ANNEX 3.1: PAKISTAN ENVIRONMENTAL PROTECTION ACT, 1997

DHA Power and Desalination Plant Karachi - Pakistan

DCL Plant Status Report

2007 - 2010

SUMMARY OF THE PROJECT

DHA Cogen. Limited (DCL) is an independent power and water producer (IPWP) comprising of a combined cycle power plant and a multi effect desalination plant (MED). The Power Plant was designed for a rated electrical output of apporx. 87 MW (base load design conditions) or 94 MW ISO conditions, and steam production for seawater desalination of 3.0 MGD.

The power plant consist of a single shaft unit with one gas turbine (GT), one steam turbine (ST) and one generator, coupled by gearbox units to a common shaft. The ST can be decoupled from the power train by a flexible SSS clutch.

The unit is equipped with SIEMENS V-64.3A natural gas fired GT with annular combustion chamber; The exhaust gas from the GT is fed to an unfired heat recovery steam generator (HRSG), which is designed as a horizontal, double pressure, natural circulation boiler. The steam turbine, of type NK 40/56, is a condensing turbine. The turbine exhaust steam is condensed in the inlet section of two multiple effect desalination (MED) process units and if the desalination plant is not able to accept expanded steam from ST, in a dump condenser with limited capacity.

(Annex: *I)*

Procurement and erection of DCL was done under three separate contracts. Contractual parties to DCL were:

1. SIEMENS AG-Power Generation, Germany
2. SIEMENS Pakistan Engineering Co. Ltd.
3. Alfa Laval Copenhagen A/S, Denmark

Mott McDonald (Pakistan) were appointed by DCL to act as Owner's Engineer for the purposes of the Contract, all construction/ erection activities at site and equipments received at site were verified by the Engineers for payments to the Contractor (SAG).
(Annex: *II)*

COMMISSIONING & TESTING

The commissioning of the complex started in July 2007, during this phase SIEMENS carried out all necessary cold and hot commissioning tests at site and the complex achieved full load operation by 31st January 2008. (Annex: *III*)

For continuous operation of the complex in compliance with the PPA, 96 hours Reliability Run Test from 12.4.2008 to 16.4.2008 was carried out, under the supervision of IMTECH, the independent engineers appointed by KESC. Subsequent to successful completion of RRT, determination of contractual output and certification by IMTECH, the complex started its commercial operation from 17th April, 2008. (Annex: *IV*)

EVENTS POST COD

In May 2008, the vibration of GT compressor bearing started to increase gradually, SIEMENS were promptly informed about this issue, the vibration reached alarm level (9.5 mm/s) in June 2008; In the end of July 2008 SIEMENS suggested balancing of the rotor to cure the vibration, five (5) attempts were made by the balancing engineer during August 2008, data after each attempt was analyzed by the experts in Germany, the vibration came down below the alarm level. (Annex: *V*)

In the beginning of September SIEMENS communicated that the vibration cannot be cured as it is the result of creep deformation of the central hollow shaft, connecting the compressor and the turbine section. The remedy was to replace the shaft with a new shaft of improved metallurgical properties (Annex: *VI*)

The machine was switched OFF on 12th September 2008 on the STOP order of SIEMENS, as it was suspected that further operation would cause further damages. SIEMENS sent fact finders to further investigate the damages on the GT, the findings and the road map for the rehabilitation were explained in the first week of October 2008, Siemens Germany, assisted by Siemens Pakistan carried out fact finding, dismantling and repair of rotor and other components of gas turbine from Oct 13 to December 15, 2008. During this work central hollow shaft, the main cause of vibration was replaced with a new one of a different material composition. At this point Siemens demobilized as repair of stage 2 vanes of the GT compressor required long lead time.

Siemens resumed assembling of CTG on June 4, 2009 and completed assembling work by June 30, 2009. In doing so, they replaced compressor and turbine bearing and tilting pads, bearing supports, gas

pipes and manifolds, AVIT fittings of burner, first stage turbine blades and stage 2 vanes & blades and performed repair work on for inlet guide vanes. Insulation of Gas Turbine was carried out from July 4 to July 23, 2009.

RECOMMSSIONING OF GT

Since the turbine underwent complete rehabilitation, with several important components replaced as a result of the outage, comprehensive re-commissioning plan was undertaken by SIEMENS. Cool commissioning was completed on July 27, 2009 and hot commissioning commenced from Aug 5. All GT and plant systems were brought on line and successfully tested. The unit was successfully synchronized with the system on 14th Aug. 2009 and brought up to base load operation.

FIRST SURGE

On Aug 24, 2009, while running the plant on base load (82~83 MW); it tripped on surge protection, accompanied by a bang, at 1907 hours when grid frequency dropped to 49.1 HZ. Grid frequency was disturbed since 12:00 noon. It was varying from 49.9 to 49.2.

GT however, came on turning gear as normal and there was no abnormal sound and no other abnormal observation. The event was promptly communicated to SIEMENS, who sent a checklist, listing all items to be checked, to assess the damage caused by the surge.

SIEMENS suspected malfunctioning of IGV position sensor giving a wrong signal to I&C causing the whole consequential surge and the unit trip and recommended preventative exchange of the positioning sensor and checking the plug and all contacts and cabling, which could have caused the malfunctioning.

After carrying out the above checks, GT was started on 28.08.09 and synchronized with the system. (Annex: *VII*)

SECOND SURGE

On August 29, 2009 at 1406 hrs. GT tripped on surge protection again with a loud bang. All vibrations shot up to more than trip level as can be seen from attached trends. At the time of trip frequency was 49.2 HZ. Turbine came on turning gear without rattling or any other abnormal sound. GT air inlet was inspected and some filters had their flappers pushed outwards.

All checks as per SIEMENS documents were carried out, bore-scope inspection of different stages of compressor and turbine were carried out; there was no damage to the stator or rotor. *(Annex: VIII)*

SIEMENS dispatched a mechanical commissioning engineer and a governor control engineer, a new IGV position sensor was installed; SIEMENS finding were that the compressor has degraded which has raised the surge line closer to the operating speed, the surge protection trip, therefore, results when low grid frequency reduces the operating speed of the compressor. SIEMENS made the compressor pressure ratio limiter active, so that it would start closing the IGV when the frequency starts decreasing.

With the above mentioned changes incorporated in the control, GT was started on 16th Sept, 2009.

(Annex: IX)

THIRD SURGE

On 17th Sept, 2009 at 1948 GT again tripped on surge protection when frequency dropped. SIEMENS engineers were still present at site, the GT was again thoroughly checked, bore-scope inspection of the compressor, turbine were carried out and no damage to any GT part was found out.

(Annex: X)

SIEMENS implemented a threefold formula on Thursday, Sept 23, 2009 to avoid another surge event.

This would include:

1. A new polygon which means new value for compressor pressure ratio limiter which would allow IGV to close more during low frequency
2. Open cooling air valve during low frequency
3. Reduce OTC to 550 deg C during low frequency, this would additionally, reduce the combustion chamber pressure to prevent pile-up of air in the compressor last stages.

   These changes were tested during frequencies as low as 48.9 Hz and were able to protect the machine against surge.

   (Annex: *XI*)

The above mentioned changes in the GT compressor pressure ratio limiter resulted in protecting the gas turbine from surge but on the other hand the output of the machine also decreased, DCL accepted this solution even though it caused considerable revenue loss to DCL, as the dependable capacity when tested during the RRT conducted from 14th Oct, 2009 to 17th Oct, 2009 dropped down to 71 MW as compared to the contractual 80.3 MW.

FOURTH SURGE

The GT successfully continued to operate in this mode till 2nd November, 2009, when due to a grid disturbance, the generator was heavily overloaded resulting in an unprecedented frequency drop rate (6.7 Hz/sec), much faster than the PI controller of the GT compressor pressure limiter, which was programmed for a frequency drop of 1 Hz/sec, could handle. The GT tripped on surge protection and actual surge occurred accompanied by a loud bang and heavy vibration.

A complete physical check of the gas turbine, according to the SIEMENS check list was performed, bore scope inspection by third party was carried out and the pictures sent to SIEMENS; however SIEMENS sent their own fact finder to investigate the damages due to surge.

(Annex: *XII*)

SIEMENS decided to open the machine, as they could not calculate the risk of damage by operation of the GT without opening and detailed fact finding. DCL opened the LC to cover Siemens expenses Siemens mobilized their team including site supervisor, shift supervisor, fact finders, NDT specialist, turbine technicians and NDT specialists

The gas turbine was opened up in December,2009 , rotor was taken out, there were number of findings on the compressor stationary vanes. Due to large number of defects on 3rd stage vanes, complete replacement of diaphragm 3 was necessary, additionally 16 stationary vanes of different compressor stages were also replaced. Turbine end bearing was also replaced. The rotor blades and vanes were polished to mirror finish by 600 grade emery

To minimize the risk of surge occurrence SIEMENS recommended:

1. An up-graded version of the breaker (Thyristor controlled Plug & Play module) for IGV actuator, fast enough to close the inlet guide vanes to prevent overloading of compressor.
2. To cope with the high frequency changes of the grid, installation of the SIPROTEC 7VE6 multifunction paralleling device, this will isolate DCL from the grid in the event that a high frequency drop is encountered again.

GT was assembled by the end of January 2010; Recommissioning of GT started in the beginning of February 2010. A new up-graded thyristor based switchgear was installed & commissioned for IGV. GT was started and performance of the machine checked at base load in open cycle. The performance of GT compressor was analyzed by SIEMENS-Germany and it was decided to make the control less stringent than what it was in October 2009. This enabled GT to generate more power under given conditions of ambient temperature and humidity.

To prevent deposits on compressor blades which, in SIEMENS opinion, were the main cause of compressor deterioration, following Off-Line and On-Line washing regime for GT compressor was recommended by Siemens:

- **Daily on line washing with de-mineralized water**
- **On line washing every 3rd day with detergent**
- **Off line washing every two weeks with detergent**

FIFTH SURGE

On May 1, 2010 at 1000 hrs, DCL Complex tripped carrying 69 MW. The GT "Surge Protection" operated, Physical surge was experienced characterized by loud noise and high vibration. Grid frequency at the time of this happening was 49.0~49.01 Hz; however the surge event was not initiated by any disturbance on the grid.

Subsequent to the trip, air intake filter house was inspected for damages but none was found, the filter elements were intact. Delta P across the filters was ~3.5 mbar prior to the surge event, indicating the filters were not chocked.

On May 2, 2010 bore-scope inspection from the compressor inlet end was carried out revealing several cracks on vanes of the 2nd stage ring. Inspection of the turbine last stage was carried out but nothing abnormal observed.

The bore-scope results were sent to SIEMENS, who advised not to start the machine; further recommending bore-scope inspection of the vanes of 4th stage, which was carried out on May 4, 2010, during that inspection, further damages were found on vane stage 2. At this point Siemens recommended

to open the compressor for root cause analysis.

In their rehabilitation proposal, SIEMENS have suggested replacement of all compressor stationary vanes and rotor blades with new and coated blades including 45 vanes of the IGVs to avoid corrosion and subsequent degradation of the compressor which results in surge. The issue of cracks at the hook of the stationary vanes is still unsettled, SIEMENS admits that this is a known issue and it has been solved by an improved design.

In mean time, DCL and Siemens air intake supplier were engaged in lengthy discussions on improving the air intake system with the aim to reduce ingress of salt on to the compressor and turbine blades. The air intake supplier recommended certain modification in the existing filter house which was endorsed by Siemens. As per their joint recommendation, the first barrier of coalesce filter will be replaced by what is called GT Dua filter which is a combination of coalescer and pre-filter. The original pre-filter and fine filter will be retained as 2nd and 3rd barrier. Moreover, a mist eliminator upstream of the three filter barriers would be installed on the weather hood of the filter house.