AEGIS

Loss Control

Steam Turbine/Generator Emergency Shutdown

White Paper

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Introduction

This paper provides insight and guidance for securing turbine/generator oil systems with the intent of both minimizing equipment or building damage and helping to control and extinguish an oil or hydrogen fire.

For the majority of steam turbine/generator installations, the maximum foreseeable loss (MFL) postulated by AEGIS is a steam turbine/generator failure with an ensuing large oil fire. Steam turbine/generator installations use lubricating oil, which is combustible. In any firefighting scenario involving combustible oil, one of the primary goals of firefighters is to determine and secure the source of fuel — that is, to shut off the oil supply. Conversely, power plant operators are trained to keep lube oil systems operating to prevent damage to the steam turbine/generator, a multimillion-dollar piece of equipment. If the generator is hydrogen-cooled, the event could also involve the release of hydrogen, potentially resulting in a hydrogen fire or explosion.

Scope

This white paper is focused on providing guidance for the development of a Steam Turbine/Generator Emergency Shutdown Plan/Procedure. Although the safety of personnel is critical in all aspects of plant operations, normal or emergency, this white paper does not directly address personnel safety. Neither does it address the firefighting aspects of a power plant oil or hydrogen fire.

Background

Operating Experience

There have been numerous events in the power industry where large oil fires have led to significant losses, impacting insurance coverage. In many cases, had the oil systems been more quickly shut down or secured, damage to equipment and structures could have been substantially reduced.

Considerations in Development of a Steam Turbine/Generator Emergency Shutdown Plan/Procedure

When developing an effective Steam Turbine/Generator Emergency Shutdown Plan/Procedure, there are many factors to consider. These include but are not limited to:

Location of Equipment

The physical location of all equipment that needs to be operated/secured should be clearly identified. This will help reduce the time it takes to operate or secure the equipment. It will also provide insight into the potential for equipment to be inaccessible due to smoke and hot gases resulting from a fire. Depending on the fire scenario, there may be cases where operations personnel will need to don self contained breathing apparatus to gain access to equipment and controls. An example of a tabulation is provided below:

Example Tabulation

Equipment Description	Location	Operation/Securing Method
Main turbine lube oil pump 1A Primary lubricating oil supply to steam turbine bearings	Elevation 100' Turbine Building, Room 122 On top of lube oil storage tank 1	**Operation** 1. Control room panel 7A: control switch 7A 1A 2. Local panel 1-01: control switch 1A-2 (adjacent to lube oil storage tank) **Securing** 1. Control room panel 7A: control switch 7A 1A 2. Local panel 1-01:c switch 1A-2 (adjacent to lube oil storage tank) 3. Remotely open breaker: breaker 1-01-1A (switchgear room 2 on el. 125')

Identify Multiple Ways of Operating or Securing Equipment

The plan/procedure should identify the various ways that a piece of equipment can be operated or secured. A fire could prevent the control of equipment via normal means, such as from the control room, so alternate methods of controlling/securing equipment should be identified. Examples include but are not limited to:

- Normal means, for example, from the control room (Note: If the control room is affected by the event, it might be necessary to control or secure the equipment from another location or by some alternate means.)
- Local means from a local panel in the vicinity of the equipment
- Remote means from a distant location. This could include opening/closing a breaker in a remote switchgear area/room, closing/opening a valve, or securing/starting a pump or compressor. All applicable control systems should be considered, including air and hydraulic fluid.

If, to control an event, operators have to access drawings or other documents, it could lead to a critical loss of time and significant additional damage. Damage from a growing fire can increase exponentially.

Identify Actions That Can Be Done in Parallel

The plan/procedure should not only identify what equipment needs to operated/secured and where it is located, but also if those actions can be done simultaneously. To implement the plan/procedure as quickly as possible, if these actions can be performed in parallel, they should be.

If a Site Has Fire Pre-Plans

There may be some necessary "interconnections" or overlap between the Steam Turbine/Generator Emergency Shutdown Plan/Procedure and other site procedures. If the site has fire pre plans, they should provide guidance for maintaining communications between firefighters and the main control room, including status reports from firefighters in the field. This information is crucial to the main control room so operators can determine a course of action, whether or not particular equipment is accessible, or if they need to act with more urgency.

The fire pre-plans may also need to provide specific guidance or refer the control room to other operating procedures. They may, for example, direct the control room to pump down drainage sumps to minimize oil pool fires or prevent additional fire hazards.

Urgency

Time is crucial when a fire is raging, and until oil systems are secured, firefighters may not be able to extinguish or control the fire. This is especially true if the fire is an oil spray fire being fed from a pressurized oil system. These kinds of fires produce tremendous amounts of energy and cannot be extinguished until the fuel source is secured.

Entry Conditions

The entry conditions in the plan/procedure need to be broad enough to cover most situations and detailed enough to ensure that operators take the correct course of action. Generally, there are three primary entry conditions.

Catastrophic Failure

In this entry condition, it is evident to plant operators that the turbine or generator is a complete loss. This could be a catastrophic turbine or generator failure resulting from thrown turbine blades, a severed turbine shaft or a turbine/generator that is no longer spinning. This entry condition would necessitate taking immediate action to secure all oil sources, since the equipment damage would be extensive and any attempt to protect it would not be practical. The focus would be on preventing or helping to control/extinguish an oil fire.

Turbine/Generator Oil System Leak and/or Fire

In this entry condition, there is a large leak and/or fire that involves one or more of the turbine/generator oil systems. This could be a fire at the turbine/generator, on one of the oil system skids (H2) seal oil, turbine lubricating oil, turbine control oil, etc.) or at any location where oil piping is routed. The leak or fire may or may not have been a result of a turbine event. In some events, maintenance activities have resulted in pressurized oil releases and subsequent fires. Often in these cases, the unit is still operating, and mechanical damage to the turbine/generator has either not occurred or is unknown. The plan/procedure must consider what actions to take if the event is limited to oil leakage, if there is a fire that is under control, or if the fire is growing and becoming uncontrolled.

If no fire has occurred (the event is limited to strictly oil leakage) or if the fire is under control — and is not expected to grow — there is the potential to control the turbine/generator in a more “normal” fashion. If the fire is not under control and/or is growing, then plant operators need to act more urgently to control the turbine/generator before more severe damage occurs. Conditions in the field will determine the urgency.

Depending on the severity of the fire and the damage that has occurred or is occurring, there could be a point when a choice must be made between allowing some mechanical damage (e.g., bearing/journal damage) to the steam turbine/generator or allowing substantial fire damage to the turbine building and other equipment, cabling and systems contained within.

Hydrogen Fire in the Turbine Building

This entry condition would be applicable to those stations that have hydrogen-cooled generators. Hydrogen can become involved if there is a loss of the hydrogen seal oil system or an excursion of any type that allows hydrogen leakage out of the generator. The plan/procedure should consider the potential for the hydrogen release and the potential fire or explosion that could occur. Guidance should be provided on how to quickly vent/purge hydrogen from the generator, the accessibility of hydrogen isolation valves, the operating building ventilation systems, etc.

If any of the above entry conditions are met, the procedure/plan should be executed. In cases where the turbine/generator is still operating and a significant fire is present, the first step will be to begin a shutdown of the turbine/generator in the safest and most expeditious manner.

Trip the Turbine / Break Condenser Vacuum

Turbine Trip

Typically, the first step is to trip the turbine. The plan/procedure should include verifying that all turbine valves are closed, the output breaker is open, etc.

Break Condenser Vacuum

The conditions in the field would determine whether or not to break condenser vacuum to slow the turbine down rapidly. Breaking condenser vacuum will substantially decrease the coast-down time for the turbine. To prevent or minimize damage to the turbine, the original equipment manufacturer (OEM) should be contacted about how fast vacuum can be broken without causing significant damage. The plan/procedure should include multiple ways of breaking vacuum, including verifying that vacuum pump(s) are off, vacuum breaker(s) are open, and alternative accessible valves that aid in breaking vacuum are open.

Identify/Isolate Oil Leakage Source

If an oil leak and/or fire has occurred, the source of the leak needs to be identified. Items to consider include but are not limited to:

Generator H2 Seal Oil Systems

Is the oil source required to keep H2 in the generator (that is, is there a redundant oil system available to perform this function)?

If the answer is no:

- Immediately shut down the associated oil pump or isolate the oil source

If the answer is yes, then actions may include:

- Emergency H2 venting

- Opening vacuum breaker(s) to slow down the steam turbine/generator as soon as this is reasonably achievable (based on OEM guidance)
- Starting to introduce CO_2 to the bottom of the generator
- Based on turbine speed, determining the actions necessary (such as to prevent seal damage — the OEM may provide guidance on the level of potential damage)

Turbine/Generator Bearing Oil

- Open vacuum breaker(s) to slow down the turbine/generator as soon as this is reasonably achievable (based on OEM guidance)

Below the OEM-provided speed:

– Damage would be localized to the bearing pedestals (wiped bearings, damaged journals, etc.)

Above the OEM-provided speed:

– Damage could be severe, to both the pedestals and the blade path
– There would be the potential for blade liberation
– Operations personnel will need to evaluate securing oil to the bearings in this speed range when there is a severe oil fire, since significant damage could be expected
– AC and DC bearing lubricating oil pumps would both need to be secured (Note: The shaft-driven pump would also still provide oil at a reduced pressure and flowrate during coast-down — the OEM may provide guidance on the potential level of damage.)

Bearing Lift Oil

At normal operating speed, no damage will occur to turbine components when bearing lift oil is isolated (it should be off at normal operating speed), so immediate shutdown/isolation of the associated bearing lift oil pump can be performed. At a lower speed, the pump will automatically start to maintain oil on the bearings. This should be considered in the development of the procedure.

High Pressure Turbine Control Oil

This would include mechanical hydraulic control (MHC) and electro hydraulic control (EHC). In most cases, high pressure turbine control oil (MHC and EHC) is not needed following a turbine trip, so the associated MHC or EHC pump should be immediately shut down. Turbine valve closure should be verified as part of this evolution.

What a Plan/Procedure Should OR Should NOT Be

The Plan Should Be Site-Specific

There is no one-size-fits-all approach. Insights can be gained from other sites' plans/procedures, but each plan/procedure is unique to that facility and is dependent on its individual design features, location of equipment, staffing and other resources.

The Plan Should Consider the Guidance Discussed Herein

This document contains a minimum framework for the plan/procedure. Some plans/procedures may need to contain more information, depending on a plant's design or individual needs.

The Plan Should Be a Stand-alone Document

The plan/procedure should not be treated simply as one of multiple existing procedures, since in an emergency that could slow down the process of controlling/securing equipment. It should not simply be part of a list of normal operations procedures to reference. The plan/procedure is meant to address an abnormal/emergency condition, and existing, more routine operating procedures may not contain the methods or urgency to rapidly secure equipment or perform other necessary actions. It should instead be a stand-alone document so that it can be implemented quickly and successfully. It should also be referenced in other procedures/documents.

The Plan Should Not Be Located in a Firefighting Procedure

Firefighting procedures, including fire pre plans, should contain firefighting directions only. The operation of equipment belongs in operating procedures. In this situation, this plan/procedure should be part of some type of emergency operations procedure, such as an "off normal" operations, "abnormal operations," "special" plan/procedure, etc. It should not be located in a firefighting procedure.

It Should Contain the Appropriate Level of Detail

Depending on a site operator's experience and/or training, the plan/procedure should contain enough detail to be successful but not so much that it becomes cumbersome or unusable. Each site's plan/procedure will contain a different level of detail, depending on the size and complexity of the plant. For larger, more complex facilities, procedure writers need to be mindful of the length of the plan/procedure. If the salient points are buried on page 30 of a 50-page document, it could lead to failure. The plan/procedure needs to balance detail with efficiency.

- Example: What level of detail is right for you?
  - Not enough:
    Secure the oil on the turbine bearing oil system…
  - More reasonable:
    Secure the unit 1 turbine bearing oil system AC oil pump A1 by taking switch 1 at panel 1-A1 to the "OFF" position.
    Secure the unit 1 turbine bearing oil system DC oil pump A2 by taking switch 2 at panel 1-A1 to the "OFF" position.
  - Ad absurdum:
    Get up, get out of bed, take a shower, get dressed, drive to the site, have a cup of coffee, put on your PPE, go to elevation 100 adjacent to the turbine bearing lubricating oil skid, proceed to panel 1-A1 located at column lines L-2. With your right hand, take control switch 1, which is located in the upper left hand corner of the panel, to the "OFF" position. Then stop-think-act-review…etc.

Training

Operations

Developing the Steam Turbine/Generator Emergency Shutdown Plan/Procedure is just step one in the process. Plant operations personnel need to be periodically trained on the plan/procedure. Training should be part of normal periodic operator training programs. Training not only makes the operators more familiar with the plan/procedure and the scenarios it addresses, it often leads to improvements in the plan/procedure that are not foreseen during the writing and development process.

If it's possible that operators would need to operate equipment in hazardous environments, the plant should consider training some or all operators on the use of self contained breathing apparatus. Emergency response equipment needs to be provided in locations expected to be accessible during the event and maintained/inspected according to applicable standards.

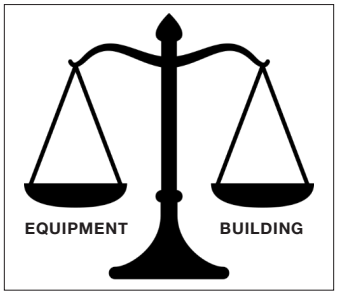
Emergency Responders

The local emergency response organization should be periodically trained in fighting industrial oil fires, including but not limited to a plant walk-down for hazard identification and plant familiarization. If a site has an in-house fire brigade, those firefighters should be periodically trained in fighting industrial oil fires, including but not limited to live fire training and incident command operations. A model practice would be to drill the fire brigade or fire department on a turbine oil fire scenario, including coordinating with control room personnel and knowledgeable observers to provide a constructive critique of the event. AEGIS can assist with such an exercise upon request.

Recommended Actions

Any site with an operational steam turbine/generator should develop a Steam Turbine/Generator Emergency Shutdown Plan/Procedure as soon as reasonably achievable. The plan/procedure should contain the elements described in this document and should be incorporated into plant operator training programs as described herein.

Contact your AEGIS Property or Machinery Loss Control Professionals for more information.



Conclusion

If a large steam turbine/generator fire event occurs, plant operators may be left with a difficult decision. Save/protect the equipment…or save/protect the building and its contents.

Having a plan/procedure in place will help prevent that large fire event from getting to the point where that difficult decision is necessary.

AEGIS Loss Control Property Operations can provide an example of a previously written procedure/template, additional guidance, and/or perform a review of a completed procedure upon request.

References

1. NFPA 850, 2020 Edition, “Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations” (Section 5.4.6.1)
2. NFPA 1620, “Standard for Pre-Incident Planning”
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5. Power Magazine, Mar 27, 2012, “Preventing and Mitigating Oil Fires in Power Plants” (https://www.powermag.com/preventing-and-mitigating-oil-fires-in-power-plants/)
6. AIG Communication COM CG 08 0036 “Turbine Generator Lube Oil Fires”
7. NUREG-1275, Vol. 11, “Operating Experience Feedback Report — Turbine-Generator Overspeed Protection Systems”
8. Marsh Risk Management Research, August 2014, “Historical Loss Experiences in the Global Power Industry”

Attachments

1. None

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