USAID ENERGY POLICY PROGRAM

VISIT REPORT - JUNE 19, 2011

GUDDU THERMAL POWER STATION

June 2011

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Visit Report
Guddu Thermal Power Station
GTIP
June 19, 2011

Ghulam Abbas and Michael Gembol visited Guddu Thermal Power Station (GTPS) on June 14 -15, 2011, to discuss FARA work with the plant management. The CEO of GENCO-2, Aslam Shaikh, was recently promoted into that position from Chief Engineer at Jamshoro TPS. We also met with Hidayat ullah Shaikh, Plant Manager of GTPS Units 1-2; Zafiq, Plant Manager of GTPS Units 3-4, and Nadeem Ahmad, Plant Manager of the Siemens CCGT Block 1, comprising GTPS Units 11-13.

The overall impression of these discussions is that these managers are dedicated professionals, intensely focused on the issues of the day, working as an interactive team. All were eager to answer questions and share ideas.

CCGT Block I FARA 1A

Under FARA, GTPS had planned an $18 million rehabilitation of the GE CCGT Block IIa comprising GTPS Units 5,7, and 8. After negotiating with GE for a year over pricing, GTPS has rejected the GE proposal and decided instead to request USAID approval to assign the funding as FARA IA to rehabilitate CCGT Block 1. It now appears that Block I is in more need of rehabilitation than Block IIa, so the expected improvement in efficiency and capacity will be greater and the return on the FARA investment will be higher.

GTPS Units 11 and 12 are 18-year old Siemens V92.4 combustion turbines, each designed to produce 136 MW at 32.1% efficiency. Due to normal wear and tear, the units have deteriorated since their last overhaul to about 85 MW capacity and 24.4% efficiency for Unit 11; 51 MW capacity at 24.4% efficiency for Unit 12. The two CTs exhaust to a heat recovery steam generator that produces high pressure steam for a single Siemens steam turbine, Unit 13. That turbine's design capacity is 143

MW at 44% efficiency. In that configuration, known as Combined Cycle Gas Turbine (CCGT), the steam turbine runs on the exhaust heat from the combustion turbines and does not require any additional fuel, so its output increases the overall efficiency of the 3-unit block to about 47.63%, with a total capacity of 415 MW. The steam turbine has also deteriorated and now produces about 58 MW at 34.69% efficiency. Block 1's total capacity is now only 194 MW at 41.69% efficiency. GTIP estimates that the overhaul can return the units to full design load and efficiency, recovering 221 MW of capacity and 5.94% efficiency.

For economic evaluation of this FARA rehabilitation, the improvement in efficiency will save about $6.5 million/year and the improvement in capacity will be worth about $985 million to the general economy, taking the economic value of electricity at 60 c/kWh. At the average collected tariff, about 8 c/kWh, the value of the recovered capacity would be worth about $13.5 million/year.[1] Taking the latter number as more conservative, the total savings will be about $138 million/year. With the cost of the overhaul annualized at the national discount rate of 14.5%, the Benefit/Cost ratio for the FARA funding is 39:1, an extremely favorable result.

When the savings per year are so extraordinarily high, the overhaul costs are recovered in less than 2 months of operation. This suggests that the overall management of the sector has been poor. The GENCO has had to depend on PEPCO or MWP for funds to schedule an overhaul.

Block 1 operates on a mix of low-BTU gas from several fields, including KaldhKot and Mari fields. While Pakistan pipeline gas runs about 935 Btu/SCF, the gas to Guddu runs about 744 Btu/SCF. The gas is now priced at about $4.47/MMBTU.

NEPRA is not maintaining any semblance of proper capacity payments to the GENCOs. The units all receive capacity payments for their official derated capacity. In the case of GTPS Block 1, that is 355 MW, so GENCO-2 receives 187 Rs/kW-mo for that capacity. Since the actual current capacity of the units is far below the official derated capacity, GENCO-2 is receiving excess capacity payments. However, GENCO-2 is not receiving the full cost of fuel. The NEPRA fuel tariff is based on a test conducted in 2006 under artificial test conditions. Block 1 today has deteriorated and is operating under varying day-to-day and seasonal conditions that reduce its efficiency to well below the official NEPRA heat rate. Fuel tariff adjustments also lag well behind the rapid fuel price increases of recent years. The combined effect of these tariff mismatches is that they partly offset each other. However, the value of adding capacity in this confused tariff regime is indeterminate.

Another major issue for the proposed FARA 1A is the method of contracting. OEM work is preferred in general; however, Siemens estimates for the Scope of Work are considered high compared to former outage costs and estimates. We reviewed the Scope of Work provided by Block 1 management. It has many items dependent on findings when the turbines are opened: "replace if

[1] The actual tariff increase to GENCO-2, however, would be only the variable O&M cost based on the NEPRA Variable O&M tariff of 0.06990 Rs/kWh, or about $1.4 million/year. Another approach is to value capacity addition at the incremental cost of new capacity, which would be about $1.5 million per MW, so the value of the recovered capacity is about $160 million, which can be annualized at 14.5% discount factor to about $27 million/year. The value of a capacity increase under the NEPRA tariffs is indeterminate.

required", "repair if required", "adjust if required". On a fixed-price contract, the contractor must protect himself by bidding enough contingency for emergent work. Another contractor with a lower bid might be inclined to stretch limits to avoid emergent work. GTIP recommends two possible solutions:

1. Define a tight Scope of Work under a fixed cost lump sum contract. Set aside a reserve fund for emergent work to be done on a time and materials basis. The reserve fund may be provided by USAID if allowed under FARA rules or by the GENCO.

2. Recognize that the Benefit/Cost ratio for recovered performance will be 39:1 and take the contract with the strongest assurance of quality work, which is probably the offer from the OEM.

Another serious issue, however, is availability of contracted workers. GTPS must ensure the work can be completed before summer peak 2012. This must be absolutely certain, with contracted sureties from the contractor.

GTPS Units 1-2

These units were built by the Czechoslovakian company, Skoda, in 1974, so they are now 37 years old. Both were designed for 110 MW with 36% efficiency. Unit 1 now reaches 85 MW with 25% efficiency; Unit 2 reaches 60 MW with 24% efficiency. Both burn mixed low-Btu gas.

The major work item for Units 1-2 is to upgrade the burners to handle the larger volume of low-BTU gas. This is limiting the fuel flow into the boiler, resulting in about a 20% reduction in capacity, or 42 MW. Other deterioration accounts for the some of the rest of the capacity loss: turbine blade wear, air heater and duct leakage, air preheater fouling, and cooling tower deterioration.

However, normal deterioration cannot account for the total efficiency and capacity loss. The GTIP team may have uncovered a major performance problem. The station reported some problems with the FD and ID fan motors tripping on overload. The plant assumed the problem was flow restrictions. That does not make good engineering sense, as the load actually decreases on a motor when gas flow is impeded at either the inlet or the outlet side. We suspected a problem with the boiler airflow control system. On older boilers like Units 1-4, airflow is often managed by a proportioning system using the fuel flow volume as the primary input. Since low-Btu gas has about 20-25% higher volume per unit of heat input, that would cause the FD fans to provide 20-25% higher total boiler airflow than required. Since the load on the FD fans increases as the square of the airflow, that would require 56% more load on the FD fans and about the same on the ID fans. That would explain why the fans have been tripping on overload when the unit was operating well below full load and why the auxiliary load has been running about 10% instead of the design 7%. That amount of unneeded airflow and associated leakage would cause a decrease in efficiency of several percent in addition to the auxiliary load loss.

On investigation, we found that all the excess O2 sensors in the backpasses of Units 1-4 were out of service. The plants were relying on excess air measurements performed by lab technicians *once a week!* And those readings were 37% on Unit 2 and 43% on Unit 3! Excess air readings should be

under 10%, corresponding to excess O2 readings under 2% for a gas-fired boiler! This would tend to confirm that the control system was not properly modified for low-Btu gas. It also exposes points out management, engineering, supervision, operator training, and record-keeping problems at the station. Boiler airflow is a primary parameter for a boiler, with major implications for efficiency, capacity, and safety. The proposed Performance Monitoring Units are intended to ferret out inconsistencies of this nature, comparing real measurements with theoretical measurements and then attempting to account for the differences.

The excess O2 sensors (zirconium oxide cells) on these boilers should be repaired immediately. This should result in an immediate improvement of several percent in the efficiency and perhaps 10-30 MW of capacity on all 4 units, depending on the restriction in fuel flow through the burners, which also restricts capacity. These are rough estimates that should be confirmed by thermal modeling. To ensure full safety of the units, the inoperable CO sensors should also be repaired to alert operators if there is incomplete combustion. The control systems should be modified to accept a fuel Btu/MCF adjustment, proportion airflow accordingly, then trim the airflow according to excess O2 recommendations from the OEM.

The total cost to repair or replace the excess O2 sensors and CO2 sensors on all Units 1-4 should not exceed $100,000, with payback probably in less than one week.

Units 3-4

Unit 3 is of Russian manufacture; Unit 4 is Chinese. These units were designed for 210 MW capacity at 35% and 34% capacity, respectively. Today Unit 3 is capable of 150 MW at 24% efficiency; Unit 4 is capable of only 140 MW at 23% efficiency.

Units 3-4 normally run on HSFO; GTPS management is experimenting with 75% mixed low-Btu gas and 25% HSFO. That minimum amount of HSFO is needed for flame stabilization. The result is satisfactory boiler performance with a reduction of fuel cost from over $23/MMBTU to about $9/MMBTU. This enormous reduction in fuel cost should recover some efficiency and capacity and decrease the O&M costs and rate of deterioration of the boilers, as well.

While Units 3-4 have been shut down much of the time recently for load shedding due to their high fuel costs and inefficiency, the switch to HSFO/low-Btu fuel may make it possible to run these units for added years.

The real issue with Units 3-4 is the availability of gas. In the past, SSGC provided 330 mmcfd to Guddu TPS; this has been reduced to 235 mmcfd, partly in response to Circular Debt problems. However, with recent payments, supplies have been increased to 250 mmcfd and more low-Btu gas is available if the GENCO can pay for it. There is a report that 50 mmcfd have been re-allocated to a local fertilizer plant.

Another major question facing Units 1-4 is whether they will still have fuel after a proposed 747-MW CCGT plant is installed at Guddu. The GTIP Team diverted to Lahore to meet with the CCGT project director at PEPCO Thermal Wing to find the expected construction and startup schedule.

The loss of efficiency in these Units 3-4 is costing about $51 million per year, though part of that is being saved because the units are shut down frequently for load shedding.

Plant Tour

Michael Gembol made a quick tour of Units 1-4 for general impressions. All four units were serviceable; Units 1 and 4 were shut down for lack of gas. Unit 2 was running at 50 MW, Unit 3 was running at 130 MW and load was being increased with expectation to reach 150 MW. The GTPS management was congratulating workers on getting the station above 900 MW for the first time in over a year, yet with some units off line or limited by gas supply from SSGC.

These are old units provided by then-Socialist bloc countries. There are no frills. Some digital instrumentations and indicators have been added. The control cabinets are hard wired. Data is recorded on paper strips. Control room display panels have small instruments and recorders that are too small to be read from the supervisor station or from adjacent panels. There is some attempt at mimic bus layouts, but this is not very successful. Operators have to rely on rote memorization to identify patterns in the displays. The whole control room layout would benefit from a digital controls retrofit. The issue is whether the age of the units, cost of fuel, and supply of fuel would warrant that investment.

Control room operators were attentive and responsive. Discussing excess O2 instrumentation, the shift supervisor on Unit 1 and 2 was at a loss, though the shift supervisor on Unit 3 and 4 was familiar with the parameter and quickly produced the lab reports. In the GTIP Team judgment, though, the operators were not familiar with proper airflow, unable to recognize a serious efficiency problem, and the management supervisors had also failed to recognize a long-standing problem with deep effects on the efficiency and capacity of the units. These are smart and attentive people; the problem lies in lack of training and simulator operations. Also, a Performance Monitoring Unit would certainly have tracked down the cause of the efficiency problems. It is entirely possible that the GTIP Team, acting on just a few pieces of information, has jumped to a wrong conclusion about boiler airflows. That will have to be verified before any radical changes are made. However, the need for training is undeniable.

Operators in the plant suffer from the heat. With temperatures around 45 degrees, plus heat from operating equipment, plus radiant heat from hot pipes and ducts, this is a brutal place to work. The plant could use some additional personal fans and water coolers with electrolyte dispensers.

As stated, working conditions are brutal and do not encourage workers to do extra work over bare minimum requirements. However, there is a general appearance of neglect and poor repair on these units. Nooks and crannies are packed with dirt. Crumbled insulation rests in piles. Nothing shows signs of washing, wiping down, or painting.

A few instrument enclosures have been left open, exposing electronics to dirt and moisture and, one Units 3 and 4, to flue gas with high sulfuric acid levels. These sloppy habits will cost reliability eventually. Insulation has been damaged and not repaired. In places, oil has soaked into the insulation and into piles of dirt and loose insulation, creating a moderate fire hazard. Gauges do not show signs of calibration work.

There are positive signs, too.

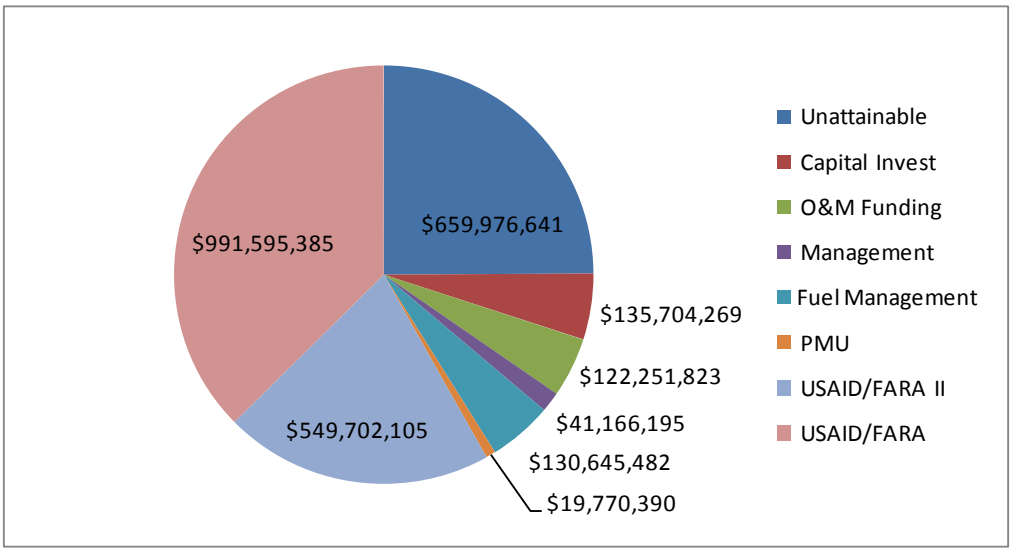
The turbine halls are well kept. The control rooms were clean and essentially all instruments were in service, suggesting the technician crews are keeping up despite short funding. There is little sign of steam or water leakage other than normal vents from drain collectors. The grounds and laydown areas were proper. For 37-year old units, the overall impression is not at all bad, though there are some loose standards in evidence.

The GTIP Team did not tour the newer CCGT blocks.

Attainable Improvements Analysis

The GTIP Team collected performance data on all the Guddu units, including estimates and calculations of the improvements that can be made by FARA work. The data is being factored into a study called an Attainable Improvements Analysis, which will be provided by separate report to USAID. The Attainable Improvements Analysis attempted to document the present performance condition and the design performance rating of each GENCO unit for efficiency, capacity, and reliability. Then, GTIP made reasonable for improvements that would result from several initiatives, including FARA, possible additional FARA work, establishment of Performance Monitoring Units, fuel switching, and the proposed private O&M Contracts. Putting all these estimates in one framework puts them in perspective, prevents the totals from exceeding 100% of what is possible, and supports decisions like FARA funding and private-sector O&M contracting.

This pie chart shows the overall attainable improvement at Guddu TPS. The wedges show GTIP estimates of the improvement attainable by each proposed activity.



Values are based on reductions in fuel costs due to improved efficiency and on the value of increased capacity using the economic value of generation at 60 c/kWh.

The pink wedge, USAID FARA, refers to the proposed overhaul of CCGT Block I, Units 11-13. The light blue wedge, USAID FARA II, shows the GTIP estimate for attainable improvements by a proposed set of rehabilitation measures at Units 1-4. The red, green, and purple wedges show improvements that might be obtained through a private-sector O&M Contract, assuming that the contractor would make investments to overhaul the two GE CCGT blocks, Units 5-10 and make other improvements in station management and O&M funding and effectiveness.

The pie chart shows that, together, the FARA 1a and proposed FARA II activities will recover almost 2/3 of what is attainable.

FARA Considerations

A simple overview of the Guddu units is that the best use of the initial FARA funding has now been identified for rehabilitating Block 1, Units 11-13. Additional funding is certainly warranted at Units 1 and 2, which are burning inexpensive gas that cannot be sold by pipeline. If Units 3 and 4 can operate continuously on 25% HSFO and 75% low-Btu gas, they are worth limited investments to

keep them in service, especially as some other units are forced to burn expensive furnace oil, or other gas turbine units are forced to shift to HSD or to expensive LNG or comparably priced domestic gas. Despite their age, burning 75% low-BTU gas, Units 3 and 4 will be less expensive to operate than the Muzaffargarh units on HSFO or the Jamshoro units on Kunnar Pasakhi gas.

All this changes, though, if a planned 747 MW CCGT plant is installed at Guddu. Commissioning could be as early as August, 2013, according to the GM Thermal at PEPCO, Rafiq Butt. This unit would take the entire available supply from Kandhkot Field at about 822 Btu/SCF, leaving insufficient gas to run the steam units at Guddu and probably restricting the CCGT units. Despite the improvement in efficiency of a new CCGT unit, the value of the investment has to be discounted for the loss of service life of 440 MW of capacity at GTPS units 1-4. The plant will be financed by HSBC and the China Export Bank. Final approvals are not yet given; the 2013 date looks exceedingly optimistic. Obviously, there is sufficient experience building CCGT plants at Guddu, but there is also a severe shortage of infrastructure to support the construction work. Roads are jammed and in poor repair; security is an issue. The GTIP team would base its recommendations for more FARA funding on at least 3 years of continued service for Units 1-4, not on 2 years.

End of Report

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