SIL Assessment in Combined Cycle Power Plant – Case Study

SIL study is usual practice in the Chemical and Oil & Gas industries. Nowadays, SIL studies are being applied to power plants by Owners. IEC 61511 standard requires a safety life cycle (divided into three phases analysis phase, implementation phase and Operation/ Maintenance phase). In the analysis phase, a SIL workshop is carried out to identify the required integrity levels based on Health/Safety, Environmental and Financial considerations using the IEC SIL Risk Assessment Matrix (Normally, the Risk graph method is followed in Power Projects). All the participants (Owner, EPCs, OEMs and other O&M teams) must have appropriate skills to understand and share their experience to arrive at the required SIL level of Safety Instrument function (SIF). This case study covers the number of SIL loops for a typical Combined cycle power plant, Mitigation measures, Inputs requirements and the SIL achieved for the High high-level trip. The following power plants are taken into consideration

- Combined cycle power plant (1450 MW): 2 blocks (2 GTG+2HRSG+1 STG) in Algeria
- 275MW IPP PROJECT in Indonesia. The proposed project consists of one (1) combined cycle power block (2+2+1) comprising two (2) gas turbines and generators (GTGs), two (2) heat recovery steam generators (HRSGs) & one (1) steam turbine and generator (STG), and Balance of Plant (BOP) equipment.

Need of SIL Assessment

- Identify potential process hazards
- Recommend actions be taken to minimise risks.

Challenges

- Proper backup for asset loss, financial loss, mean time to repair, frequency of occurrence and IPL layer
- All participants shall have appropriate skills and experience to arrive at the required SIL level

CASE STUDY

In general, EPC companies do not carry out SIL Assessment Studies during the Prebid engineering stage and consider cost margins to perform a complete SIL study during the detailed engineering stage. With the procurement for major equipment already completed and designs frozen by OEM, it is a difficult task for any engineering company to perform a SIL study and implement the study result in the design. Normally implementing the SIL study result at the latter part of detail engineering will impact EPC or OEM design – Cost & delivery impacts. This case study will attempt to explain the SIL assessment of combined cycle power plants to address the various practical difficulties in achieving the SIL levels, Mitigations, involvement of OEMs and their inputs. The GTG and STG systems are not covered as part of this case study, as the SIF in the GTG and STG are proven standard designs or have dedicated SIL systems.

Following are the specific SIF of combined cycle projects and associated learnings

1. **Lack of data to calculate the Asset loss & Frequency of occurrence:** The owner, OEMs and EPC contractors do not have or give accurate data to calculate the Total Asset Loss - asset loss due to equipment damage, financial loss due to generation loss, time is taken to repair or replace the equipment or system, frequency of occurrence of an event.

   Solution: Respective parties must be informed upfront to obtain accurate details. Also, awareness sessions are to be conducted for respective parties to understand the significance of this.

2. **ESDV downstream Pressure high high will close ESDV (SIL-2):** High High Pressure will result in possible over-pressurisation of the pipelines and equipment downstream of ESDV. This may result in fuel gas conditioning pipeline rupture or equipment damage. The approximate cost is greater than 20 Million USD as the possibility of gas release at high pressure may result in fire or explosion.

   Solution: A High-Pressure Alarm as an Independent Protection Layer (IPL) to be added to provide additional information to the control room operator through FGS PLC. Also include two solenoid valves to close ESDV (1 out 2) as part of the ESDV actuation scheme.

3. **Condensate Separator Level High High will close ESDV(SIL -1):** High High Level in the Final Filter-1 Upper Chamber will lead to liquid carryover to the Gas Turbine, which will result in Damage to the Gas Turbine Combustion Chamber.

   Solution: OEM (GE) Team needs to reaffirm whether the impact of liquid carryover is limited only to the damage of the Combustion Chamber and shall not affect the Gas Turbine.

4. **On High High level in LP, steam drain-2 will open the steam drain valve (SIL -2):** High High level in the last LP steam drain pot will result in water carryover to the LP stage of STG and which may damage the STG (LP turbine blades, etc.). Asset loss is greater than 5 Million USD.

   Solution: Include the last drain pot level and drain valve operation as part of the ST control system. Also, the last drain pot level switches and drain valves can be SIL2-rated.

5. **On High High steam pressure downstream of the HRSG HP Bypass will close the HRSG HP steam bypass pressure control valve:** High High steam pressure downstream of HRSG-11 HP Bypass will result in over-pressurisation of downstream piping and possible damage to the re-heaters of HRSG which may result in loss of power generation (125 MW). The time to restore re-heaters is approximately two months. The total approximate cost is 15 Million USD.

   Solution: Pressure relief valves can be considered as the IPL. However, the Owner has been informed to submit the reliability certificate to have proof and accept the safety valve as IPL. OEM was not able to submit the reliability certificate and hence provided generic data

6. **On High High steam temperature in downstream of HRSG HP Bypass will close the HRSG HP steam bypass pressure control valve (SIL-1):** On High High Downstream Temperature of HP Bypass Steam, the pipeline gets overheated and can crack, leading to an increase in Temp of the tubes, and after prolonged periods of heating over the life, this may damage the Reheater inlet manifold and tubes

   Solution: Inter-SIF credit to be taken to ensure that the IPL, i.e. On HRSG HRH O/L Temperature High High, is connected to an independent and different Logic Solver (will cause HRSG trip by Gas Turbine). Also, it is advised to consider SIL-2-rated bypass valves.

7. **On Condenser High High temperature will close HRH and LP bypass valves (SIL-1):** High High HRH Bypass Outlet Temp will lead to a rise in Condenser Temperature and LP Turbine Last Stage Blades

   Solution: LP turbine exhaust hood Temperature measurements to be considered as same are independent of DCS. Also, it is advised to Consider SIL-2-rated bypass valves (HRH bypass valves & LP bypass valves)

8. **On High High level, the HRSG Drum will close the diverter damper (SIL-1):** High High level in the Drum will result in moisture carryover to pressure parts which may result in damage (over a prolonged period). The approximate loss, including power generation loss, is 15 Million USD.

   Solution: Hardwired High-Level Alarm from RDLI can be connected to a different control system. Remote Drum Level Indicator is present in CCR. Also, it is advisable to consider SIL-2 related diverter damper.

9. **On High High Pressure in the HRSG HP Drum will close the diverter damper (SIL-1):** High High Pressure in Drum will result in over-pressurisation resulting in rupture

   Solution: Safety relief valves can be considered as IPL. However, Reliability certificates from OEMs are to be submitted as proof. Also, it is advisable to consider SIL-2 related diverter damper.

10. **On High High pressure in the HRSG duct will close the diverter damper (SIL-2):** High High Pressure will result in over-pressurisation of the HRSG casing leading to damage to the casing and diffuser.

    Solution: Auto Open of the main stack damper (similar to Safety relief valves function; mechanical actuation of the damper by pressure) can be considered IPL. However, Reliability certificates from OEMs are to be submitted as proof. Also, it is advisable to consider a SIL-2-rated diverter damper.

RESULTS AND DISCUSSION

The Risk Graph analysis is performed by a multi-disciplinary team knowledgeable of the evaluated design and IEC 61508/ 61511 standards. The team shall consist of people qualified to review the chemical process, identify potential process hazards, and recommend actions to minimise risks. Proper backup for asset loss and frequency of occurrence and IPL layer to be considered. Conduct brainstorming sessions internally and Standardise SIL assessment reports for typical combined cycle power plants. Normally GTG and STG OEM designs are standardised by their SIL study results. Inform upfront and include SIL requirements as part of respective vendors' specifications. Minimum SIL-2-rated dedicated instruments for protection if the project demands SIL study.