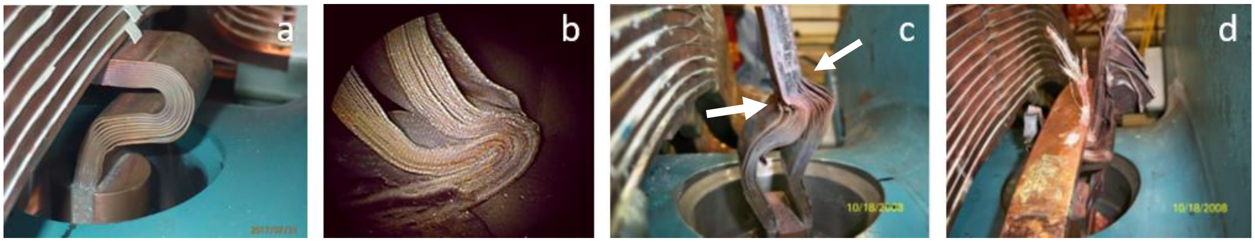
The inspection of generator rotors is another challenge where Borescope inspection can provide valuable insight. Gaining access to the areas under the retaining rings is the objective, and can easily be accomplished when the rotor is out of the stator and also can typically be accomplished with the rotor still in the stator with only access covers removed. The exciter end is usually of greatest interest as the main rotor leads, coil connectors, and pole to pole connector(s) can usually be accessed. Observing the level of contamination, alignment of coils, migrated, torn, or loose, turn insulation, migrated or damaged blocking, and cracked or distorted coils or turns should be the objective on the exciter end as well as the turbine end of the rotor if time and access allows.



Under Rotor Retaining Ring Findings
Figure 3

Findings from a rotor borescope inspection during a routine outage with the rotor in place inside the stator, can be seen in Figure 3. The findings were not catastrophic, but were insightful helping the maintenance planning effort for the next outage. Photo 3a shows the presence of a fair amount of contamination. Photo 3b shows a bit of frayed tape insulation and 3c shows migrated turn insulation. Photo 3d is a view facing the rotor sub slots and 3e is a view from inside a sub slot showing significant corrosion on the forging sub slot walls

Some borescope findings can be more urgent, requiring swift attention to prevent a failure or forced outage.



Main Lead Findings
Figure 4

Figure 4a is a standard photo taken of a rotor main lead found to be in relatively good shape, with the retaining ring off. The borescope photo in 4b is from another unit similar in design to 4a. Severe lead distortion is visible. Cracking can be seen on both the inside (smashed area) leaves and on the outer leaves with one outer leaf about to break away. The plant corrected this condition before the unit was returned to service. 4c and 4d are both standard photos taken of another rotor of similar design, after the retaining rings and number one coils from both poles were removed from both poles. This unit failed in service due to the damage seen in 4d. Had a borescope been performed during a prior maintenance outage, it is likely indications would have been discovered like those at the white arrows in 4c and the forced outage could have been prevented.

Borescope inspections have not really been utilized to their full extent by most users. Users would be well served to consult with service specialists experienced with both borescope equipment and generators to help best understand the advantages and how to more fully utilize borescope technology.

Robotic technology has also continued to rapidly evolve. Robots have incorporated advanced optics just as noted with borescopes. They have enhanced maintenance testing capabilities for stator slot wedge tightness and stator core inter laminar insulation testing. The biggest advantage of modern robotic technology is the ability to gather important visual insight and data without completely disassembling and removing the rotor. The robot device or trolley can be seen on the left in Figure 5 and the control station for the robot is pictured on the right.

Robot & Robot Control Station
Figure 5

Visual inspection insight is gathered from three points of view as seen in figure 6a, b, & c. The clarity is very good and the color of objects very true, both very helpful characteristics to properly interpreting what is seen.

Figure 6c shows a specific rotor concern, looking through the wedge vent hole. The greenish filler seen in the area pointed to by the white arrow has migrated axially in the slot, partially blocking the cooling vent. The black area is the conductor stack cooling vent, and should be unobstructed relative to the retaining ring vent hole. This migration of the top filler is a known potential problem on this particular model of generator. Based on this finding, the user planned a future rotor out outage to address the condition with a proven rotor modification to prevent the top filler and amortisseur from migrating adversely.

A typical mapping from the digital stator slot wedge tap test can be seen in Figure 6d. The ElCid report shown in Figure 6F is concerning as the peaks seen are well above the allowable 100 miliamp threshold established as the acceptance criteria.

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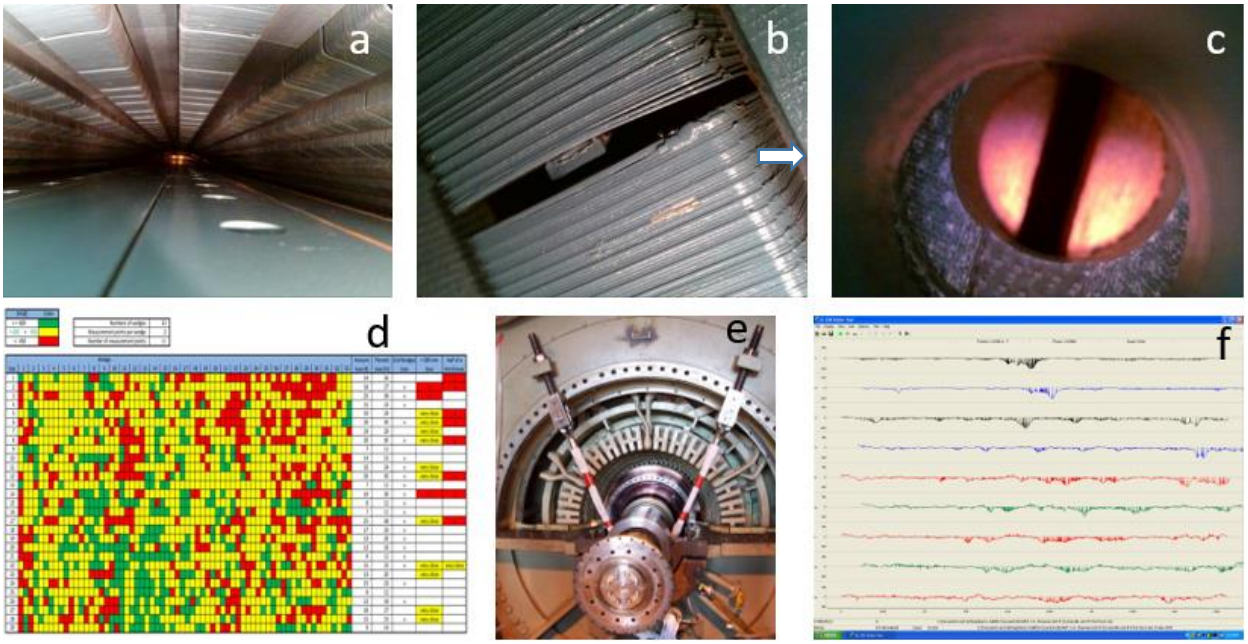

Robot Inspection & Testing
Figure 6

Some disassembly of the generator is necessary to gain access to insert the rotor and umbilical cable between the stator step iron & rotor retaining ring nose then into the generator air gap. Figure 6e shows the exciter end of the generator with the upper end bell and inner shroud removed, that is sufficient to perform just the visual inspection and the digital wedge tap testing. To also perform the ElCid test, it is necessary to have the same disassembly on the opposite end (turbine end) so that the trigger or excitation cable can be run through the air gap and completely around the stator core / frame.

Modern borescope and robotic technology can help accommodate market pressures to increase the time between maintenance periods and to decrease the duration of the maintenance periods by decreasing the level of disassembly while still gathering valuable insight about the generator condition and be able to assess and plan needed activities during appropriately timed future outages.

There are many electrical tests that can and should be considered for use as an integral part of a good maintenance program. Maintenance professionals and planners should consult with their internal engineering and support resources for guidance and may want to also consider outside assistance from experienced generator consultants and reputable generator maintenance and repair houses. In addition to IEEE there are also a number of other good resources that can be consulted and some are noted in the reference section of this paper. Table 1, below, is a basic maintenance summary prepared as a quick reference guide or check list to aid managers and planners as they consider and plan upcoming outages or when they are working to get through an unexpected outage.

Another facet of maintenance that continues to evolve and grow in capability is digital on line monitoring and data collection. Being able to gather and access key data is very valuable if what is being monitored is also being processed or trended to actually realize the value. There have been cases where the sheer quantity of data gathered has been masked or hidden from being considered and acted upon. There have been other cases were monitoring systems have been applied but are not regularly accessed or even accessed at all. The value of any monitoring system can only be realized if the data gathered is reviewed, evaluated, and if necessary, findings acted upon.

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Table 1
Generator Maintenance Activities

MAINTENANCE ACTIVITY	SHOWS	FREQUENCY
Dielectric Absorption	Winding cleanliness	Major Outage
Polarization Index (PI)	Winding cleanliness/moisture	Major and Minor Outage Cycles
Power Factor	Insulation integrity	Major Outage Cycle
Partial Discharge (PD)	Coil tightness; insulation integrity	On-line or Outage Cycle
Megger	Integrity of Insulation	Major and Minor Outage Cycles
Blackout	Corona suppression integrity	Rewind
Resistance	Integrity of joints and connections	Major and Minor Outage Cycles
Flux Probe	Rotor winding shorts	On-line, Rewind
Rotor Impedance	Rotor winding shorts	Rewind
Ground Fault	Rotor Ground	Continuous
Split Voltage	Location of rotor grounds	As Needed
Voltage Drop	Presence of shorted turns	Major Outage Cycle
El Cid	Integrity of stator core	Major Outage Cycle
Core Loop	Integrity of stator core	Major Outage Cycle
Bolt Torque	Stator core looseness	Major Outage Cycle
Ultrasonic	Cracks, defects in forgings	Major Outage Cycle
Temperature Monitoring	Normal/abnormal operation	On-line and Continuous
Dye Penetrant	Cracks, defects in forgings	Major Outage Cycle
Eddy Current	Cracks, defects in forgings	Major Outage Cycle
Magnetic Particle	Cracks, defects in forgings	Major Outage Cycle
Wedge Mapping	Stator winding tightness	Major Outage Cycle
Hi-Pot	Insulation integrity	Major Outage Cycle
Vibration	Rotor imbalance	Monthly and On-line
Visual Inspection	Normal/Abnormal Performance	As Available
Oil Chemistry and Count	Bearing oil contamination	Twice Yearly

A plant reached out for assistance with a generator rotor vibration condition. They expressed that the vibration had been present for some time (about a year) but initially at a much lower level. An operator mentioned he thought current circumstances had the level of vibration following the MVA output of the generator. While mechanical aspects were still being considered and evaluated, the possibility of shorted turns in the rotor winding was mentioned to the plant as a possible contributor to the vibration. With the knowledge that a Flux Probe had been installed on the generator during an outage about 4 years earlier, the plant was asked for the flux probe data. The plant provided initial data taken immediately after the Flux Probe was installed, that data indicated the rotor had no shorted turns, at that time. Unfortunately, no other periodic or subsequent readings had been taken. Flux Probe readings were subsequently taken indicating the presence of multiple rotor turn shorts with the majority residing in the second and third coil of one pole. Without intermediate readings, it was not possible to determine when, or over what duration the shorted turns had emerged. Given that vibration levels at normal plant loading had elevated near alarm levels, the plant made arrangements for a planned rewind several months later. The cost of maintenance monitoring equipment, installation, and readings are a good investment to help maintain generators, but unfortunately in this instance the plant did not realize a return on the investment in the Flux Probe because they did not monitor, evaluate, and trend the data.

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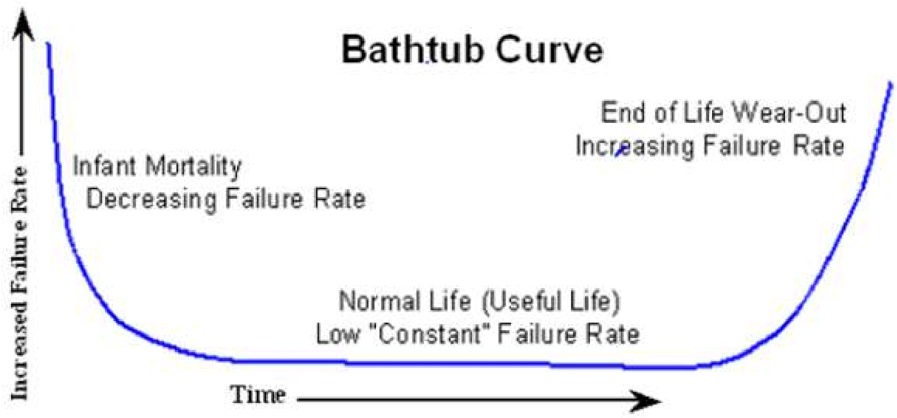
GENERATOR LIFECYCLE AND MAINTENANCE

Understanding aging and the relationship to failure rate and time is very important. The bathtub curve depicted in Figure 7 should aid in this understanding as it conceptually represents the three primary periods that make up the generator life cycle.



Bathtub Curve
Hypothetical Failure Rate -vs.- Time
Figure 7

A poll of today's experienced industry professionals would most likely identify 30 years as the average generator life span benchmark. Actual generator life span duration is not a finite duration. It is rather a period determined by quite a few factors such as generator design, operational scenario, commercial market circumstances and of course how well the generator is maintained, just to mention a few of the most prominent determinants.

The infant mortality period should not be considered a wait and see what happens period. It is best to approach this period as an opportunity to get to know the idiosyncrasies and design weaknesses of the new generator. Careful monitoring and diligently following Original Equipment Manufacturer (OEM) recommendations is a good practice to follow. Users can also gain valuable real time insight by engaging in dialog with other users at user group meetings and conferences. On line forums, web sites, and competent service providers are also valuable resources that can be mined to gain timely insightful information to help navigate this challenging period.

Figure 8 offers an example of a specific rotor component that has experienced infant mortality period failures across several OEM's and models. Rotor pole to pole crossover design configurations can vary greatly, as can be seen in Figure 8. Each of the failures occurred during the infancy period. The left photo is from a TLRI model. It was not the first of the model to fail, but from that failure the independent service provider, working with a number of users was able to identify the cause, solidify a solution, implement a temporary inspection protocol, and use trending to determine average cycles to failure to help users plan. Sharing these items at the next user group meeting lead to many other users proactively addressing and preventing what certainly would have been other unplanned outages during the infancy period. Another important note about pole to pole failures is that the failure contributors accelerate in their detrimental effect as cyclic activity increases.

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Rotor Pole to Pole Connector Failures
Figure 8

Getting to know and documenting the idiosyncrasies and design weaknesses of the new generator is a very important priority during the infant mortality period. That priority also helps identify and guide those? activities of the useful life period and subsequent end of life plans of the generator life cycle.

Perhaps the biggest danger during the useful life period of the generator life cycle is complacency. Users become comfortable having some degree of insight from inspections and testing, and become less diligent in the timely monitoring and performance of recommendations and lessons learned. A valuable resource squandered by some users are outage reports. The outage reports document findings, actions taken and usually make specific recommendations. Users are best served when the reports are preserved and organized chronologically with an ongoing register of recommendations notating when accomplished or the plan and timing to accomplish. It is also a very good idea to incorporate into the register insight and recommendations from OEM bulletins and memos. Maintaining the register can help prevent complacency and is a valuable guide to planning maintenance activities. If unexpected problems arise, the data from the reports can be trended (if not already done by the plant) to help consultants and service providers quickly gain an understanding of generator characteristics leading up to the emergence of the problem(s).

I have often wondered how users might react if they received a formal notification stating "*you are now entering the end of life period of your generator life cycle"*. If there were such a notification, I imagine there would be a small portion of users that would immediately "circular file" (garbage) it. Another small portion would be appreciative and reexamine their maintenance and life extension plans. The remaining group, likely larger in number than the two smaller groups put together, would likely be a bit concerned and ask the question "what do we do now?" The appreciative group worked diligently through the previous two life cycle periods, now prepared to enter the end of life period with a well-founded plan including a detailed budget and duration to effectively maintain the generator until the point when a proactive rewind / life extension will be performed.

Those that imagine themselves outside the diligent appreciative group, should take solace as it is still not too late. But it is time to buckle down and get working, starting by quickly gathering the insight and documentation that should have been gathered and organized during the first two life cycle periods. Once gathered, the challenge is to digest the information and ask the inevitable questions that will arise so that a rough understanding of the generators condition and prognosis along with a strong awareness of the primary concerns or issues with your specific generator can be solidified. If you are wondering who you should consult to get the answers to your questions, look to other users that have "been there and done that", as well as the OEM, trusted consultants and service providers. The objective is to have a strong plan to renew your generators life cycle. Knowing your generators prognosis and specific concerns should help establish a solid scope of work to use as a foundation for an estimated schedule and budget. At this point you are in a much better position, even if an unexpected failure preempts your plans, you should be able to respond and meet the challenge.

There are still details that can be worked on that will help make the inevitable execution of a rewind / life extension easier and perhaps even more successful. Identifying proven solutions and experienced solution providers to execute them will help you sleep much easier. This is especially true if in addition to technical details you have put in place a mutually agreed commercial foundation that will allow immediate response should a forced outage occur or an earlier window of opportunity arise. It should go without saying that a

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generator rewind / life extension program should be comprehensive, addressing the rotor and stator primary generator components thoroughly. Another important, but often overlooked detail is the identification of what specific generator components will be reused and how they will be requalified for continued use. Again, experience from other users, insight from the OEM, trusted consultants and independent service providers can be invaluable to help establish at least an outline of components for reuse and the methods and criteria used to help ensure they are suitable for continued service and provide long term reliable operation.

STATOR VIBRATION AND RESONANCE

It is important to first state that vibration and resonance are definitely not the same thing, but they can be closely related. A very simplified pragmatic perspective will be shared to hopefully convey an appreciation for the concerns through fundamental understanding.

Stator vibration has been a well-known phenomenon and concern with generator stators for well over half a century. With normal operation, the magnetic flux traveling through the rotor and stator, produces forces that act on the stator coils. The forces are commonly referred to as “steady state pounding forces”, for the way they act upon the coils, mostly in a radially direction. It is this action that leads to vibration and potential looseness in the stator winding assembly. Indications of the vibration and looseness are often found from visual inspection.

The left picture in Figure 9 shows “dusting” from components moving that produce a dust that is formed from the vase material of the components and their fretting movement. The right picture in Figure 9 shows “greasing”. Greasing is dust that collected oil from the internal generator environment. The combination of the oil and dust creates a material that looks very similar to standard grease. Dusting and greasing are both tell tail signs of vibrational movement.

Examples of Dusting (L) and Greasing (R)
Figure 9

During the past few decades, generators have grown larger in electrical output and in physical size. As part of the physical growth, stator end windings have become much longer. The added end winding length presents a greater challenge to physically restrain, and therefore an important to add to the maintenance program visual inspection check list.

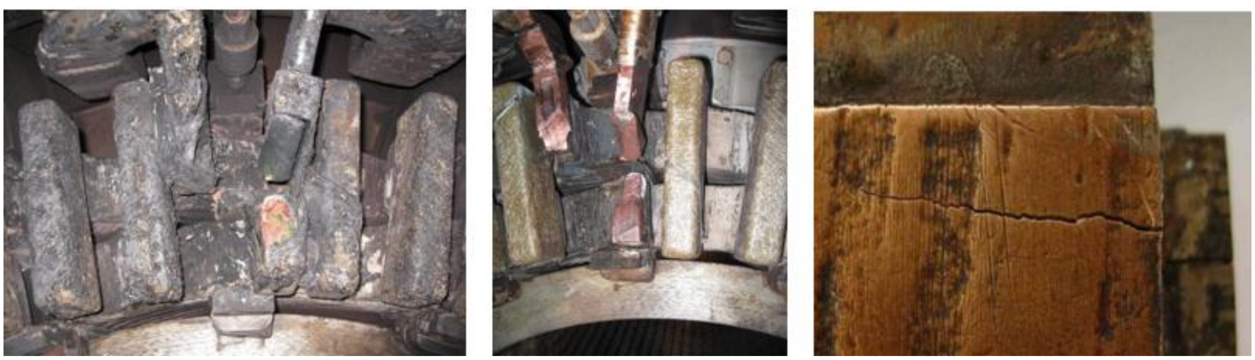
Resonance in generator components can be very concerning due to high levels of vibration that can be very violent. Experienced maintenance personnel may suspect the existence of a resonant condition when exceptional visual observations are found. Photos to the left of center of Figure 10 show such an observation. The good news is that Frequency Response and Modal Testing, more commonly referred to as Bump Testing, can be performed to confirm the resonant condition. The two photos to the right of center of Figure 10 show bump testing being performed. Bump testing primarily focuses on the end winding, phase connections and circuit rings and it identifies resonances that would be readily excitable by the electromagnetic forcing frequency. Users should establish an exclusion zone range for two pole generators ranging from 115 to 135 Hz for 60 Hz generators (95 to 115 Hz for 50 Hz generators). Note that the range

is higher above than it is below, twice the line frequency. The higher range makes allowance to prevent operational temperatures from allowing high tuned components from dropping into the critical range
.

Extreme Dusting and Bump Testing
Figure 10

Bump testing should be incorporated into the scope for stator rewinds and when major repairs or end winding modifications are performed. Machines having potential for a resonant stator condition should have a bump test performed as a bench mark, an considered for re-performance if the stator incurs a significant operational event.

Resonant conditions can be corrected in several different ways. Adding mass and changing component stiffness are the most common methods used to make adjustments to tune the component away from the exclusion zone. When corrections or adjustments are made, a final bump test is strongly recommended to confirm success. A bump test is often necessary prior to making corrections to best understand the condition and calculate the best method and location to have the best chance of successfully detune the resonant condition.



Consequences of Resonance
Figure 11

Consequences of resonance can be pretty dynamic if not detected or not promptly addressed. Figure 11 shows a combined cycle steam turbine generator that experienced an early life failure (~18 months). The left photo was taken shortly after the failure, and the center picture is the same area after cleaning. The right phase connection failed and was completely severed. The corner of the left connection was melted from the failure intense heat. The phase connections that did not fail were bump tested with results ranging from approximately 121 to 124 Hz, well within the 60 Hz exclusion zone. Subsequent evaluation and NDE of the connections found several with cracks, one crack was clearly visible without NDE, and is shown in the right photo of Figure 11.

The unit required an expedited partial rewind. The phase connections were modified to relieve mechanical stress concentrations. An improved phase lead design was developed and applied. A final bump test was performed, just before assembly, confirming the key components were outside the resonance exclusion zone.

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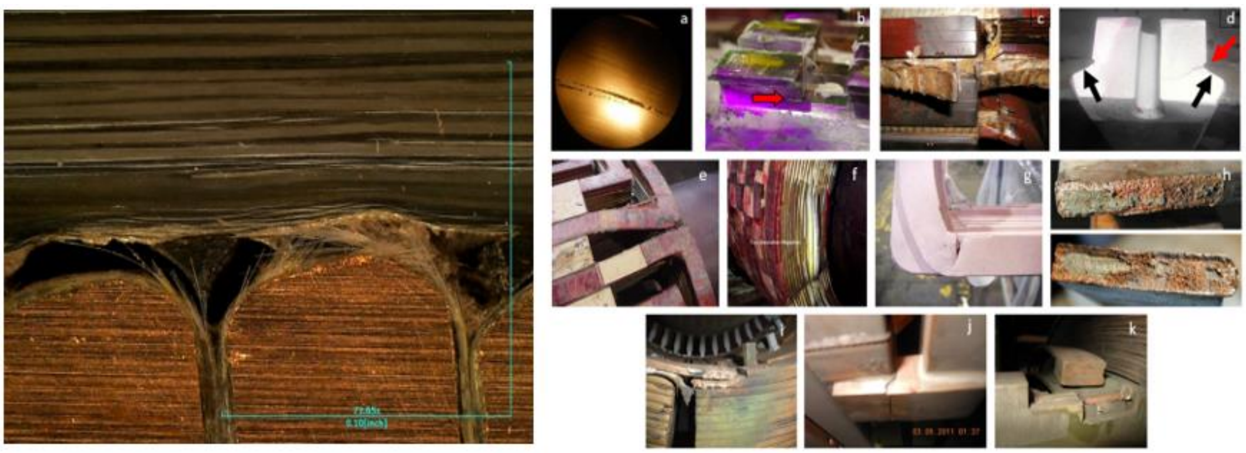
OPERATIONAL CHANGES THAT IMPACT MAINTENANCE

Plant operational changes have presented significant maintenance challenges that need to be effectively addressed. Pressures to extend the time between planned outages and compress the duration of actual outages are well known. Fortunately, technology improvements such as those mentioned earlier with borescopes and robots can be effectively utilized to help minimize the need for periodic disassembly. Using these technologies coupled with proper documentation and trending will help monitor potential emerging issues to maintain long term reliable operation.

Unit cycling is perhaps the most significant and far reaching operational change that raises several maintenance challenges. In discussing cycling it is important to first make the distinction between speed and load cycling. While the operational difference between the two is self-evident, the consequences of each are not as intuitive. The primary distinction is that speed cycling primarily effects rotor components while load cycling primarily effects stator components. Load cycling swings can create a thermal differential between the stator core and the coil conductor, that in turn creates sheer stresses that damage insulation as seen in the left photo of Figure 12. The collage of photos on the right show the consequences of speed cycling on rotor components. Load and speed cycling have become a business reality unlikely to change any time soon, so maintenance plans and activity need to adjust to help monitor and prevent the consequences that can emerge from these operational factors.



Components Affected & Consequences of Load and Speed Cycling
Figure 12

Another cycling related concern relates to machines that were originally designed and manufactured for base load operation but were changed to a cyclic operational scenario. As noted speed cycling has the greatest impact on rotor components. There have been quite a few instances of older units designed for base load operation that shortly after changing to cyclic operations, experienced failures of critical rotor components. Further detailed information regarding generator cycling are accessible from a presentation and paper shared during the 2021 virtual - International Conference of Doble Clients.

Hydro vs Fossil

Hydro generator maintenance needs have many distinct similarities with Fossil in regard to stators. Two significant similarities they share are cleanliness and Partial Discharge (PD). Various cleaning methods are applicable to both applications however, CO_2 cleaning has emerged as a preferred choice, when properly performed, due to effectiveness, ease of cleanup, and overall cost. There have been significant improvements with coil manufacturing materials and processes that when applied can help address PD in both applications, and these should certainly be incorporated into specifications and applied as part of any rewind. PD is generally considered to be a long term deterioration phenomenon, except perhaps in the most severe and unattended instances. If properly monitored and maintained PD can be effectively managed to allow a full life for quality air cooled stator coil insulation systems. A multi authored paper referenced in this document, shares valuable insight regarding PD materials, and proven repair and maintenance processes. These should be incorporated into the maintenance programs of all hydro and turbo air cooled generators.

The segmented frames and stator cores of most hydro generators are a notable difference from fossil stators. Nevertheless, the value of ElCid testing and full flux testing is applicable to both to monitor and assess laminar insulation integrity. The segment splits of hydro units do require some special consideration and maintenance attention. The core lamination material is similar for both designs, however, it is rare to find a large commercial high voltage fossil turbo stator core still actively operating after a century or more of service, but this is not so uncommon for hydro. Older hydro cores should be assessed relative to possible advantages of reliability and performance if the core were replaced along with a stator rewind.

The cylindrical rotor designs of Fossil Turbo applications are discernably different from the Salient Pole rotor designs of Hydro applications. This design difference is self-evident from even a quick glance at the photos of Figure 13.


Cylindrical – Turbo Rotor Design (left)
Salient Pole – Hydro Rotor Design (right)
Figure 13

Hydro Salient Pole rotor designs have been well proven from over a century of reliable service, but to help ensure reliability, maintenance attention is necessary especially regarding the rotor coils, amortisseur system, and the system securing the salient poles to the rotor. Cylindrical rotors also need maintenance attention to ensure reliability, some are addressed in other sections of this paper.

CONCLUSIONS

The importance of strong well planned and executed maintenance programs is as important as ever to help ensure long term reliable operation of generators.

New generator designs and operational changes, have raised new generator concerns and challenges requiring maintenance program adjustments.

New and enhanced maintenance technologies have emerged and should be considered for inclusion to bolster existing generator maintenance programs.

Users should take better advantage of opportunities to gather insight and guidance to help with the overall generator maintenance challenge. Users will be well served to keep in mind the tremendous value and insight that can be gained by interacting with other users, and utilizing experienced consultants and service providers early in the maintenance planning process.

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BIOGRAPHY

W. Howard Moudy graduated from Western Kentucky University and immediately began his career joining the Apparatus Repair Division of Westinghouse Electric Corporation. His career progressed through a number of different companies and positions of increasing responsibility over the past 41 years. His primary focus has been large high voltage rotating electric machines with an emphasis on coil manufacturing. Howard has been with National Electric Coil (NEC) for the past 21 years. As Director of Operations, he has oversight for NEC's high voltage stator coil manufacturing operation, generator field service operations, and rotating equipment service center/high speed balance operation. Throughout his career, Howard has been integrally involved in projects serving Utilities, Independent Power Producers, Industrials and Government. Howard has been an active content contributor and presenter supporting power generation organizations for many years.