The Afghanistan Engineering Support Program assembled this deliverable. It is an approved, official USAID document. Budget information contained herein is for illustrative purposes. All policy, personal, financial, and procurement sensitive information has been removed. Additional information on the report can be obtained from Firouz Rooyani, Tetra Tech Sr. VP International Operations, (703) 387-2151.

USAID | AFGHANISTAN
FROM THE AMERICAN PEOPLE

ENGINEERING SUPPORT PROGRAM

WO-LT-0070 AMENDMENT 3
Tarakhil Thermal Power Plant Site and Power Block "B" Control Assessment

Final Report

April 22, 2014

This publication was produced for review by the United States Agency for International Development. It was prepared by Tetra Tech, Inc.

This report was prepared for the United States Agency for International Development, Contract No. EDH-I-00-08-00027-00, Task Order 01, Afghanistan Engineering Support Program.

Principal Contacts:

[redacted]
VP International Operations
Tetra Tech, Inc.
Washington, DC
[redacted]

[redacted]
Senior Vice President
Tetra Tech, Inc.
Framingham, MA
[redacted]

[redacted]
Technical Support Manager
Tetra Tech, Inc.
Framingham, MA
[redacted]

[redacted]
Chief of Party
Tetra Tech, Inc.
Kabul, Afghanistan
[redacted]

April 22, 2014

[redacted], COR
[redacted] ACOR
Office of Economic Growth and Infrastructure (OEGI)
U.S. Agency for International Development
Great Massoud Road
Kabul, Afghanistan

Re: Afghanistan Engineering Support Program (AESP)
WO-LT-0070 Amendment 3, Tarakhil Thermal Power Plant Block B Controls Assessment
Final Report

[redacted]

Please find enclosed our final report for the Tarakhil Thermal Power Plant Power Block "B" Controls Assessment. This report describes the findings and recommendations resulting from an on-site operational evaluation and troubleshooting conducted at Tarakhil on February 18, 2014 through March 11, 2014 by a specialized controls team from the Afghanistan Engineering Support Program (AESP). Ongoing operability and controls issues have prevented all six Power Block "B" diesel generators from providing power to the grid.

The Power Block "B" control problem was resolved by installing a patch to the power block Programmable Logic Controller (PLC). The team also resolved some other control issues and performed a general mechanical and electrical assessment of the plant. Currently 15 of 18 generators are fully operational with a plant capacity of 88 MW. One additional generator could be made operational by commandeering a part from another out-of-commission generator.

Included in the Appendices of this report are the Daily Troubleshooting Activity Log and an Outbrief Memo dated March 12, 2014. These documents were previously submitted under a separate cover. This report also includes a recommended scope of work for follow on corrective action.

Please contact us at your convenience should you have any questions or comments regarding this report.

Respectfully,
Tetra Tech, Inc.

[redacted]

Chief of Party (AESP)

cc: [redacted],

AFGHANISTAN ENGINEERING SUPPORT PROGRAM

WO-LT-0070
Amendment 3
Tarakhil Thermal Power Plant Site Visit and Power Block “B” Control Assessment

Final Report

April 22, 2014

EXECUTIVE SUMMARY

This report provides the findings of an on-site operational evaluation and troubleshooting of the Tarakhil Thermal Power Plant (TTPP), conducted from February 18, 2014 through March 11, 2014 by a specialized controls team from the Afghanistan Engineering Support Program (AESP). The evaluation and troubleshooting was requested by USAID to resolve ongoing issues with the Power Block "B" control systems. These ongoing issues prevented all six-diesel generators in the power block from providing power to the grid.

During the AESP team's three weeks on site, the power block operability problem was resolved by installing a permanent patch to the Programmable Logic Controller (PLC). The team also resolved some other control issues and performed a general mechanical and electrical assessment of the plant. Currently 15 of 18 generators are fully operational with a plant capacity of 88 MW. One additional generator could be made operational by commandeering a part from another out-of-commission generator.

The team observed that the plant's mechanical and electrical condition was good. Senior staff operational and maintenance knowledge was also good, considering the amount of operational experience they had with the plant. Nonetheless the AESP team observed a number of problems with control systems at the plant. These control system problems were beyond the capability of plant staff to troubleshoot and correct. It should be noted these problems were complex enough that had they occurred at a plant elsewhere in the world, outside consulting services would likely have been required to correct them.

The AESP team recommends that additional work be completed at the plant, including:

- Purchasing of various spare parts;
- Development of a power supply management system for generator control computers;
- Development of a training program, including mechanical maintenance training and potentially a long-term operations and maintenance training contract;
- Obtaining a copy of the PLC software source code, to facilitate troubleshooting and plant upgrades;
- Upgrade of generator SCADA control software and hardware;
- Troubleshooting and validation of switchyard control software;
- Implementation of a SCADA version control and backup system;
- Development of an error code master list to facilitate plant operations;
- Improving grid stability in general through upgrades to other generation and distribution components such as hydro-electric governors;
- Adding additional key staff to the power plant organization;
- Implementing a computer-based technical library and asset management system; and,
- Improve internet connectivity at the plant.

Beyond this report, AESP is currently developing a detailed scope of work to complete most of the above described follow-on work. Full details of the completed operational evaluation and troubleshooting and recommended follow-on work are presented herein.

TABLE OF CONTENTS

LIST OF FIGURES

APPENDICES

1.0 BACKGROUND

The Tarakhil Thermal Power Plant (TTPP) located in Kabul, Afghanistan, is owned and operated by Da Afghanistan Breshna Sherkat (DABS). The maximum capacity of the power plant is 105 Megawatts (MW). The power plant is designed with three independent power blocks, each with a nominal output of approximately 35 MW. Each power block is equipped with six Caterpillar CM series model 16CM32C diesel engine generator sets with turbochargers. Power is generated at 11,000 volts (11 kV) and passes through step-up transformers that feed it to the public grid at 110,000 volts (110 kV). The plant was built in 2008, with generator acceptance testing conducted in June of 2008.

The engines and support systems are designed for base load operations; operating 24 hours/day, 7 days/week. Due to economic pressures, the plant is being operated as a peaking plant, only operated to provide peak kW support during times when the Afghanistan hydroelectric resources are low, during line maintenance, or during times when the North-Eastern Power System (NEPS) connection line is at or near capacity. Based on review of run-hour logs included in Appendix A, the plant is being dispatched at 2.6% of its MW capacity.

This report provides the findings of an on-site operational evaluation conducted at the request of USAID to determine current conditions at the TTPP, specifically identifying problems with the Programmable Logic Controller (PLC), as well as the operation and other control issues in Power Block “B” (Block B). The evaluation team was deployed for three weeks to the project site to review the design specifications, current plant operations, and outstanding issues. The assessment team consisted of a US-licensed professional engineer with power plant experience and an embedded controls/software engineer with PLC troubleshooting equipment. The team provided an out-brief memo to USAID (Appendix B), and kept a contemporaneous account of daily troubleshooting activities (Appendix C).

There have been two previous USAID-funded studies at TTPP. The first was WO-LT-0036, The Tarakhil Operational Power Plant Evaluation conducted in June of 2011. The mentioned evaluation reviewed operations and maintenance (O&M) practices, and assessed the feasibility of using Heavy Fuel Oil, a more economic fuel source. The second was WO-A-0079, a Tarakhil O&M cost estimate, providing an estimate of costs for a 3-year O&M contract at the plant.

2.0 POWER BLOCK “B” DEFICIENCY ASSESSMENT

The assessment team mobilized to investigate the power plant deficiencies due to Block B engines (Genset) not starting and aligning to the power the grid.

2.1 POWER BLOCK “B” PROBLEM STATEMENT

Block B engines are locked out from starting.

Block B consists of 6 engines rated at 6 MW each, connected to a common bus by individual generator breakers (Figures 1, 2). The generator bus connected to a Generator Step-Up Transformer (GSUT) via a breaker.

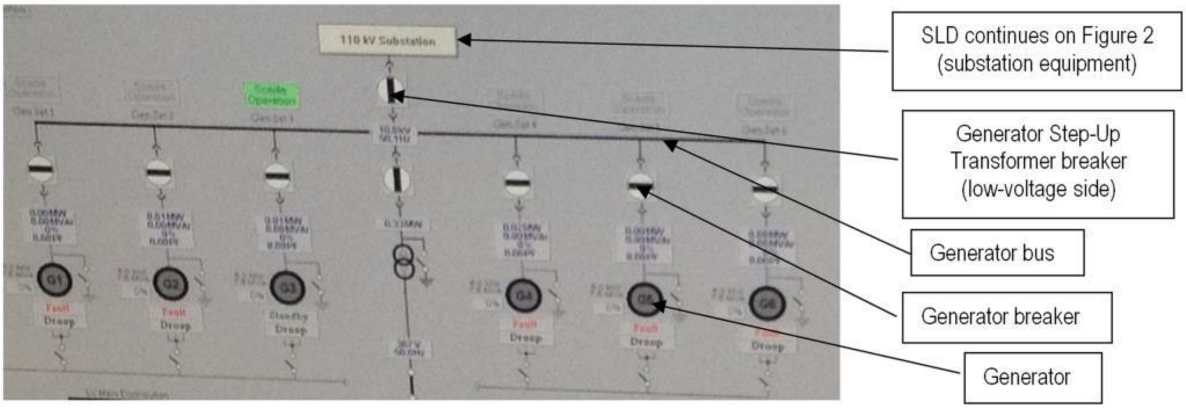


Figure 1: SLD of Generators and Generator Bus

The GSUT is connected to the grid via the following (in series, beginning with the 110 kV side of the transformer):

- A dry disconnect switch (Q9)
- An SF6 breaker (Q0)
- Disconnects Q1 (connecting to Afghanistan hydro power) or Q2 (connecting to import power). These disconnects are interlocked to prevent simultaneous connection to domestic and import power, and were verified to operate correctly.

The Block B engines will not start (in normal mode, by design) unless the generator bus is powered. The generator bus cannot be powered because breaker Q0 will not shut.

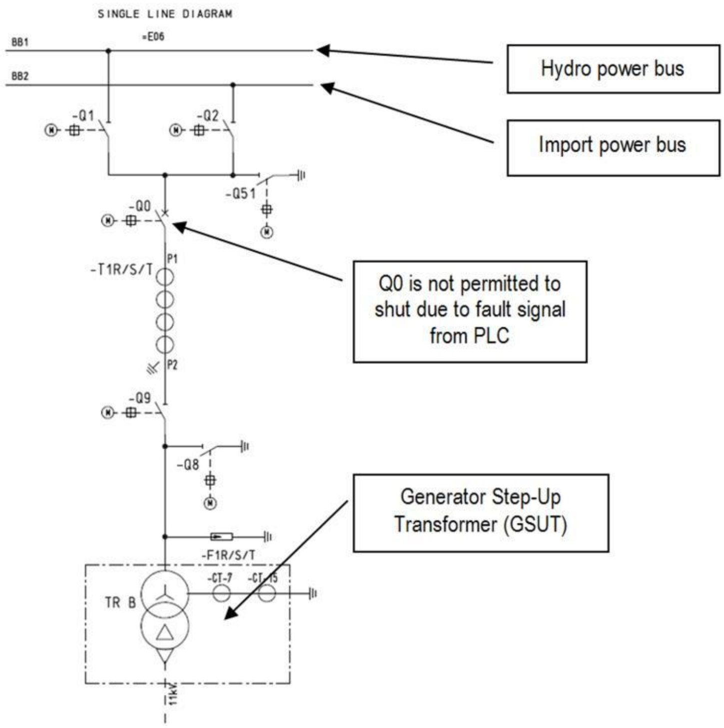


Figure 2: SLD of Switchyard Equipment

Breaker Q0 is receiving a fault signal (“Transf external protection trip”) from the Block B PLC (Programmable Logic Controller). This output was confirmed to come from the GSUT protection panel relay K9. It was confirmed by removing relay K9 and observing the signal clear at the PLC. Of note, the PLC still sends a fault signal to breaker Q0 itself, preventing Q0 from shutting. Removing relay K9 by itself, will not allow Q0 to shut.

The Block B PLC is also sending "Generator Step-Up Transformer: C.B. Not Released" and "Sta Transf MV C.B. Not Released" signals to the GSUT and the Station Transformer.

2.2 PROBLEM HISTORY

The Plant Manager related that the plant operated properly until approximately November 27, 2012. At that time Block C SCADA began to alarm, followed days later by Block B SCADA, then days later Block A SCADA.

After unproductive troubleshooting by DABS technical personnel, Caterpillar was called to repair the SCADA. Caterpillar provided software and a programming unit to install the software to the PLC units. During the time the PLC was inoperative, the power blocks were operated manually.

The last time Block B gensets powered the grid was April 23, 2013. Because of spring demand lull, no power was demanded from the station after that.

On May 19, 2013, the provided software was loaded onto all PLCs.

On June 4, 2013, none of the Block B gensets would start, either manually or automatically. The alarm "Start Blocking" was observed, and the 11 kV GSUT breaker would not shut manually (or automatically). Afghanistan Engineering Support Program (AESP) was asked to assess the plant in early February of 2014, and the assessment team arrived on site Tuesday, February 18, 2014.

2.3 PROBLEM RESOLUTION

After days of troubleshooting, the AESP team de-compiled PLC code and observed a software bug that prevented Q0 from being reset. The team patched the code, installed it on the PLC, and observed proper operation of Block B gensets, including powering the grid as designed.

Ongoing communications with Caterpillar and Woodward to obtain copies of the PLC source code have been fruitless; Woodward to date insists the code is their intellectual property, and will not release it.

3.0 OVERALL ENGINE ASSESSMENT

The team assessed the material condition of each power block gensets (Figures 3, 4, 5). The condition was generally good, with evidence of good housekeeping practices and periodic preventative maintenance. This was to be expected given the young age of the plant..

Figure 3 Block B Gensets

Figure 4: Block B Genset Head Covers

A summary of the plant's run-hour report is attached as Appendix A. Of note, the gensets run, on average, 2.3% of the time. The team observed that the engines were generally run in the evening, for only a few hours, to augment import or hydro power. The frequent starts and stops will accelerate wear on the engines. Moreover, because the plant is not operated at steady state for long periods of time, the staff takes much longer to gain operational experience.

Figure 5: Genset B1

Balance-of-plant equipment (lube oil, air, fuel oil systems and the like) was also assessed in good condition, with evidence of good housekeeping practices and periodic preventative maintenance (Figures 6, 7). During Power Block B light-off, the team observed some equipment that failed to start or operate correctly. We believe this is due to the infrequent operation of the power block and plant. Specifically, on light-off of Power Block B on March 1, 2014, the team observed:

- Faulty viscosity sensor on Genset B1 (Figure 8); requires replacement.
- On Genset B3, several fuses blown in fuse block F5; still require replacement.
- Genset B2 HT cooling water pump #1 breaker failed; replaced from spare inventory.
- Various loose connections in several gensets; tightened.
- Genset B6, starting air shut off valve sensor inoperative; cleaned and reinstalled.
- Genset B3 and B5, main breaker for automatic voltage regulation showed open when actually shut; cleaned contacts.
- Dirty air distribution filters on Genset B3 and B6; cleaned.

The staff's ability to conduct minor repairs was good; we observed the staff repairing a leaky fuel pump gasket and correcting the light-off deficiencies observed above.

Discussions with the Plant Manager revealed some concerns about the plant staff's ability to conduct more complicated periodic maintenance. Although some of the staff had been trained through an operations and maintenance contract executed by Black and Veatch, many of the staff were new hires, and did not have any maintenance training. This lack of training increases the risk of component failure due to improper or infrequent maintenance. In general, senior plant staff has an excellent knowledge base, but junior operators and maintainers are not trained and lack experience.

Figure 6: B1Fuel Oil Equipment Skid

Figure 7: Lube Oil Pump Skid
(Note: Evidence of generally good Material Condition and Housekeeping

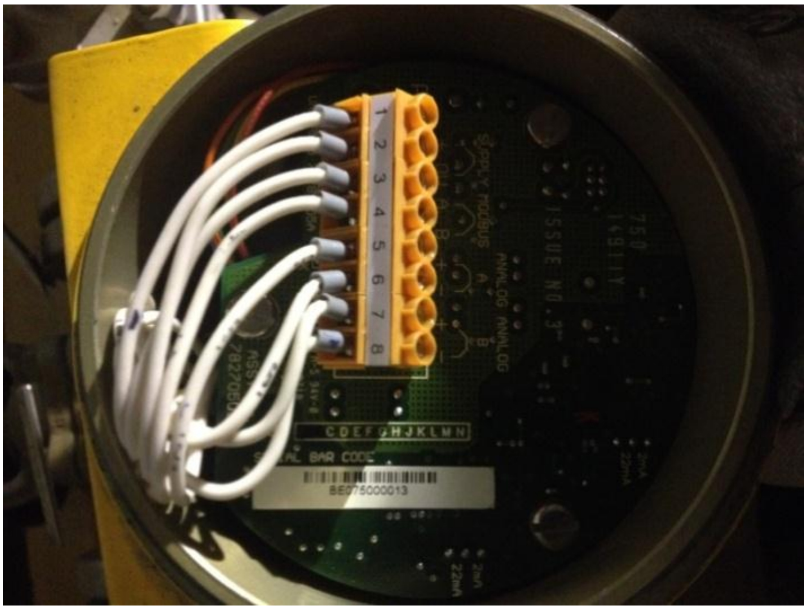


Figure 8: Faulty Viscosity Sensor on Genset

4.0 OVERALL SWITCHGEAR ASSESSMENT

As with the engines and balance-of-plant, the team assessed the material condition of the electrical switchgear in the switchyard (Figures 9, 10, 11,12). The condition was also generally good, with evidence of good housekeeping practices and periodic preventative maintenance. The Plant Manager was also very focused on safety, and did an excellent job enforcing safety rules at the plant and in the switchyard.

The team observed breakers in the switchyard tripping several times due to grid instability. The frequent cycling of breakers and associated switchgear components will accelerate wear and reduce component lifespans.

Figure 9: Open Disconnects from Hydro Power Bus To Switchyard

Figure 10: Closed Disconnects from Import Power Bus to Switchyard

Figure 11: Breaker Q0 in Switchyard

Figure 12: Generator Step-Up Transformer in Switchyard.

5.0 OVERALL CONTROL SYSTEM ASSESSMENT

The team assessed the control systems in the plant and switchyard, and observed software issues in several of the systems.

5.1 CONTROL SYSTEM DESCRIPTION

Generators are controlled by a Woodward control system. The system allows startup, shutdown, and parameter adjustment either locally (in the power house) or remotely (in the control room). The team observed problems in both operating modes.

Components in the switchyard are controlled by an Areva control system, which allows operation of components from inside the switchyard (Figure 13) or from remote terminals (Figure 14) inside each power block.

Figure 13: Areva Local Control Interface

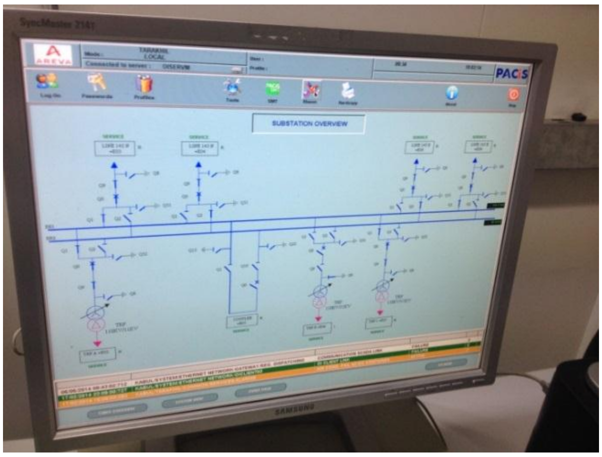


Figure 14: Areva Remote Control Interface

5.2 LOCAL GENERATOR CONTROL ISSUES

The generator control software runs on a small industrial computer (Figures 15, 16) in the generator control panel, inside the power house. This industrial computer can be controlled locally via a human-machine interface (HMI), or remotely, through network connections to the control room computers. The control software is run on Wonderware, running in Windows XP.

Figure 15: Local Generator Control Computer

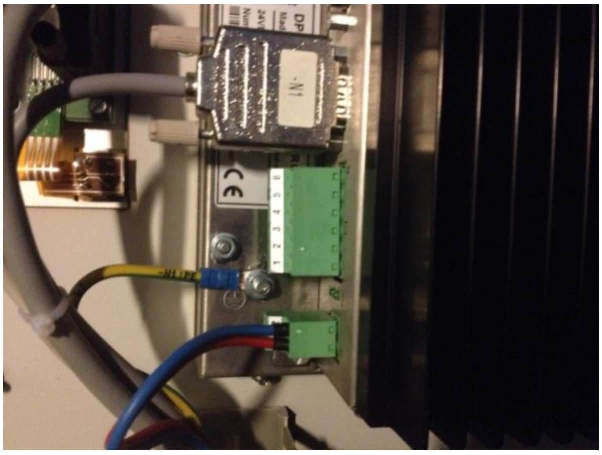


Figure 16: Power and Interface Connections for Local Control Computer

The industrial computers are hard-wired to their power supply, with no startup or shutdown protocol. Although they have a battery backup power supply (uninterruptible power supply, or UPS), the backup only lasts a matter of minutes. Because of grid instability, there are frequent outages that exceed the battery's capability, affecting the control computers. These outages cause a loss of power to the industrial computer without a proper shutdown of Windows. Over time, we believe the improper shutdowns caused file corruption and a failure of the Windows operating system in some of the computers. We believe it also caused a hardware failure in one of the genset HMI's.

To recover from the file corruption, the plant's procedure is to copy ("image") working software from a working industrial computer onto the faulty computer. Plant operators have experienced difficulty imaging to some of the computers, but the team provided better imaging software that was proven to work on all industrial computers in the plant. The power outage problem remains, however, and we

Figure 17: Faulty MPU-2S Multifunction Relay

Figure 18: Faculty PCK-4 Gateway

believe it could lead to hardware damage in the future. According to the Plant Manager, the software becomes corrupt and requires re-imaging every 2-3 months.

In addition to the industrial computers, each genset control panel contains a programmable multifunction relay (part # MPU-2S)(Figure 17). Two of these relays are currently inoperative and prevent starting of their associated gensets (A5 and C1). When they are replaced with a relay from a different genset, the genset operates correctly, so it is reasonable to assume the problem is with the relay. These relays can be programmed by hand, entering values using a button; or with a computer, connecting to the relay with a special cable. The power plant does not have this cable, so the team programmed the relays by hand, but was unable to make them work. We believe that either the relays are faulty, and require replacement, or there are additional programming steps that require the use of the cable.

Finally, each genset also contains a “gateway interface converter” (part # PCK-4) (Figure 18). This converts between communication protocols within the control system. One of these converters is currently inoperative and prevents starting of its associated genset (A6). It requires replacement

5.3 REMOTE GENERATOR CONTROL ISSUES

Normal generator operation is remotely controlled from the control rooms. There are three control rooms; one per power block, and they are connected via network so that any power block can be operated from any control room (e.g. Block A could be operated from Block C’s control room). The preferred operational mode is to operate all power blocks from the Block B control room because of its central location.

The power block SCADA (Supervisory Control and Data Acquisition) software was coded by Woodward, and runs on desktop computers in the control room, on Wonderware, running in Windows XP.

Currently, power blocks cannot be reliably operated from control rooms other than their own (e.g. Block B can be controlled from the Block B control room, but not from Block C’s or Block A’s control room). We believe this is due to corrupt SCADA (Supervisory Control and Data Acquisition) software installed in Block B. The Plant Manager related to us that after experiencing software problems with the SCADA in Block B, DABS IT staff deleted the Block B SCADA and replaced it with an image of the Block A SCADA. We believe that the inconsistent and unreliable control response observed when trying to control a power block from a different control room is due to communication crosstalk. The system appears to behave as though there are two Block A’s, and inconsistently updates information and does not reliably execute commands.

5.3.1 Switchyard Control Issues

The Areva system in the switchyard gives incorrect indications. Specifically, it shows some components closed when they are actually open. The team observed the following erroneous position indications:

- E03 (Line 145 N): Bus Bar Protection #1 shows Q2 shut, but Q2 is actually open
- E05 (Bus Coupler): Bus Bar Protection #2 shows Q1 shut, Q1 is actually open
- E06 (Transformer B): Bus Bar Protection #2 shows Q2 shut, Q2 is actually open
- E09 (Line 145 E): Bus Bar Protection #1 and #2 both show Q2 shut, Q2 is actually open

Of note, each of the disconnects listed above were correctly indicated on other panels. We believe this means it is not a problem with the mechanical position indicators physically on the disconnects, and is instead software-related.

The Areva system also showed various errors on its local panel inside the switchyard (e.g. “isolator/CB error”). With the exception of the faulty indications, the system appeared to work properly in both local and remote operation.

6.0 RECOMMENDED TROUBLESHOOTING AND REPAIR PLAN

The following section discusses outstanding issues and presents recommendations for resolution:

6.1 MATERIAL ISSUES

Although the plant was in generally good material condition, the following recommendations are provided:

6.1.1 Equipment Purchasing

Some equipment requires replacement, and should be purchased as soon as feasible. Also, a programming cable should be purchased to more easily enable programming of multifunction relays. Specific equipment to be purchased includes:

- HMI for genset B1 (Berghof DPC 3110)
- Woodward interface cable kit: #5417-557 (allows easier programming of MPU’s)
- SEG genset control module (at least 4) (Model PCK-4, #8445-1008)
- SEG MPU 2-S (at least 5) (Model MPU2-S-I5-U4-L, #8440-1123)
- Viscosity sensor (Mobrey Solarton Viscomaster circuit board, from valve type #7829FEANAJB)
- SEG MPU1-F (at least 2) (Model MPU1-F-I5-CAN, #8440-1014)
- CR 1620 batteries (at least 24) for HMI’s
- Backup desktop computers for SCADA

The items are listed in order of priority for purchase.

6.1.2 HMI Power Management System Design and Implementation

The genset HMI’s are also at risk of failure due to power-cycling. Because the existing UPS does not last long enough to protect the system, and because the existing UPS does not properly shut down the software before powering down, we offer the following solution.

An off-the-shelf microcontroller-based device should be utilized, along with accompanying software, to act as a power controller. It would also manage the power supply to the HMI, monitor UPS battery health, and issue shutdown and startup commands when appropriate. A basic outline of the circuit is outlined in Figure 19.

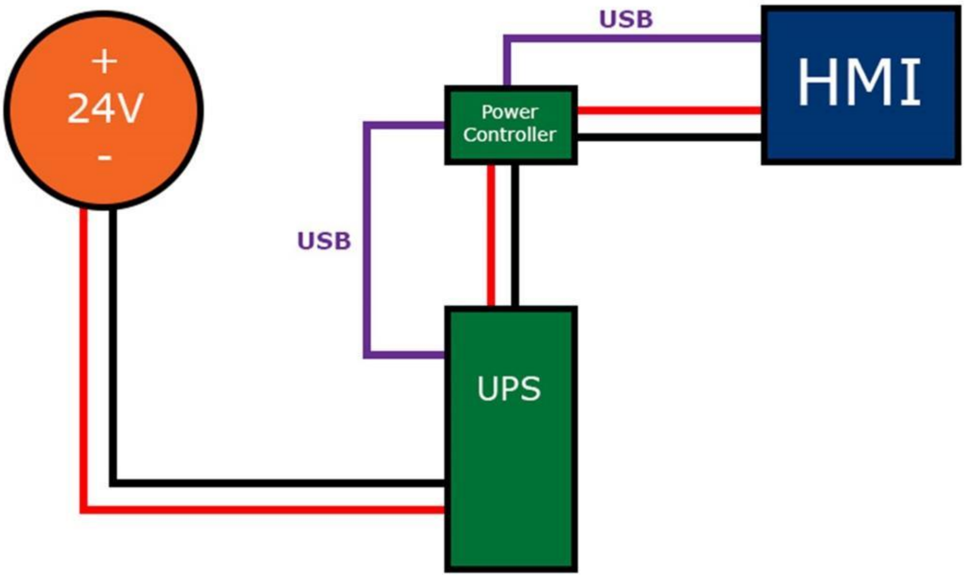


Figure 19: Proposed Power Supply Management Circuit Diagram

A UPS will be used to provide battery backup power to sustain the HMI when power to the station is lost. A power controller circuit will then be designed which acts as an interface between the UPS and HMI. Through USB interface, it will communicate with the UPS to monitor operational status and battery health. When operating on battery power, the power controller would issue an orderly shutdown command to the HMI through the USB interface when remaining battery life reached a specified low value. Corresponding software on the HMI would receive the command and then exit the HMI SCADA application and shut down Windows properly. After station power is restored, the power controller would sense this through the USB interface to the UPS and restart the HMI. In addition to this, the device would provide external controls for turning the HMI on/off properly and hard-power-cycling the unit when necessary.

An existing battery bank is currently in place in the equipment panel for the PLC and HMI. This bank is severely undersized and does not provide status indications, battery monitoring, or interface to the HMI. Research needs to be done to determine whether this existing system can be used as a starting basis for the UPS in the proposed solution, as opposed to a new and separate system dedicated solely to the HMI. Rather than going with an entirely new UPS system dedicated solely to the HMI, it may be preferable to upgrade the existing system and expand its capacity, or create a second battery bank dedicated to the HMI fed from a common charger.

The existing battery bank and charging system does not provide sufficient feedback to plant operators. It does not, for example, indicate when battery replacement or system maintenance is required. The power control unit could also be designed to provide external information about the status of the UPS system. This information could be made available through Windows so that plant operators will quickly become aware of any issues and notified to take action. Because the Windows-based HMI feedback assumes the unit to be online, battery status would be displayed via visual indicators on the device itself, such as LED lights and a single-line LCD screen.

UPS protection is important for PLC operation as well. If a separate, dedicated UPS is recommended for the HMI, it would be recommended that the power controller be designed to interface with both UPS systems so that it may monitor them both and provide that feedback to the plant operators.

6.2 TRAINING ISSUES

Operational knowledge of senior staff was good. Because of the infrequent operation of the plant, it is difficult to gain and maintain proficiency as an operator or maintainer. Additional operations and maintenance training is recommended to continue to build workforce capacity and operational capability.

Ideally, a multi-year operations and maintenance mentoring program would be implemented, similar to the program in place after plant construction. If a long-term program cannot be implemented, consideration should be given to flying some of the maintenance personnel to Dubai for a diesel maintenance school. This training would enable plant staff to better perform the routine periodic maintenance on the generator sets and turbochargers. Plant electricians should be trained on 11kV breaker periodic maintenance, transformer periodic maintenance, and relay setting and maintenance.

Training should also be provided on any software installed in the plant, with focus on restoration after failure, and explaining existing system settings. This software includes the PLC, SCADA, Areva system, and individual programmable elements such as the MPU-2S multifunction relay.

Of note, the training classroom (Figure 20, 21, 22, 23) built and used after the plant was first constructed remains in place, with most of the training equipment inside. This classroom and equipment would facilitate a local training program.

Figure 20: Interior of Training Classroom On Site

Figure 21: Classroom Area

Figure 22: Mechanical Training Workbench

Figure 23: Electrical Training Workbench

The site's technical library contains several training syllabuses, complete with lecture notes and teaching guides. These should be incorporated into a periodic training program for all shifts, conducted by shift leadership

6.3 SOFTWARE AND CONTROL ISSUES

The majority of problems observed by the team were related to software and the control system.

6.3.1 PLC Control Software

As discussed above, the PLC source code is closely held by Woodward, and cannot be easily viewed for troubleshooting. The only software available is the compiled source code, which is in STL, a form of assembly language. Some LAD code is available for higher-level function blocks, but the SCL code, which constitutes some of the most substantial parts of the PLC logic, is entirely missing for critical function blocks. Without the SCL, troubleshooters can only look at the lower-level STL code, which highly limits the ability to debug and make changes to the PLC configuration. Any configuration changes would require contracting with Caterpillar and Woodward, who would then reconfigure their code.

Currently, without contracting with Caterpillar/Woodward, changes to the plant could result in PLC application breakdowns. If any changes are made to the plant, a design change to the PLC circuit would be required, and those would require changes to the PLC application. Moreover, if any particular piece of equipment failed, it could require changing to another model that serves a similar function if a replacement was not readily available. This would also require a program change to the PLC.

There are two options to resolve this issue.

- First, acquire full source code from original designer. The team is currently pursuing this option through Caterpillar and Woodward. Thus far, they have insisted that the code is their intellectual property, and they will not release it.
- Second, do nothing. Any changes to the code would require contracting with Caterpillar or Woodward for a partial re-commissioning.

6.3.2 SCADA Software

The SCADA software runs on Wonderware, on a Windows XP operating system. As discussed above, The Block B SCADA was erased and replaced with a copy of Block A’s SCADA, causing communication problems in the system. The Wonderware/XP software situation is also problematic.

First, the Wonderware software installed is an older version, and will only run on Windows XP, a 12-year-old software package. It does not run on more recent versions of Windows. Also, Microsoft has stopped supporting Windows XP, and no longer sells it. This means when one of the control room SCADA computers fails, it cannot be replaced with a new machine. The solution is to replace the SCADA software with a more recent version of Wonderware, or transition to a different system.

Second, the SCADA system does not operate at full capacity. Because of the deletion of Block B SCADA, and replacement with a Block A copy, the control system behaves inconsistently, unreliably, and erratically when trying to control a power block from a different block’s control room. Absent recommissioning the system, restoration of the SCADA system requires the purchase of a Wonderware developer’s license and rebuilding the Block B code.

New SCADA software should be bought and installed, and Block B’s SCADA restored to proper operation. Other SCADA solutions are available if Wonderware is not desired. During the Block B restoration, the user interface and error coding should be improved to facilitate smoother operations. This installation, restoration, and improvement will require a developer’s license as well as individual licenses for machine running the SCADA software.

6.3.3 SCADA Hardware

There is no backup computer hardware in inventory to replace any failed SCADA components. If a motherboard, hard disk drive, or memory module fails, there are no hardware components in inventory to repair these systems and bring them back online. Moreover, the SCADA system computer hardware is not interchangeable. Each control block's Master SCADA is on a different type of desktop than the individual workstations. If a control block's Master SCADA fails, workstation hardware cannot be used as a replacement.

We recommend maintaining replacement components in inventory. Because the system is over four years old, it is likely that much of this hardware has been discontinued. Consequently, in the case of the Master SCADA systems, we recommend the primary computer components be replaced with newer models, and that several backup components be purchased at the same time for storage in inventory. Components that should be replaced are:

- Motherboard /CPU
- Memory (RAM)
- Graphics cards
- LAN adapters
- Power supplies

Existing chassis, hard disks, and DVD drives, can be preserved.

Alternately, complete new PC sets could be purchased, and their hard disk drives imaged to match the installed computers. These "bench spares" would remain in inventory, and would be used to immediately replace any failed system components.

This problem is also in the Areva SCADA system. There is no backup hardware for any of the Areva systems controlling the switchyard. When upgrading the hardware for the Master SCADA, the Areva SCADA hardware should be upgraded as well and made compatible.

6.3.4 Switchyard (Areva) Software

The Areva system should be troubleshot and validated, and erroneous indications cleared. The system appeared to be well-documented when the team assessed the plant, but there was insufficient time for the team to complete troubleshooting.

6.3.5 SCADA Backup and Version Restoration Capability

The SCADA computer systems that control the power blocks are currently not backed up regularly. As discussed above, problems exist with the SCADA configurations. These problems were caused after various SCADA systems crashed, and plant operators and IT staff copied the hard drive image from a working SCADA workstation and to the crashed system. This has caused SCADA misconfiguration and Ethernet communication issues between power blocks, preventing common control from a single control room.

Each SCADA system also keeps a historical archive of log files. These files are currently recorded on the local computer's hard drive, but not accessed or archived. Eventually these log files will consume the volume of the hard disk and cause the SCADA system to crash due to lack of virtual memory.

A version server and log file archive computer should be configured to maintain a copy of each SCADA system, and to archive the daily log files and clear them from the SCADA hard disk. This system could be automated, or could be done manually. In the event of a SCADA system failure, the failed system could be expeditiously restored to the last working version, by copying from the version server.

6.3.6 Control System Error Codes

Error code documentation for the control system was incomplete. Error conditions on the SCADA were not intuitively named, and operators had difficulty clearing them or troubleshooting their cause. Moreover, error codes could be modified by operators (e.g. changing the name of "Low Lube Oil Pressure" to any text string, such as "Error #1").

A list of all error codes, and the input condition that causes the error, should be developed. This list could be expanded into a troubleshooting guide. It is recommended that such a guide be developed by plant staff as a training tool. Also, when SCADA is restored, operator permission to change error coding should be revoked.

6.3.7 Remote SCADA Monitoring

The team observed that the plant SCADA was not configured to allow remote monitoring. This configuration should be considered when SCADA is restored to proper operation. Remote monitoring would allow DABS or contracted personnel to observe the system and perform basic troubleshooting in real time, without requiring a physical presence at the plant. Remote monitoring would require a continuous reliable Internet connection. Security setting would require configuration to prevent unauthorized access, and to control the amount of access remote users have to the system.

7.0 GENERAL RECOMMENDATIONS FOR IMPROVEMENT

In addition to the above recommendations, the following general recommendations are provided below.

7.1 NEPS GRID STABILITY

The team observed several breakers tripping due to grid instability. Specifically, grid under voltage caused station transformers to trip. Moreover, frequency control from the grid's hydro generation is unstable, and oscillates below and above 50 Hz. This oscillation creates the indication of changing system load, and causes any gensets running in parallel with the hydro system to load and unload as bus frequency changes. Any efforts to promote grid stability will also benefit the Tarakhil Power Plant.

7.2 ORGANIZATIONAL IMPROVEMENT

The team discussed the plant operations and maintenance organization with the Plant Manager. Organizational charts are attached as Appendix D.

7.2.1 Office Equipment

During the assessment, it was noted that none of the printers in the control rooms worked. All printers were older Hewlett-Packard ink jet color printers, and all were out of ink. We recommend purchasing several inexpensive black-and-white laser printers of a reliable make, with several spare toner cartridges, and installing them in the control room for operator use.

7.2.2 Additional Staffing

Appendix D contains the plant's organizational charts. Four additional positions are recommended, and shown on the organizational charts in *italics*. The positions are:

- A safety manager, reporting directly to the Plant Manager for all matters of safety.
- A tool custodian, reporting to the mechanical team lead, who will maintain a tool library. Currently tools are controlled by warehouse personnel, who report to the Admin/Finance

Manager, and who only work during the day. If maintenance or special tools are required at night, production work is slowed because of lack of tools.

- A fire protection lead, reporting directly to the Plant Manager
- A fire protection mechanic, reporting to the fire protection lead.

7.3 TECHNICAL LIBRARY AND ASSET MANAGEMENT SYSTEM

The plant had a good collection of hard-copy technical documentation available in the administration building. Frequently used documents (e.g. control system drawings and schematics) were available in each power block control room. These documents were stored on shelves in binders, however, and it was often difficult to retrieve the correct drawing or schematic when troubleshooting a specific component.

Equipment logs were also not stored in a readily accessible location, and equipment maintenance and repair frequency was difficult to validate.

An interactive database was developed for use in southern Afghanistan that could be readily adapted for use by DABS at Tarakhil. The database is a three-dimensional virtual world, identical to the power plant. To navigate the database, a user would navigate to the component of concern (e.g. switchboard, pump, mechanical or electrical component) and select it. Each component in the virtual world would contain technical data, drawings, schematics, and maintenance logs. The user, upon selecting the component, would have access to all data related to that component. This database could be installed on laptops or tablet computers, and taken anywhere in the plant, facilitating repairs by acting as an "electronic technical manual". The database can also be synchronized in real time with all users, so operating and maintenance logs could be viewed remotely by DABS staff or consultants assisting in plant operation.

A demonstration version of this database is being prepared and can be presented to interested parties upon request. The software runs on a standard Windows-based computer. Training, licensing and terms-of-use can all be discussed during the software presentation.

7.4 SITE INTERNET CONNECTIVITY

The team observed very poor Internet connectivity at the power plant site. This lack of bandwidth and reliable connectivity hampered troubleshooting efforts. Faster and more reliable Internet would enable access to vendor technical documentation, and would facilitate communication between the plant and various entities inside and outside of DABS.

We recommend the Internet traffic at the site be assessed to determine the cause of the bandwidth limitations. Appropriate measures should be taken based on the assessment, varying from installing filtering software to purchasing a dedicated satellite connection. Monthly connections are available for approximately $500USD/month from several different satellite communications firms. This dedicated internet connectivity would facilitate remotely access and troubleshooting of the PLC and SCADA systems from outside of Afghanistan.

APPENDICES

APPENDIX A
GENSET RUN-HOUR LOGS

GENSET:	Lifetime runhours	Lifetime MW-h generated	Avg load:	As of:	3/2/2014
A1	1,326.00	5,534.21	4.17		
A2	1,292.00	5,523.94	4.28		
A3	1,270.00	5,349.40	4.21		
A4	1,193.00	4,858.22	4.07		
A5	1,037.00	4,156.03	4.01		
A6	1,144.00	4,632.35	4.05		
B1	686.00	2,320.20	3.38		
B2	1,361.00	6,010.59	4.42		
B3	1,274.00	5,534.48	4.34		
B4	632.00	2,147.09	3.40		
B5	915.00	3,720.66	4.07		
B6	869.00	3,394.59	3.91		
C1	1,596.00	7,235.65	4.53		
C2	1,657.00	7,556.52	4.56		
C3	1,733.00	7,918.97	4.57		
C4	1,269.00	5,525.71	4.35		
C5	1,367.00	5,704.76	4.17		
C6	1,110.00	4,686.13	4.22		

Acceptance test 3/26/08
=> ~6y of operations
52560 =# hrs in 6y

GENSET:	% use:
A1	2.52%
A2	2.46%
A3	2.42%
A4	2.27%
A5	1.97%
A6	2.18%
B1	1.31%
B2	2.59%
B3	2.42%
B4	1.20%
B5	1.74%
B6	1.65%
C1	3.04%
C2	3.15%
C3	3.30%
C4	2.41%
C5	2.60%
C6	2.11%

APPENDIX B
OUTBRIEF MEMO

MEMO

To:	[redacted] PE, BCEE, Tetra Tech, Inc. AESP Chief of Party
Cc:	[redacted] USAID OEGI Program Officer, AESP Contracting Officer Representative [redacted] USAID OEGI, Program Manager, Power Transmission Expansion and Connectivity Project
From:	[redacted] PE, Federal Global Department Manager, Power Engineers, Inc.
Date:	March 12, 2014
Subject:	AESP Work Order WO-LT-0070 AMD 3 Tarakhil Powr Plant Site Visit and Power Block "B" Control Assessment

This memorandum is presented in partial fulfillment of the Task 2 scope of work for the subject Work Order Amendment 3, and it summarizes key findings and activities undertaken by Power Engineers during a three week mobilization at the Tarakhil Thermal Power Plant (TPP). The Power Engineers team, supervised by Tetra Tech AESP, mobilized at the Tarakhil TPP on February 18, 2014 and demobilized on March 10, 2014. This memorandum describes what the team accomplished at Tarakhil during the three-week mobilization, and what remains to be done for follow-on work.

Task 5 of the subject work order provides for a thorough technical report to describe issues and problems with the Tarakhil TPP control systems, and the report will propose options for solutions. That technical report is scheduled for delivery on or about April 1, 2014.

SUMMARY

The Power Engineers team spent three weeks on site, and resolved the original problem, defined as Power Block B generators unable to supply the grid. The team also resolved some other control issues and performed a general mechanical and electrical assessment of the plant. Some control issues remain, which are discussed below and will be described in more detail in the final report.

Currently 15 of 18 generators are fully operational, for a plant capacity of 88MW. Generators A5 and C1 have MPU-2S controllers that require programming, and A6 has a faulty PCK-4 controller. A6 could be made operable (for a total of 16 of 18 operable generators) by moving a PCK-4 from either A5 or C1.

Although the plant is operational, control issues persist. The plant does not operate in the error-free, fully capable mode that is to be expected after commissioning. Operational procedures have been put in place to mitigate the control issues, but additional effort on site is required to restore the plant to its post-commissioning state.

INITIAL SITUATION

- Block B generators, while mechanically operational, were not able to be connected with the grid, due to a control system malfunction that prevented the proper breaker lineup. This left the plant with only 12 of 18 generators to supply loads.
- Block B generator operating software was corrupt, preventing their operation from the local Human-Machine Interface (HMI).
- Block A generators would switch from "Baseload" to "Droop" mode during bus frequency excursions; this condition causes the generators to surge and rapidly load or unload, which creates problems managing load on the grid and causes accelerated generator wear. This condition further reduced the number of reliable generators to 6 of 18. Because this power block was not operating reliably, operators ran the six (6) Block C generators almost exclusively.

Tetra Tech, Inc.
Afghanistan Engineering Support Program
Shash Darak, Kabul, Afghanistan

- Power blocks could not be operated remotely from other block control rooms (e.g. Block A could only be operated from the Block A control room; by design, any block should be operable from any other block's control room).
- Multiple erroneous indications were present on the Areva control system in the switchyard.
- Other minor control-system-related problems were present throughout the plant.

ACCOMPLISHMENTS

- Restored operability to Block B generators by patching code in the Programmable Logic Controller (PLC). The PLC's faulty code was preventing fault conditions from clearing on breakers, which prevented the breakers from closing and properly aligning the electrical system to permit generator startup.
- Restored all Block B generator HMI software to operability, and provided software to operators, which will allow them to resolve this problem in the future (if it recurs).
- Corrected the "Droop" issue by transferring settings from Block C Supervisory Control and Data Acquisition (SCADA) system to Block A SCADA.
- Restored some remote operability of power blocks. Many communication errors persist, which we believe are related to improperly installed SCADA in Block B. The quantity of errors is such that remote operability is not a reliable operational mode, so power blocks must be operated from their respective control rooms (e.g. Block C must be operated from the Block C control room, and not from other control rooms).
- Corrected some control and communication errors. Minor control problems, however, are still evident at the plant.

PERSISTENT ISSUES

- Erroneous indications in the Areva switchyard control system remain outstanding.
- Power block control issues are still outstanding. Specifically:
  - Master SCADA in Block B was incorrectly installed after a failure; this faulty installation is causing problems with block remote operability.
  - Blocks B and C do not properly display power output in some system locations. We believe this is a SCADA issue.
  - Block B's station transformer breaker will not close remotely; closes manually, and opens remotely and manually.
  - Block B's Generator Step-Up Transformer (GSUT) medium voltage breaker (connecting the generator bus to the transformer that takes the power to grid voltage) does not open automatically when the GSUT's high voltage breaker opens. It also does not open manually. It does open when the GSUT's high voltage breaker trips.
- SCADA software is outdated, and will not run on newer computers. Consequently, when one of the SCADA computers fails (they run Windows XP, which is an obsolete operating system), and a new computer is installed, new SCADA software will be required at the same time.
  - Cost for new SCADA for the plant is quoted at ~$160,000.
  - We believe that upgrading to new SCADA now will resolve existing SCADA-related problems.
- PLC software source code is locked by the vendor, and not readily viewable for troubleshooting. The vendor has, to date, refused to provide full access to the software.

FOLLOW-ON RECOMMENDATIONS

- Decide on a course of action to remedy the SCADA problem.
  - Upgrade SCADA or recommission existing SCADA
- Troubleshoot, or potentially recommission, switchyard Areva system.
- If PLC code remains unavailable, consider recommisssioning the PLC system, and ensuring that a copy of the most recent working code is provided to the plant operators.
- For items that are not recommissioned, redeploy a software/controls engineer to continue to resolve controls problems, and execute a plan for SCADA resolution.
- Purchase the following spares:
  - HMI for genset B1 (Berghof DPC 3110)
  - CR 1620 batteries x24 for HMI's
  - SEG gateway interface converter (>4ea) (Model PCK-4, #8445-1008)
  - SEG multi-function relay MPU 2-S (>5ea) (Model MPU2-S-I5-U4-L, #8440-1123)
  - SEG multiple measuring converter MPU1-F (>2ea) (Model MPU1-F-I5-CAN, #8440-1014)
  - Woodward interface cable kit: #5417-557 (allows easier programming of MPU's)
  - Viscosity sensor (Mobrey Solartron Viscomaster circuit board, from valve type #7829FEANAJB)
- Improve operator's operations and maintenance skills through training.
  - Ideally a full-time, year-long expat maintenance manager, mentor, and trainer.
  - If a long term program in not feasible, most efficient use of resources is to send mechanical operators to Dubai for a Caterpillar maintenance course.
  - Staff electrical proficiency was commendable; plant staff should conduct frequent in-house training to improve junior operator troubleshooting skills. ,

End Memo

APPENDIX C
DAILY TROUBLESHOOTING ACTIVITY LOG

Draft daily log:

Tuesday 18FEB: Arrived at Tarakhil and conducted an in-brief with Tt and Tarakhil staff.

Attendees:

[redacted]

[redacted] discussed the project with all present; [redacted] agreed to assist.

All present then toured the control rooms, plant and warehouse. During the course of the tour, Safi briefed the group on general operation of the plant. [redacted] said that the plant is used to augment the hydro system, and operates during peak times, usually from 1700 to 2200.

The plant and control rooms appeared to be in good repair, with evidence of good housekeeping and preventative maintenance practices.

The warehouse contained a large amount of troubleshooting equipment and spare parts, many still in original packaging. The warehouse did not appear to be well-organized. An auxiliary warehouse (bank of Conex boxes) contained additional equipment, including software and electronic spares.

Upon conclusion of the tour, Safi accompanied POWER to the Block B control room, where we began to troubleshoot.

Troubleshooting activities:

- Reviewed schematics and operating procedures.
- Discussed plant operation with operating staff
- Observed proper remote operation of bus disconnects
- Observed lightoff and proper operation and loading of a Block C genset
- Traced PLC outputs, comparing Block B with Block A
- Retrieved programming unit and reviewed software on it

Day 2: Weds 2/19

Troubleshooting activities:

- Reviewed schematics and operating procedures.
- Reviewed PLC code

- Traced PLC outputs
- Observed proper remote operation of bus disconnects
- Reloaded Block B PLC software using programming unit
- Observed proper operation of breaker Q0 with PLC disabled
- Observed transformer E06 energized while Q0 was shut (PLC disabled)
- Tried to shut Block B GSUT; it would not.
- Observed proper operation of Block C's Station Transformer with Block C generator bus energized and PLC disabled (same configuration as Block B)

Day 3: Thurs 2/20

Troubleshooting activities:

- Reviewed schematics.
- Reviewed PLC code
- Unlocked blocks of PLC code that were previously locked, and reviewed them

Day 4: Fri 2/21

Troubleshooting activities:

- Reviewed PLC code
- Conducted in-line debugging with PLC (attaching programmer to PLC and stepping through code in real time)
- On Block A, secured all genset PLCs from the engine room, and observed that Block A's GSUT breaker was **not** locked out. This told us that the lockout signal is not likely to come from the gensets.

Day 5: Sat 2/22

Troubleshooting activities:

- Reviewed PLC code
- Conducted in-line debugging with PLC (attaching programmer to PLC and stepping through code in real time)
- Confirmed trip relays for breaker Q0 reset in switchyard (per recommendation from POWER reachback)
- Racked out GSUT breaker to inspect trip coils. Replaced 110VDC fuse providing control power to GSUT breaker.
- Disabled protection sequences in Block B PLC code, and remotely shut Q1 and Q0 (energizing the GSUT), and remotely shut the GSUT breaker, energizing the generator bus. We did not remotely start a generator because the protection sequences were disabled.
- Contacted [redacted], in Germany, to obtain a copy of the PLC code. He agreed to e-mail a POC from Caterpillar, whom we will contact Monday.

Day 6: Sun 2/23

Troubleshooting activities:

- Reviewed PLC code
- Reviewed reports from previous troubleshooting attempts
- Conducted in-line debugging with PLC (attaching programmer to PLC and stepping through code in real time)
- Reviewed software in-line in Block "A" to see how a properly configured system responds while stepping through the code.
- Checked error conditions present in Areva system (in switchyard). Observed a number of improper indications that appear to be creating error conditions (e.g. disconnects that are actually open are indicated as shut). These error conditions are present for all 3 power blocks, and for the bus coupler, though, so it is doubtful this is the source of the problem.
- Believe we have traced the problem to a specific input, I31.6 (in the GSUT cabinet), which takes input from the switchyard. (THIS LATER TURNED OUT TO BE AN INCORRECT ASSUMPTION)
- Reviewed protection system drawings for Areva system and GSUT protection system

Day 7: Mon 2/24

Troubleshooting activities:

- Reviewed PLC code
- Reviewed protection system drawings for Areva system
- Obtained POC in Caterpillar; M[redacted]. Sent e-mail requesting phone conference ASAP. The telephone # for CPGS is [redacted]; made contact with [redacted] who is working with us.
- Conducted in-line debugging with PLC (attaching programmer to PLC and stepping through code in real time)
- After blocking input 31.6 and still seeing the same problem, we believe input 31.6 is **not** the problem.
- After changing some initialization variables in the PLC code, the system appears stable. Intent is to attempt to remotely shut the GSUT breaker tomorrow with PLC enabled to check stability.
- Observed the following erroneous indications present in the switchyard's Areva system:
    - E03 (Line 145 N): Bus Bar Protection #1 shows Q2 shut, but Q2 is actually open
    - E05 (Bus Coupler): Bus Bar Protection #2 shows Q1 shut, Q1 is actually open
    - E06 (Transformer B): Bus Bar Protection #2 shows Q2 shut, Q2 is actually open
    - E09 (Line 145 E): Bus Bar Protection #1 and #2 both show Q2 shut, Q2 is actually open
    - Of note, each of the disconnects listed above were correctly indicated on other panels. We believe this means it is not an indication problem.

Day 8: Tues 2/25

Troubleshooting activities:

- Reviewed PLC code
- Discovered an apparent bug in the code for Block B that prevents resetting a fault condition; there is a miscoded circular logic loop.
    - Because the PLC's default state on startup is to be in a fault condition, turning the PLC off and on will not clear the fault.
    - This problem is not observed in other blocks because their default state on startup is **not** in a fault condition.
    - We added code so that when the PLC detects a fault, it takes protective action, waits 30 seconds, and then allows the fault to be reset. After reset, it checks to see if the fault still exists. This will allow the system to be reset after a fault, but still maintain protection.
- After patching the software, we energized Block B's generator bus and station transformer with no problems. Of note, the erroneous indications in the Areva cabinet related to Transformer "B" also cleared. We plan to try to light off a Block B genset tomorrow. We discussed startup preps with the Plant Manager before securing for the day.
- Observed problems with position indication on bus disconnects. The bus disconnect motor operator does not fully open the disconnect, so the position indication switch does not show "open"; the disconnect must be fully opened manually to give proper indication. We believe this is a mechanical problem with a relative simple fix.
- Inspected Block B's #1 genset, in preparation for lightoff tomorrow.
- Contacted [redacted] of Caterpillar After-Sales Support and provided him with a waiver to pass to Woodward; he relayed that he would talk to Woodward and get the PLC code.
    - [redacted]

Day 9: Weds 2/26

Troubleshooting activities:

- Briefed Plan Manager on PLC code changes
- Reviewed Genset HMI software
    - HMI software in Block B gensets is inoperative. Without the HMI, alarm conditions on the genset are no visible, both locally and remotely. Therefore HMI software must be reinstalled to enable safe operation of the genset.
- Observed several undervoltage trips of the Block B station transformer breaker while Block B was connected to the grid. This is due to poor grid power quality (not a Tarakhil-related problem), but confirms that the protection system remains operable after our software patch.

- Observed that the SCADA system will not shut the Block B station transformer (low side) breaker. (The breaker can be manually shut.) Ran the Block B software in Block C to see if the same symptoms occurred; observed they did not, and we ruled out the PLC as the cause of this issue.
- Simulated a ground fault and confirmed proper operation of the Q0 breaker after software patch installation.
- Did not have permission to start any gensets, because both buses were receiving import power. (Import power cannot be paralleled with Afghan power.)
- We inspected all 6 Block B gensets and obtained permission for lightoff tomorrow at 0800.
    - We moved all genset HMI modules from Block A to Block B. This is a temporary fix until we can reinstall the HMI software on the Block B modules. We will likely install the old Block B modules in Block A, since they are interchangeable.
    - While inspecting mechanical systems for lightoff, observed a leak in one of the Block B fuel oil booster (pre-pressure) pumps. The other one will be used during lightoff.
    - While installing modules, observed a hardware failure in Block B's #1 genset HMI. This is due to design that powers down the HMI on a loss of power. We believe that frequent outages have caused the hardware to become damaged, just as repeatedly unplugging a PC, rebooting, and unplugging again would damage it. We replaced the hardware with a spare.

Day 10: Thurs 2/27

Troubleshooting activities:

- Worked with Plant Manager to align gensets in Block B for startup. Ran each genset manually to confirm good operation.
    - Observed a hardware failure in SEG module in genset B1; replaced it with module from Power Block A.
    - Observed some breaker trips that the Plant Manager attributed to high starting current of equipment that had not run for a long time.
- **Successfully remotely lit off gensets 2 and 4, and observed them powering the grid.** We believe this validates our software patch.
    - During operation, we observed some problems with the cooling water system for gensets 1 and 2. We will work to resolve them Saturday.
- Briefly spoke with [redacted], DABS Thermal Power Plant Director (Plant Manager's boss). Briefed him on the lightoff and PLC software resolution.
- Worked to reinstall HMI software to modules formerly installed in Block B (per Day 9 report, we moved Block A HMI modules to Block B to enable startup).

Day 11: Fri 2/28

Troubleshooting activities:

- Obtained software from Caterpillar. Confirmed it was identical to the software on the programming unit, and missing necessary code blocks. We reengaged [redacted] to try to get all the code.
- Reinstalled Wonderware software on HMI modules for Block A gensets; confirmed they properly worked.
- Reviewed Wonderware software documentation to support operations in the powerhouse.

Day 12: Sat 3/1

Troubleshooting activities:

- Lit off all 6 Block B gensets and supplied the grid.
- Observed the following issues at lightoff:
    - On Genset B3, several fuses blown in fuse block F5, still require replacement.
    - Faulty MPU's in B1 B6; replaced with MPUS from other working engines (total of 2 faulty MPU's)
    - Genset B2 HT cooling water pump #1 breaker failed; replaced from spare inventory
    - Various loose connections in several gensets; tightened.
    - Genset B6, starting air shutoff valve sensor inoperative; cleaned and reinstalled.
    - Genset B3 and B5, main breaker for automatic voltage regulation showed open when actually shut; cleaned contacts.
    - Dirty air distribution filters on B3 and B6; cleaned.
    - Faulty viscosity sensor on B1, requires replacement.

Day 13: Sun 3/2

Troubleshooting activities:

- Met with and outbriefed Gene Lin (USAID).
- Reviewed SCADA system and checked existing settings.
    - Observed that some of the logic was inaccessible without a proper Wonderware license (developer's license). Currently the plant has an operator's license; a developer's license is needed to make any changes to SCADA, or to troubleshoot it.
    - E-mailed Wonderware license providers to get a cost for a developer's license.

Day 14: Mon 3/3

Troubleshooting activities:

- Installed SCADA settings from Block C to Block B to address the droop mode issue. **<u>We believe the droop problem is fixed.</u>**
    - Lit off 1 genset to test, changed bus frequency up to 51.8Hz and down to 49.2Hz; the genset stayed in "Baseload" mode, so we believe importing the Block C SCADA settings fixed the problem.

- Adjusted settings in Block C SCADA, genset alarm display now restored.
- Obtained POC with Woodward; sent e-mail requesting software:
    - [redacted]
- Obtained run-hour logs and passed to Tt and AID. They confirm engines are run ~2% of the time (e.g. 41 hrs/year)
- Spoke at length with Plant Manager re: organizational structure and training needs.
- Repaired lock to SCADA cabinet in Block C

Day 15: Tues 3/4

Troubleshooting activities:

- Partially restored remote operability of power block A and C SCADAs (ie any power block can be controlled from block A or C's control room); reconfigured IP addresses and properly connected fiber optic lines. (WE LATER DISCOVERED REMOTE OPERABILITY WAS NOT FULLY RESTORED)
    - B's SCADA remains incapable of controlling other power blocks. This is because of bad settings inside the software, which we believe will require a Wonderware developer's license.
- Fixed Master SCADA for Block C; replaced power supply and reconfigured BIOS.
- Set up an interim fix to allow control of other power blocks from Block B; using remote desktop software, we connected the Block C SCADA PC to Block B's SCADA PC, allowing operation of the Block C SCADA (which can remotely control any power block) from the Block B control room.
- Received word from Woodward that their company policy would not allow them to share PLC code with us.

Day 16: Weds 3/5

Troubleshooting activities:

- Observed erratic behavior of SCADA when controlling blocks remotely from Block C.
    - We believe it is due to Block B's SCADA being a copy of Block A's SCADA…communication crosstalk occurs because the system believes there are two Block A's.
    - We believe remote operation of power blocks is unreliable.
- Reviewed software on Areva OI on Block B to understand OI operation.
- Worked on programming the MPU; we believe that a special cable (see equipment purchase list) is required.
- Connected to the Areva panel to begin troubleshooting error codes and faulty indications

Day 17: Thurs 3/6

Troubleshooting activities:

- Worked on Areva panel
  - Studied Areva module source code
  - Traced out network diagram to confirm network topology
- Toured NLCC to understand system-wide SCADA requirements and application
- Discussed SCADA requirements for system restoration

Day 18: Fri 3/7

Troubleshooting activities:

- Reviewed Areva code
- Researched SCADA systems and programming requirements

Day 19: Sat 3/8

Troubleshooting activities:

- Worked on programming MPU, may have a method to manually program without special equipment.
- Assessed existing UPS system on genset HMI's
- Troubleshot spectrometer problems. Identified issues.

Day 20: Sun 3/9

Troubleshooting activities:

- Worked on programming MPU's.
  - Programmed two spare MPU's installed on gensets in Block A and C; will test tomorrow to confirm operability.

Day 21: Mon 3/10

Troubleshooting activities:

- Started and genset C1 to test MPU programming. Genset started, but would not parallel. Further troubleshooting is required; it's possible the MPU has more detailed programming requirements. MPUs still do not function correctly.
- Assembled software package for Plant Manager that contains PLC code and restoration instructions.

- Tested gensets in 3 separate power blocks. **Current plant condition is: 15 of 18 generators are fully operational, for a plant capacity of 88MW. Generators A5 and C1 have MPU-2S controllers that require programming, and A6 has a faulty PCK-4 controller. A6 could be made operable (for a total of 16 of 18 operable generators) by moving a PCK-4 from either A5 or C1.**
- Troubleshot faulty genset HMI, discovered faulty memory.

Block B Problem Statement:

Block B engines are locked out from starting.

Block B consists of 6ea 6MW engines connected to a common bus by individual generator breakers.

The generator bus is connected to a Generator Step-Up Transformer (GSUT) via a breaker.

The GSUT is connected to the grid via the following (in series, beginning with the 110kv side of the transformer):

- A dry disconnect switch (Q9)
- An SF6 breaker (Q0)
- Disconnects Q1 (connecting to Afghan hydro power) or Q2 (connecting to import power). These disconnects are interlocked to prevent simultaneous connection to domestic and import power, and were verified to operate correctly.

The engines will not start (in normal mode, by design) unless the generator bus is powered. The generator bus cannot be powered because breaker Q0 will not shut.

Breaker Q0 is receiving a fault signal ("Transf external protection trip") from the Block B PLC. This output was confirmed to come from the GSUT protection panel relay K9. It was confirmed by removing relay K9, and observing the signal clear. Of note, the PLC still sends a fault signal to breaker Q0 itself, preventing Q0 from shutting…so removing relay K9 will not, by itself, allow Q0 to shut.

The Block B PLC is also sending "Generator Step-Up Transformer: C.B. Not Released" and "Sta Transf MV C.B Not Release" signals to the GSUT and the Station Transformer.

Problem History:

The Plant Manager related that the plant operated properly, then Block C's SCADA began to alarm, then days later B's SCADA, then days later A's SCADA. This occurred around November 27, 2012.

After unproductive troubleshooting by DABS technical personnel, Caterpillar was called to repair the SCADA. Caterpillar provided software and a programming unit to install the software to the units. During the time the PLC was inoperative, the power blocks were operated manually.

The last time Block B's gensets powered the grid was April 23, 2013. Because of spring demand lull, no power was demanded from the station after that.

On May 19, 2013, the provided software was loaded onto all PLCs.

On June 4, 2013, none of the Block B gensets would start, either manually or automatically. The alarm "Start Blocking" was observed, and the 11kV GSUT bkr would not shut manually (or automatically). Mr. [redacted], of Cap-Dev Technology worked on troubleshooting the process, providing an interim report to DABS on July 29, 2013 [redacted] redeployed in late August of 2013, and left in the September 2013 timeframe, with the Block B problem unresolved.

Other Issues with Areva system in switchyard:

Several panels give improper indications of disconnect switch position. These improper indications create error conditions (e.g. when two interlocked disconnects are both indicating "shut", this generates a "isolator/CB error").

Recommended items to be purchased:

- HMI for genset B1 (Berghof DPC 3110)
- CR 1620 batteries x24 for HMI's
- SEG genset control module (>4ea) (Model PCK-4, #8445-1008)
- SEG MPU 2-S (>5ea) (Model MPU2-S-I5-U4-L, #8440-1123)
- SEG MPU1-F (>2ea) (Model MPU1-F-I5-CAN, #8440-1014)
- Woodward interface cable kit: #5417-557 (allows easier programming of MPU's)
- Viscosity sensor (Mobrey Solartron Viscomaster circuit board, from valve type #7829FEANAJB)
- Backup PC's for SCADA (specs TBD based on way forward for SCADA fix)
- More panel keys (T-handle)

Provide to plant manager:

- Imaging software
- Copy of patched PLC code
- Copy of all Areva software

Find out from Plant Manager:

- Why are there workstations with limited capabilities? Why not have all PCs in all blocks do everything? (Yes, that's ideal.)
- Is there any data you want historically backed up? (Yes.)

Safi would like:

- Training on software, focus on installing after failure and system settings
    - PLC system
    - Areva
    - SCADA
    - CMX

- Mechanical training
    - Inspection and maintenance of turbocharger
    - Periodic overhauls of diesels
- Electrical training
    - 11kV breaker maintenance
    - Transformer PM
    - Relay maintenance
- Training for shift supervisors and deputies
- Training topics
    - Binder of 50
    - **Must be specific to Tarakhil plant components**, not generic breakers or valves.
    - English and Dari
- Maybe daily training schedule, to build workforce capability?
- Procurement system reform; need to be faster (quotes expire before PO's get cut)
- Staffing issues:
    - No fire protection staff (req 1 lead, 1 mechanic)
    - Need tool custodian, or at least tools controlled by mechanics, not warehouse
    - DABS compensation not competitive; leads to workforce turnover.
        - Power plant compensation reportedly less then substation compensation; may be because of B&V stipend that went away

Follow-on recommendations:

- No backup system; no external archiving system. Recommend developing procedure for backup and archiving.
- Update video cards & monitors for multi-monitor display
    - Consider making all workstations equally capable
    - Consider larger monitors
- SCADA:
    - SCADA's Wonderware app will fail if a non-XP machine is needed. Because XP is obsolete, SCADA should be updated.
        - Could use Wonderware
        - Could use other COTS solution
        - Could use custom solution
    - Any updating will require adjustments to existing SCADA code (this code currently runs on the Wonderware application)
    - We recommend adjustments irrespective of replacement, due to design deficiencies and to improve the user experience.
        - User can accidentally rename error codes
        - Display is hard to configure
    - Obtain SCL source code for PLC
        - Facilitates updating SCADA

        - Facilitates troubleshooting in the future
        - Facilitates installing new plant equipment
        - Facilitates identification of error codes
        - If Woodward is not cooperative, we could restore the code
    - Way forward is:
        - Do you want to update?
        - If yes, to what?
        - If no, do you want SCADA adjusted?
        - Need to buy:
            - New SCADA software
            - If Wonderware, need developer's kit
        - Need to:
            - Install new software
            - Reconfigure SCADA app

AD's follow-on scope is:

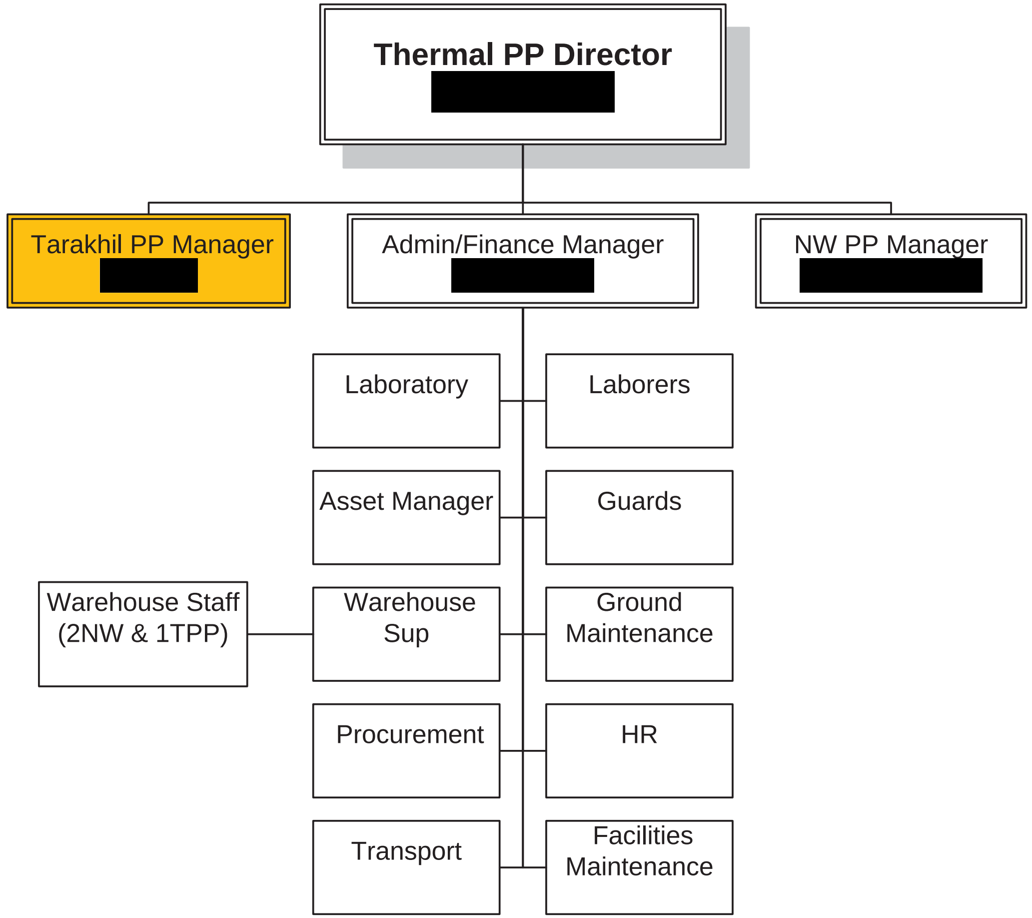
- Definite:
    - Implement SCADA solution (whatever client decides)
    - Fix outstanding control problems (Areva errors, breaker behavior)
    - Design and install HMI protection
    - Fix Internet
    - Implement remote monitoring for SCADA
        - 3 PC's, a LAN, a dedicated dish/hardline (AD to provide bandwidth reqs)
    - Provide training on SCADA as installed, and basic PLC and software/hardware issues so plant can t/s on their own.
    - Develop list of system error codes; pass to electrical lead for further development.
- Potential:
    - Design and implement backup system (if client decides)
    - Implement asset management/technical library system (if client desires)
    - Develop full error code troubleshooting manual
    - Make Areva communicate and control the Tarakhil s/y from NLCC
    - Troubleshoot NLCC control issues

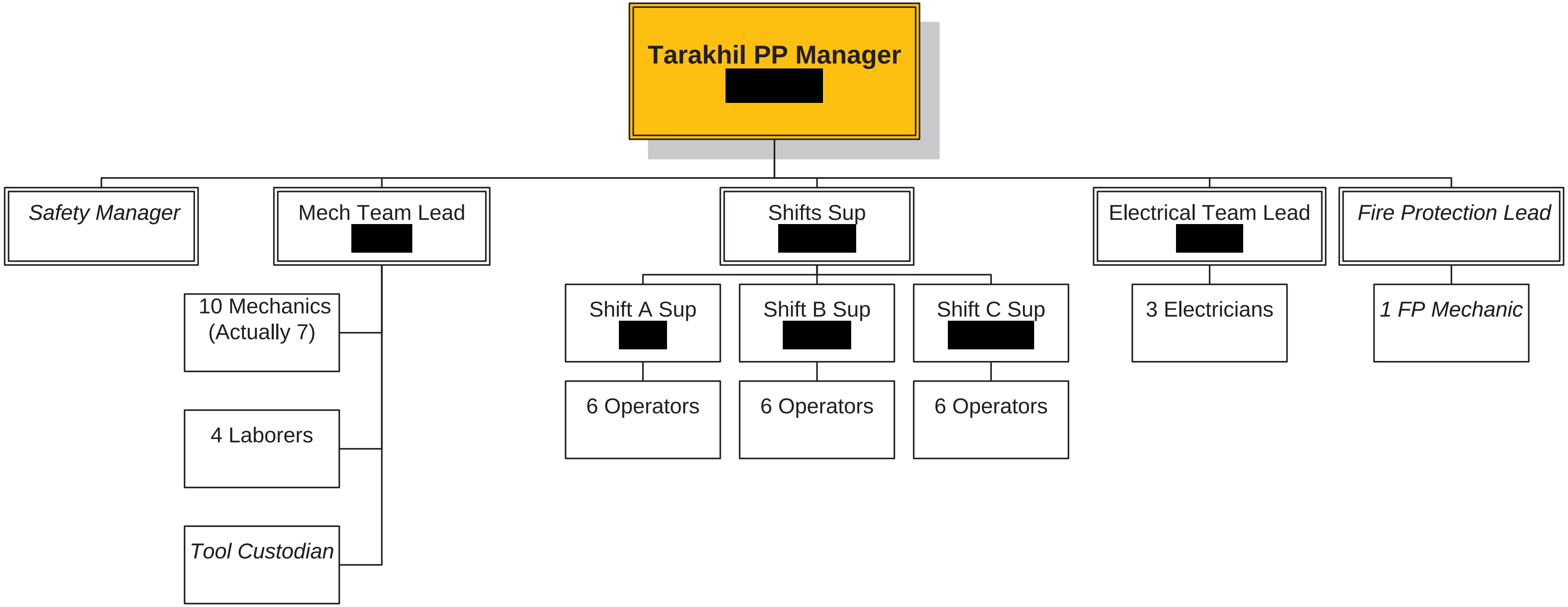
Estimate time frame:

- AD at home definite:
    - HMI protection design
    - SCADA system review & programming
        - Interface design coordination via e-mail
    - Build training package
    - Build most of the error code list
- AD at home possible:

- Backup system design
- Asset management system/tech library implementation
- Progress on troubleshooting list

APPENDIX D
PLANT STAFF ORGANIZATIONAL CHARTS


Thermal PP Director
[redacted]
Tarakhil PP Manager
[redacted]
Admin/Finance Manager
[redacted]
NW PP Manager
[redacted]
Laboratory
Laborers
Asset Manager
Guards
Warehouse Staff (2NW & 1TPP)
Warehouse Sup
Ground Maintenance
Procurement
HR
Transport
Facilities Maintenance


Tarakhil PP Manager
[redacted]
Safety Manager
Mech Team Lead
[redacted]
Shifts Sup
[redacted]
Electrical Team Lead
[redacted]
Fire Protection Lead
10 Mechanics (Actually 7)
4 Laborers
Tool Custodian
Shift A Sup
[redacted]
Shift B Sup
[redacted]
Shift C Sup
[redacted]
6 Operators
6 Operators
6 Operators
3 Electricians
1 FP Mechanic

USAID/Afghanistan

U.S. Embassy Cafe Compound
Great Massoud Road
Kabul, Afghanistan
Tel: 202.216.6288

http://afghanistan.usaid.gov