Modernization of 75-year old Turbo Generator Emergency Trip System

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Abstract

This case study presents lessons learned during the retrofit of two 75-year old Turbo Generator (TG) overspeed trip systems to meet the latest edition of API 612. The effort was initiated due to reliability issues with the overspeed trip system. Risk analysis was conducted to quantify the problem and justify the upgrade project with management. The solution integrates the latest technologies utilized by two major turbine manufacturers. Challenges encountered during construction, commissioning and operation are discussed so learnings may be utilized by others who are contemplating updates to overspeed trip systems.

Turbo Generator Trip System Malfunction

- A 1944 & 1945 6MW dual extraction condensing TG's at the Celanese Narrows, VA site experienced failures of the Trip and Throttle Valve (T&TV) 6 times over a 5 year period
- When the turbine entered a tripped state, the T&TV would remain open but close unexpectedly after operators touched the handwheel.
- The problem was not repeatable after the initial incident, which limited troubleshooting efforts
- Steam conditions on site were excellent and machines of similar size and construction did not exhibit the same problems

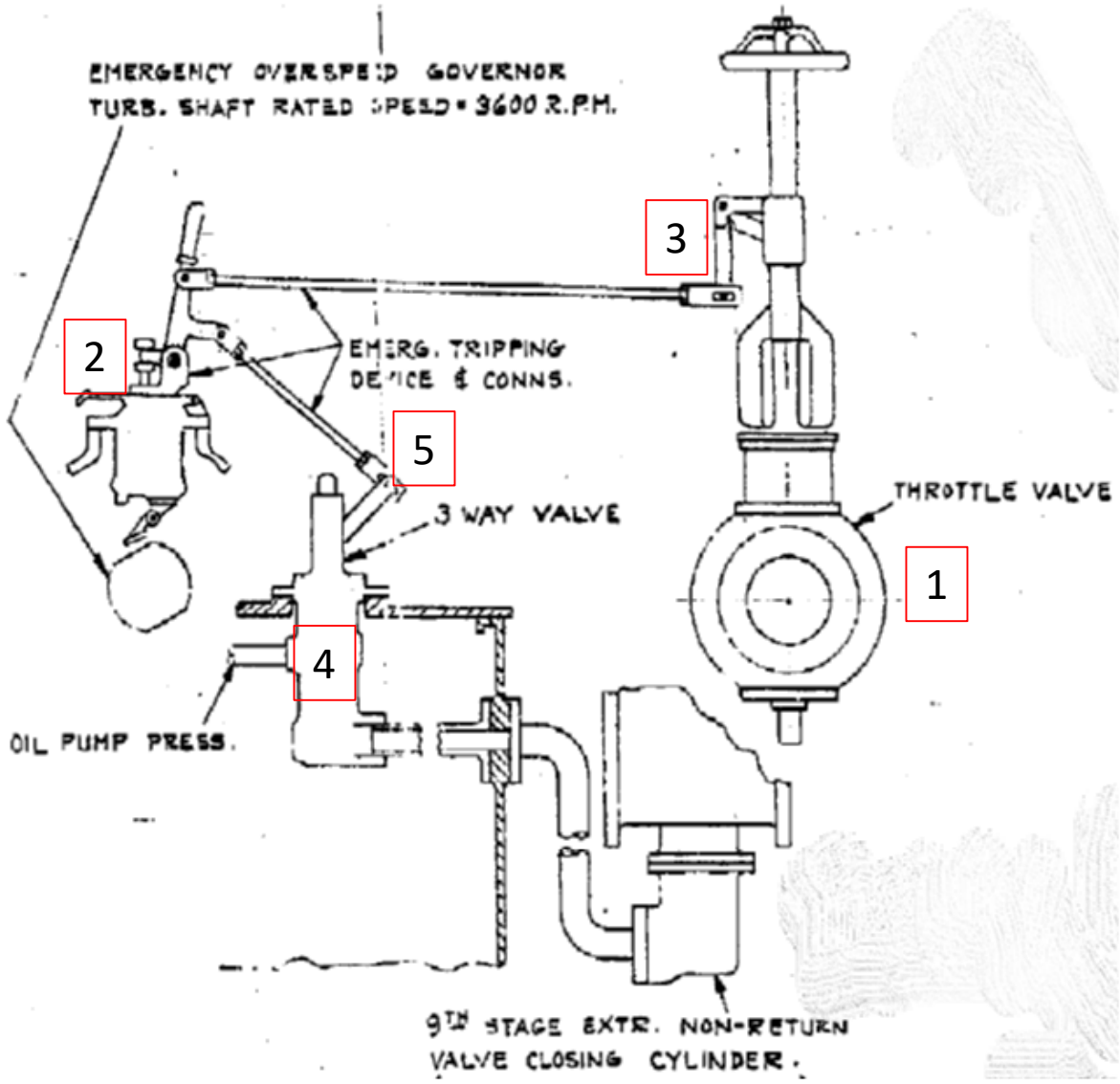
Turbo Generator Trip System Malfunction

- Previous overhauls of the valves and trip systems by the OEM field services division did not remedy the problems

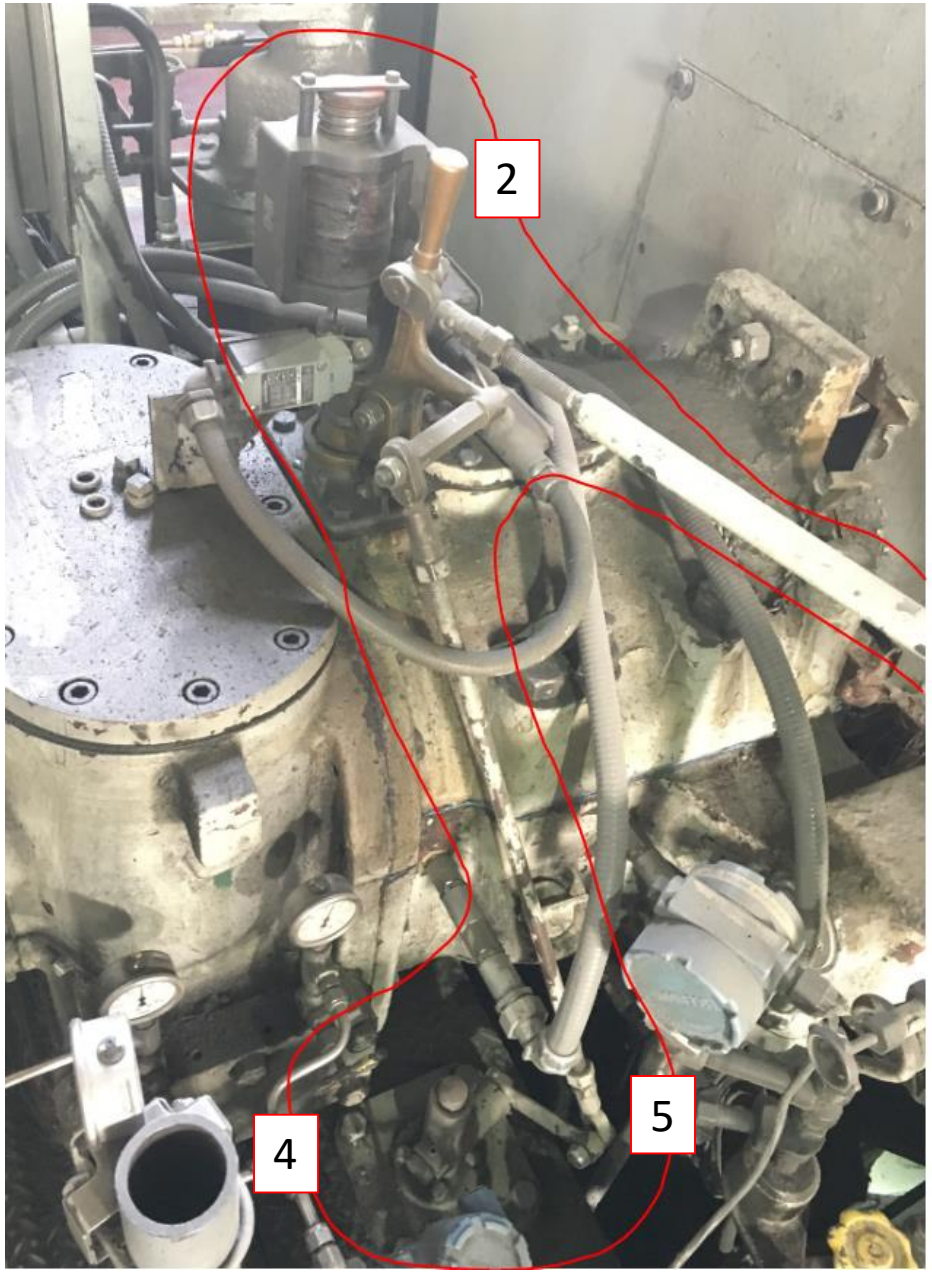
- Frequency of failure of the safety system and potential consequence did not meet Celanese Risk Assessment Risk Management (RARM) criteria and required action
  - RARM utilized actual data from events to create fault trees and event trees thereby quantifying the risk
  - After review of the calculation by committee and safety, risk was determined to be unacceptable

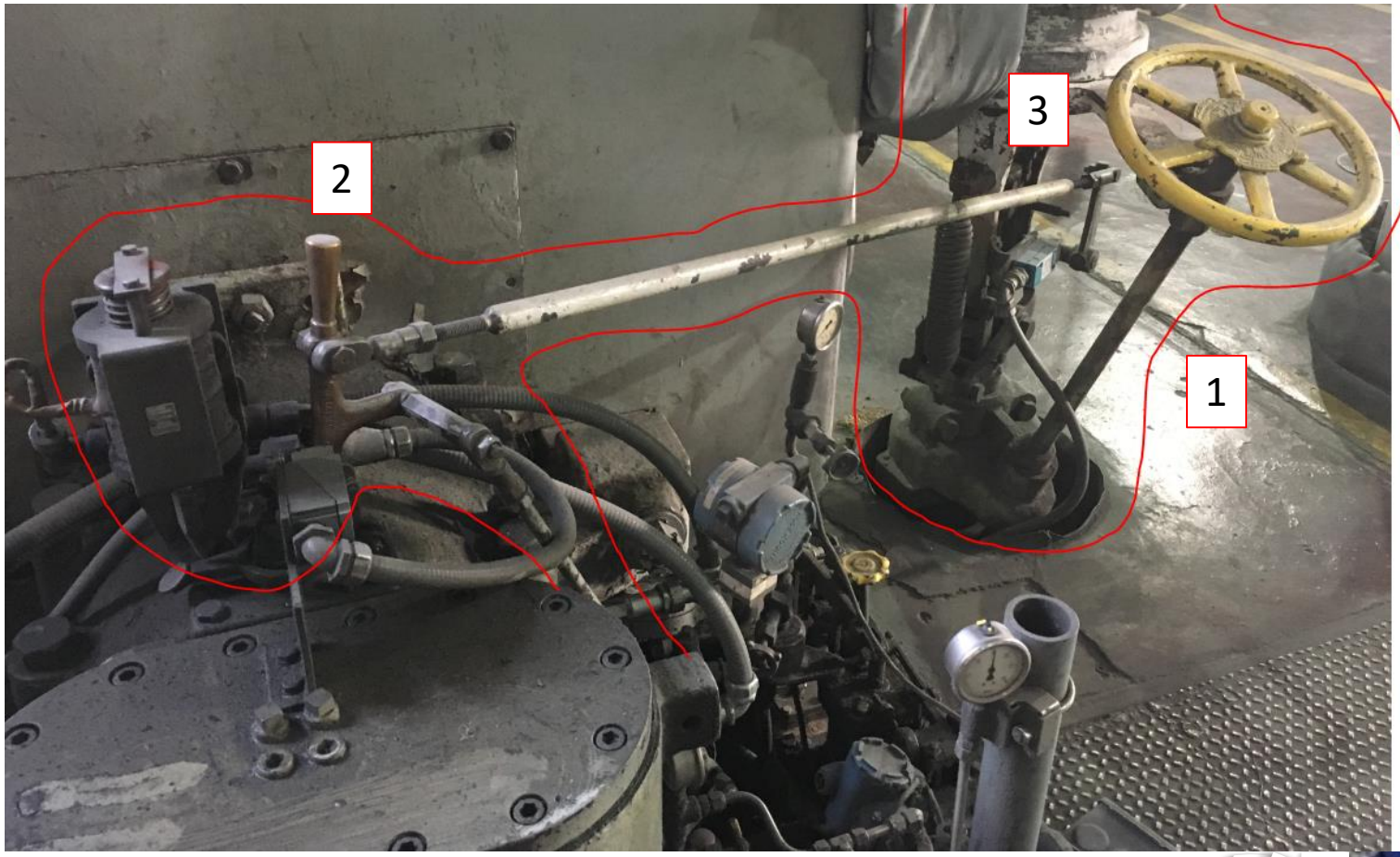
Existing Installation

1. Inverted mechanical latch T&TV
2. Mechanical bolt with spring loaded linkage actuator (with retrofit solenoid activation – not shown)
3. Hammer Blow Loop Linkage
4. 3-Way valve controlling (internal to oil sump) Non Return Valve (NRV)
5. Individual operator control of NRV during startup by linkage design



Existing Installation





Risk Mitigation and Removal

- Operations would not commit to routine valve partial stroke exercising but did agree to test the trip on a quarterly basis to exercise mechanical components
  - After implementing, no additional failures were experienced

- Multiple options were reviewed with different levels of investment, however technical review and company policy led to a full API 612 & 670 compliant update

- The existing overspeed protection system met the requirements of API 670 and did not require any further investment

- API 612 requires a direct oil operated T&TV as well as redundant electro hydraulic solenoid valves, which must be testable and maintainable online.
  - The existing mechanical design does not meet this requirement

Design Challenges

- A direct oil operated valve is required to comply with API 612, however the minimum operating pressure for these valves is 100 PSIG and the turbine lubrication system operates at 50 PSIG

- Piping supplying oil to the NRV control circuit is integrated into the lube oil sump along with the 3-Way valve for control
  - Imprecise documentation on the design

- Existing governor and overspeed trip technology is over 20 years old and has limited technical support due to obsolescence

- To prevent >120% overspeed upon trip event, T&TV had to close in 0.86 seconds and 2 seconds for the NRVs,
  - This calculation result provided by OEM

Design Hardware Selection

- Trip Valve Replacement - self contained Electrohydraulic T&TV with an integrated API 612 compliant trip block, microprocessor controlled diagnostics and partial stroke features
  - Independent of lubrication system
  - Redundant power supplies for controls
  - Uninterrupted power supplies for trip solenoid circuits
  - Isolation of trip solenoids via single block valves

- Trip Manifold Assembly (TMA) to control NRVs – API 612 compliant trip block with power and diagnostic controls via the turbine governor
  - Utilizes hydraulic pressure supplied by the turbine lube system
  - Isolation of trip solenoids via a three way valve
  - Three way valve in the oil sump to be replaced with a manifold

More Design Challenges

- The API trip blocks on the proposed T&TV and on the TMA are both API 612 compliant but utilize different approaches for isolation of individual hydraulic trip circuits during maintenance
  - The T&TV utilizes single block valves, which, if a valve is closed in either of the two circuits the trip function is defeated
  - Protection from this configuration is provided by limit switches, a local alarm, and lockable valves
  - The Trip Manifold Assembly uses a 3-Way valve with valve position switches

Project Integration

End User

- Specifications
- Bid and Technology Review
- Final Design Layout
- Electrical Design
- Procurement of Materials
- Construction
- Quality Control
- Operational Procedures

Turbine OEM

- NRV Trip Block
- 3-Way Valve Manifold
- Governor Software Changes
- Piping Design and initial Layout
- Commissioning Support
- Training on Operating new Trip Block

Third Party

- Trip and Throttle Valve
- Commissioning of T&TV
- Training on Operating new T&TV

Construction Photographs

- New Trip and Throttle Valve installed on continuous force spring cans
- Control Panel (to the right hand side of Trip and Throttle Valve in photograph)

Construction Photographs

Piping to and from TMA

TMA mounted with T&TV in background

Commissioning Struggles

- One NRV closure time was over the allowable 2 seconds
  - NRV insulation did not take into account valve closed and open positions
  - After trimming insulation valve closed in allowable time

- TMA oil leak at handle through double O-rings due to flaking of anodized coating in bore of valve handle guide bushing holder
  - Disassembly, polishing, reassembly corrected the leak

- Startup strainer removal – access cover bolts on T&TV experienced severe galling on blind studs, valve had to be removed and shopped for repair
  - Anti seize was used and bolts torqued properly during assembly but did not prevent galling
  - Recommend heat or nut splitting tools preemptively to protect studs regardless of time in service

Commissioning Struggles

- Original linkage design allowed for NRVs to remain closed during startup but this feature was not part of the TMA programming and operations insisted on a design change to allow control of NRVs

1. Software was altered to address NRV controls, then turbine could not start due to loss of additional lube oil through the new dump line from the TMA (more oil recycled than originally, reducing oil pressure)
2. A manual valve installed on the oil supply line to the TMA for operator field control and to maintain oil pressure for operating turbine valve racks, but now the TMA trips turbine after 30 seconds with no oil pressure
3. Logic changed again to remove the 30 second protection only during startup (negotiated result with the OEM)

   Now it works as desired!

Operational Performance

- One false trip experienced a month after commissioning due to a loose wire in the 24V trip circuit to the T&TV.
- Online diagnostics and testing capabilities fully utilized on both the TMA and T&TV
- T&TV Partial Stroke feature is used regularly
- No other maintenance or operations related problems with combined 4 years operating experience

Questions?