"PROVING HOUSE LOAD OPERATION OF GAS TURBINE IN PREMIX MODE IN CASE OF GRID FLUCTUATION"

Authors: 
Kulwinder Singh, AGM(O)  
D.C Tewari, DGM(O)  
Dheeraj Girdhar, SS (C&I)  
Maya Ramachandran, DS(C&I)

Presenters: 
Maya Ramachandran DS(C&I)  
Dheeraj Girdhar SS (C&I)
Presentation Outline

- House Load Operation and Benefits.
- An overview of the problem faced at FGPS
- An Introduction to the schemes at FGPS
- The long journey towards solving the problem
- Benefits accrued
- Suggestions
House Load Operation

- Gas Power Plants designed to give start up power in case of grid failure.
- In case of grid failure /heavy load fluctuations - Gas Turbines (GT) isolated from the grid
- Supposed to run on house load - provide supply to auxiliaries
- The machines should not trip - available for synchronisation to grid as soon as necessary.
Benefits of House Load Operation

• Prevents total blackouts of station
• Damage to capital equipment and auxiliaries is nil.
• Minimal dependence on DC system and BSDG.
• Keeps machine available for synchronisation as soon as grid fault is cleared.
• Can give start up power to other power plants.
A brief about FGPS

• GTs commissioned in the year 1999.

• Two modes of operation in the GTs - Diffusion and Premix.

  • **Premix Firing Mode** - Environment friendly but Unstable flame.

  • **Diffusion Firing Mode** - Stable flame but not environment friendly.

• The control system designed to change from Premix to Diffusion mode in case of load fluctuations.
Desired sequence of events in case of grid fluctuations

• Grid fluctuation detected by signal “Load Shed Set Off”
• This signal to initiate fast changeover from premix to diffusion
• In case of small fluctuations, machine to remain connected to grid in diffusion mode
• In case of heavy fluctuations, additionally:
  1. Speed mode to be activated
  2. Machine to be isolated from grid by opening of UCB and remain on house load.
Actual Scene at FGPS

• Since commissioning, whenever GTs were running in Premix Mode and heavy load fluctuations/grid failure occurred, machines used to trip.

• Machines used to change to speed controller.

• But changeover from premix to diffusion was always interrupted due to trip.

• The exact cause of trip was not known.

• The desired house load could never be achieved.
Adding to the woes of FGPS

- FGPS is connected to the grid via single point-220 KV Samaypur link.
- In case of failure of this link, the danger of heavy throw off occurs.
- Thus the probability of load throw off is very high when compared to other stations.
- There have been 21 trips on this account since commissioning resulting in a loss of Rs 2.19 crores.
An Introduction to the schemes at FGPS
Gas Turbine- An Overview
Diffusion Operation

- This is the mode of operation in which there is no premixing of air with the gas.
- Thus the flame is stable.
- Machine starts in this mode.
- In case of load throw off etc in premix mode, the machine changes over to diffusion mode.
DIFFUSION MODE OF OPERATION

NGESV - Natural Gas Emergency Stop Valve
NGCV - Natural Gas Control Valve
PGCV - Pilot Gas Control Valve

Red - Open
Green - Close
Pink - Intermediate
Yellow - 10%

DIFFUSION V/V
PREMIX V/V
PILOT V/V

LCC - Left Combustion Chamber
RCC - Right Combustion Chamber
**Premix Mode**

- In this mode air is premixed with natural gas and burnt in the burners. This mixture is lean and flame is unstable.

- So an additional thin gas line called Pilot Line is provided to increase the main flame stability.

- The temperature of flame in this mode is low as compared to that of diffusion mode, so the NOx formation is less.
CHANGEOVER FROM PREMIX TO DIFFUSION

NGCV - Natural Gas Control Valve
PGCV - Pilot Gas Control Valve
NGESV - Natural Gas Emergency Stop Valve

LCC - Left Combustion Chamber
RCC - Right Combustion Chamber

Color Key:
Red - Open
Green - Close
Pink - Intermediate
Yellow - 10%
Breaker Scheme at Faridabad

- GT 1
- Gen
- GT 1
- GCB
- Generator Transformer
- 10.5KV/220KV
- Unit Circuit Breaker (UCB)

- 6.6KV Bus
- UAT
- GT 2
- Gen
- GT 2
- 10.5KV/220KV
- Generator Transformer

- 6.6KV Bus
- UAT
- ST
- ST Gen
- GT
- 15.75KV/220KV

- 220 KV Grid
The long journey towards solving the problem
Discussions with OEM

• The case discussed with OEM experts (foreign and Indian counterparts)

• But the discussions not very fruitful as these experts were from a particular domain/sub-system and not process experts

• Due to lack of relevant expertise in India, foreign experts are deployed for such jobs, but they charge a lot of money.
In House Effort

• A team of self motivated engineers from Operation and C&I Departments took up this arduous task of solving this problem.

• Analysed the Logs, Trends, Commissioning Reports.

• Studied the Logic of Protection System, Governor System & Electrical System.
Major roadblocks in finding a solution

1. Highly complicated and interwoven system

- Protection panel issues closure command to NGESVs in case of abnormality of 72 signals
- The cause for the trip can originate in any of the various sub-systems.
- Each sub system an independent entity in itself with separate addressing and programming techniques.
Major roadblocks in finding a solution

2. Problems in the logging system.

- The logs limited in nature
- Available only in HMI of 620B
- Different scan rates for A) Different sub system B) Hardware and Software signals
  - Scan rate of A)TXP-100msec  B)95F-50msec  C)Simadyn-50msec
- As many signals are stamped with same time tag, it is very difficult to know the exact chronological order.
- Signals generated in the other sub-systems like protection panel and governor have to be routed into the HMI system.
Major roadblocks in finding a solution

3. No permission for logic modification in protection panel.

- Protection panel is TÜV certified-So no permission to modify logics to increase signal availability in logs.

Due to these problems it is very difficult to pinpoint the exact reason of a trip.
The First Step - Analysis of Logs

- Incidents of trips during grid fluctuations in premix mode were analysed.
- No signal other than resetting of NGESV command available in logs.
The first failed experiment—A learning experience

- One of the reasons of NGESV closure could be the closure of NGCV < 2.5% for more than 3 seconds

- NGCV had closed to around 0.104% for about 3 seconds
NGESV-Natural Gas Emergency Stop Valve
NGCV-Natural Gas Control Valve
PGCV-Pilot Gas Control Valve

Red-Open
Green-Close
Pink-Intermediate
Yellow-10%
Reason behind NGCV Closure

• During load throw off, speed of the machine rises.
• The governor changes to speed controller.
• It closes the NGCV to cut fuel input and tries to reduce the speed.
• As soon as the rate of rise comes under acceptable limits, the controller starts opening the NGCV again.
First trial

• On 15-08-2011, the limit of trip of 2.5% was reduced to 0.1%.

• Load throw off was replicated by opening the GCB.

• Opening of GCB is the harshest load throw off for the turbine.

• Survival in this case shall ensure survival under other throw offs.

• Unfortunately, the machine tripped.
The Second Step

• Suspicion was still on NGCV closure.
• The logs showed Flame off signal after the trip.
• This was natural.
• But team felt that it could be possible that due to the difference in scan rates, the flame off signal was getting logged later but was actually the trigger for trip.
The Next Step

• If flame failure due to NGCV was the cause, then the agent of this problem was the governor.

• NGCV is the final control element for all the loops of the governor.

• In this case, since speed controller remains in service, this loop was analysed.

• But no abnormality was found.
Back to the Basics

• House load had been proved by OEM during commissioning phase.

• The reports, graphs and logs of the trial were analysed.

• The important observation was that NGCV did not close during the commissioning trial.
08th July 1999

- In premix mode, on a load of 80MW, NGCV-39% and PGCV -95%.
- At load throw off, PGCV -70% and NGCV -5%.

Machine at 3000rpm
23rd August 2010

- In premix mode, on full load, NGCV -56% and PGCV -53%.
- At load throw off, PGCV -70% NGCV -0.104% and the machine tripped within 3 seconds.
Culprit Caught

• The significant difference was that NGCV remained open in the first case.
• In the first case while the PGCV closed from 94% to 70%, in the second case it opened from 53% to 70%.
• The PGCV was causing the NGCV to close in the second case and leading to turbine trip.
• Hence, the culprit in fact was PGCV, not NGCV.
The set point of PGCV can be any one of the following:

- -10% if machine trips.
- 10% if machine is in diffusion mode.
- 97% if there is a fault in Inlet Guide Vane system or gas pressure measurement system.
- 70% if machine is on premix mode and
  1) GCB/ UCB is opened.
  2) Fast changeover from premix to diffusion is initiated.
  3) Load rejection.
  4) Deviation between set point and actual position of PGCV > 10% for 2 sec.
- Under normal circumstances in premix mode, it is a function of natural gas pressure, compressor inlet temperature and IGV position.
Root cause of failure

- Due to the opening of the PGCV at 70%, the opening of NGCV is prevented. It closes almost completely.

- In the case of changeover, PGCV follows a fixed set point. It closes very fast once the changeover process completes.

- During the final steps of changeover, a time comes when PGCV is closing but NGCV and the diffusion burners have not yet opened.

- During this phase, flow of fuel to the chamber becomes highly restricted and machine trips on “Flame Off”.

- Thus, if the opening of PGCV is reduced during load rejection, NGCV opening shall increase and machine shall survive.
WHAT ACTUALLY HAPPENS
HEAVY GRID FLUCTUATION

LOAD THROW OFF DETECTED

CHANGEOVER FROM PREMIX TO DIFFUSION INITIATED

PGCV CLOSES

PGCV TO 55%

SPEED RISES

SPEED CONTROLLER ACTIVE

SPEED UNDER CONTROL

NGCV TO REMAIN PARTIALLY OPEN

CHANGEOVER TO DIFFUSION SUCCESSFUL

MACHINE ON HOUSE LOAD

THE PROPOSED SOLUTION
Trial Implementation

• The logic for opening of PGCV during load rejection was changed from 70% to 50% in GT#2 for trial.
• Load throw off was simulated by opening the GCB.
• Machine survived.
• The experiment was repeated with 55% for fine tuning in GT#1 and resulted in success.
Actual Test

• The real time test of this scheme occurred when Grid failed on 26\textsuperscript{th} May and 31\textsuperscript{st} July 2012. GT\#12 survived on house load.

• On 31\textsuperscript{st} July 2012, GT\#12 remained on house load of 10MW.
Benefits Accrued

• The problem was solved **IN HOUSE** with **ZERO EXPENDITURE** and **IMMEDIATE RETURNS**.

• Both the machines have proved their capabilities to run on house load.

• Under unstable grid conditions, we used to run one machine on diffusion in order to reduce risk of station outage. After this, we continuously run both machines on premix mode

• Immense learning experience.

• Better understanding of all the systems.

• We also experienced a sense of achievement in solving a perennial problem.
Some Suggestions

• Special care be taken during engineering phase to ensure the availability of the maximum number of signals in the log, especially if logic modification is not possible at site such as in our case.

• Critical testing such as house load operation should only be carried out at the final stages after the entire loop has been tuned.

• Strengthening of SOE to be given importance.

• If the multiplicity of system is reduced, maintenance will become easier and simpler.
Thank you!

Queries are Welcome