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# 1 SUMMARY

The Russell City Energy Center steam turbine and generator (STG) experienced a mechanical failure as a result of an overspeed event late in the evening on May 27, 2021.

Calpine contracted with Structural Integrity Associates, Inc. (SI) to perform an independent investigation with a focus on determining the root cause of the event. SI performed an initial onsite investigation from May 30th to June 4th, which included reviewing the condition of the STG and its support auxiliaries, examining rotor train fracture surfaces and the reheat system piping, as well as performing an initial review of the unit's operating data. At the closure of the initial onsite investigation, SI indicated that an additional inspection would be planned to take place once the STG and valves were exposed. This second onsite investigation occurred on July 26th after the steam turbine and main steam system valves were exposed.

Through review of the STG operational data, it was determined that immediately prior to the mechanical failure, the STG reached speeds equal to or greater than 146% of its rated speed. These rotor speeds are far in excess of the controller's overspeed protection settings and component mechanical failure would be expected. The radial vibration levels, as the unit accelerated from 1,950 RPM to near the rotor's ultimate speed of greater than 5,250 RPM, remained at acceptable operation levels. This lack of elevated vibration levels indicates that the rotor and bearings were in mechanically sound condition even under excessive speeds. Consistent with this conclusion, the shaft fractures lacked indications of pre-existing flaws or fractures. Therefore, no additional effort was expended to determine the exact nature of how the rotor fractures occurred as this was not required to carry out the causal analysis of the overspeed event.

The overspeed was the final event in a cascade of events that led to the mechanical overload of the STG rotor. Prior to the overspeed, a water induction event resulted in thermal seizure of the intermediate pressure steam turbine #2 intercept and stop valves, preventing their closure. The water induction event also caused an increase in the rotor axial load and position, tripping the steam turbine. Leading up to the water induction event, heat recovery steam generator (HRSG) #1 was shut down (but available) for approximately two days while the plant operated in 1x1 configuration. During this time, HSRG #1 condensed an excessive volume of water at saturation temperature and was pressurized to near operating levels. This was an undetected, abnormal condition for an out-of-service HRSG.

As combustion turbine #2 was reducing load through its normal shutdown procedure, the two HRSGs equalized in pressure, initiating the induction of water from the out-of-service HRSG #1. As water passed through the #2 intercept and stop valves, the valve components were thermally distorted preventing their closure. The valve seizure was thermally induced and was not associated with a lack of periodic maintenance. Further, the valves operated as expected in the days preceding this event. The STG's primary and emergency overspeed protection triggered properly, however, were unable to prevent the overspeed due to the thermal seizure of the valves. Additionally, the water induction resulted in the trip command that led to the automated opening of the STG line breakers. With the line breakers no longer maintaining rotor speed, the continued flow through the seized valves provided the energy source to accelerate the STG into the overspeed event.

In the hours prior to the event, a small number of alarms re-occurred[1], all during operating load transition periods. These alarms provided no new event-related information to the operator and would not have prompted operator action based on the common occurrence of these alarms during transient conditions within normal operation. The first non-recurrent alarms related to the event were triggered starting at 29 seconds prior to the trip, documenting the rapid fall of the HRH steam temperature. Operator intervention at this point would not have prevented the event from occurring as the intercept valve seizure had occurred.

Based on the operation data, the accumulation of excessive quantities of water at near operating pressure within the out-of-service HRSG was primarily driven by flow and pressure supplied by the cold reheat piping across the HRSG #1 Cold Reheat stop valve. Investigation of this valve at a valve service center identified degradation of the gearbox that was observed once the gearbox was disconnected, fully disassembled, and cleaned. Testing at the service center revealed that the degradation reduced the valve stroke, which would not have been apparent during operation as the actuator attained its full stroke. With the actuator's full stroke, both open and closed actuator limit switch positions were met such that no alarms were triggered.

Since some steam valve leakage should be expected during the operation of a combined cycle plant, limited amounts of condensation within an out-of-serve HRSG are not uncommon. This water does not specifically put a unit at risk for a water induction event as HRSG heating and drain operation during a normal startup will boil off or purge a reasonable quantity of water.

Prior to the event on May 27th, the out-of-service HRSG #1 reheat system maintained elevated pressure levels and condensed excessive quantities of high temperature water within its harps. The reheat systems were not equipped by design to reliably detect the presence of water in all circumstances. Additionally, the distributed control system was not configured by design to mitigate the presence of excessive water under near operating pressure and elevated temperatures within an out-of-service HRSG. The systems' inability to detect and drain excess water under pressure and at high temperature within the reheater system is the root cause of the STG drivetrain event at Russell City Energy Center.

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[1] The site recorded alarms during turning gear operation (07:30:00 5/23/21) up to the trip (23:45:03 5/27/21). The vast majority of these alarms occurred while on turning gear up through the shutdown (22:40:15 5/25/21) of block 1 (combustion turbine, generator and HRSG). The alarms that entered during this time period all occurred during normal, transient operating conditions and prior to the accumulation of water in the offline HRSG.