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# Kandahar Helmand Power Project (KHPP)

## CONTRACT: 306-C-00-11-00506-00

## Kajaki Hydro Power Plant Transmission and Distribution Facility Assessment Report - DRAFT

**March 17, 2011**

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# 1 EXECUTIVE SUMMARY

Black and Veatch Special Projects Corp. ("BVSPC") has been requested to conduct a technical assessment for the Kajaki Hydro Power Plant ("KHPP") substation in Helmand Province, Afghanistan. This assessment is part of the Kandahar Helmand Power Project ("Project"). This report presents the results of the findings of the technical assessment which was focused on the following points:

A. Investigate and recommend solutions to mitigate the sporadic (nuisance) 13.8 kV generator bus faults.
B. Locate potential sites for the new 110 kV KHPP transmission substation.
C. Perform a condition assessment of the Government Furnished Equipment (GFE) Tangi power transformer.
D. Determine a potential route for the new 20 kV line between the KHPP and the Tangi substation.

The conclusions to the four areas of assessment are as follows. For each area of interest, a determination of whether the recommendation is within or out of the current scope of this Contract and whether the solution can be implemented in the short term or in the long term.

A. 13.8 kV Generator Bus Faults

Assessment of the nuisance tripping on units 1 and 3 was performed by the team during a site visit in January, 2011. Solutions to mitigate the periodic tripping are outlined below and detailed in Section 4.2:

- 13.8 kV Distribution (In Scope – Short Term): The 13.8 kV distribution circuit leaving KHPP should be isolated from the generator bus via an outdoor circuit breaker shown in Figure 4-2.
- Governors (Out of Scope – Medium Term): The governor controls for KHPP Unit 1 and Unit 3 should be repaired to provide improved response to load rejection scenarios or replaced with digital controls as part of the Unit 2 construction which includes Unit 1 and Unit 3 control systems upgrades. This recommendation is further detailed in the *Kajaki Dam Unit 2 Hydro Inventory and Condition Assessment Report-DRAFT* study previously submitted to USAID.
- 13.8 kV Distribution (In Scope – Medium Term): Converting the 13.8 kV distribution circuit leaving KHPP to a 20 kV operation should be implemented as shown on Attachment 9 – Diagram D-7 Kajakai Substation Single Line included in the Contract. The GFE 16 MVA 13.8/20 kV transformer presently at site in the lay down area should be moved to a new 20 kV substation and installed next to a new 20 MVA 110/20 kV transformer as indicated in the referenced Contract attachment.
- Re-insulate Existing Distribution Lines (Out of Scope – Medium Term) To implement the above bulleted item, the distribution lines "Tangi 2 Line" and "Tangi South Line" shown on Attachment 9 – Diagram D-7 Kajakai Substation Single Line included in the

Contract will need to be upgraded from 13.8 kV system voltage insulation to 20 kV system voltage insulation. If this recommendation is pursued, additional consideration should be given to reconsider the configuration and capacity of the Tangi substation. to meet the load and feeder requirements identified by DABS during this assessment.

- 110 kV Transmission (Out of Scope – Long Term): Efforts should be undertaken to improve the 110 kV transmission line conditions to reduce transmission line trips. Trips of the 110 kV line result in large load rejection for the KHPP generators. As discussed in the second bullet item "Generators", the existing controls do not respond fast enough to the load rejection resulting in the units tripping. Furthermore, repair or replacement of the distance relays at the KHPP is recommended.

The replacement of the circuit breaker and the addition of improved protective devices will reduce the nuisance tripping. Combined with the improved response provided by new governor controls, notable generator output performance and system reliability will be achieved.

B. Potential 110 kV Transmission Substation Technologies and Site

An assessment of the use of gas insulated switchgear (GIS) technology for the replacement substation was briefly completed. Due to the lack of technical need, the added cost, and the consequential introduction of equipment not utilized elsewhere in the electrical system, the use of air insulated technology is recommended.

Then, an assessment of potential sites for the new 110 kV air insulated transmission substation was performed and a proposed site was located in a saddle/valley south of the existing KHPP 110 kV substation. The entire site is located over exposed Triassic limestone dolomite bedrock. The three sites provide each can provide an adequate base for the substation. Two of the sites would require a significant quantity of rock removal effort to provide level areas for the facility. The site proposed will require significant fill quantities (work). However, there is a substantial amount of shot rock fill on the north side of the dam that can be used for fill and only minimal excavation at the proposed site would be required.

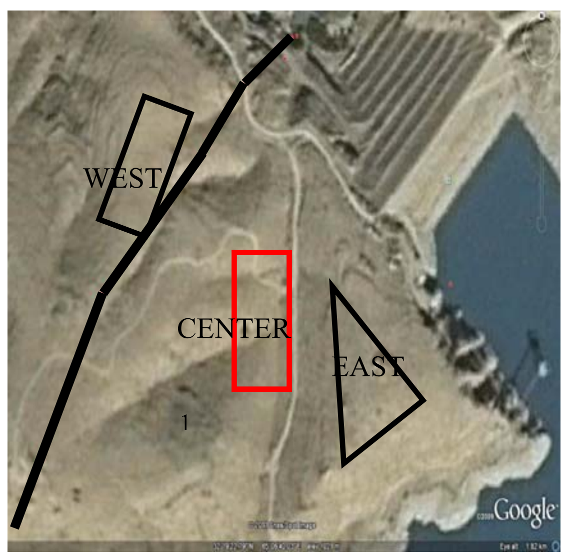


**Figure 1-1 Potential Substation Sites**

The preferred substation site is the Center site, located east of the existing 110 kV transmission line. A detailed assessment of the site is located in Section 6.

C. Tangi Transformer GFE

The GFE Tangi distribution transformer has sustained damages while in-transit to the Kajaki area; however the damages do not deem the transformer inoperable. Provided the oil tests are positive, all the accessories are accounted for and a suitable oil processing unit is available, the transformer should be able to be successfully installed and commissioned. A detailed assessment of the GFE Tangi transformer is located in Section 5.

D. 20 kV Line Route

Prior to assessment of the new 20 kV line, a preferred route through Tangi village was discussed with the local DABS staff, Engineer Rasul. The new 20 kV line route leaves the power house and follows the existing 13.8 kV line along the river via the plant access road. The new 20 kV distribution line will leave the new 20 kV substation which is proposed to be located next to the new 110 kV air insulated substation. The line route will follow the existing road from the substation to the Tangi bridge. The line crosses the Helmand river on the east side of the Tangi bridge and runs due south from the bridge, avoiding existing buildings and olive trees, before heading southwest across a hillside.

The route along the hillside will attempt to keep a relatively constant elevation before travelling down slope to an area just south of the southern most structure in the village. The line takes a small turn to the south west and traverses a broad open relatively level area before turning northwest at a main road. The line will travel along the northwest road, past the Afghan National Police Station, then turns west into the Tangi substation. A detailed assessment of the proposed 20 kV line route is described in Section 7.

# 2 ASSESSMENT OBJECTIVE

The Project identified the need to evaluate critical issues before the initial start of Component 5 pertaining to the rebuilding of the Kajaki dam substation and local distribution system. The following issues were to be assessed by the onsite technical team:

- Recommend an appropriate solution to mitigate the cause of electrical faults external to the generation powerhouse that are impacting the reliability of the generation at the powerhouse, including procuring and installing parts to better protect the powerhouse from external electrical faults.
- Preparation work for the new 110/20/13.8 kV substation at the KHPP. The RFP indicates that the location of this new substation is to be to the east of the existing substation. This location will require access to the site through the existing substation. Therefore, this assessment will investigate building a GIS substation on the roof of the existing powerhouse. This assessment will also identify an alternate site(s) for the substation using air insulated technology.
- Assess the condition and operability of the Government Furnished Equipment (GFE) i.e. the 16 MVA 13.8/20 kV transformer The condition of this equipment, including its suitability for reuse, needs to be determined during this assessment, including any recommended storage procedure changes necessary to ensure that the transformer condition remains usable.
- Determine a feasible distribution line route from the KHPP to the new Tangi Substation.

# 3 BACKGROUND

In 1975, USAID installed and commissioned two 16.5 MW hydroelectric turbine generating units in the Kajaki Hydro Power Plant ("KHPP"). The powerhouse was designed as a three unit plant with installation of Units 1 and 3 (16.5 MW each) and a vacant unimproved "skeleton" bay for the future erection of Unit 2. USAID has completed the rehabilitation of the Units 1 and 3 in 2009 with the exception of controls, switchgear, metering, and protection.

A contract was awarded to China Machine-Building International Corporation ("CMIC"), in January 2005 for the design, manufacturing and erection of an 18.5 MW hydroelectric turbine generator to be installed as Unit 2 at Kajaki Powerhouse. The CMIC contract also included supply and installation of remaining control, switchgear, metering, and protection systems for Units 1 and 3 not provided with the unit rehabilitation. Further, the CMIC contract also included supply and installation of certain upgrade and replacement of power house common equipment, required because of additional power output of the station with the installation of Unit 2. The components were manufactured by various manufacturers and delivered by CMIC to Afghanistan.

Delivery of components began in the summer of 2006 and ended in March 2009. Delivery was difficult due to the non permissive environment created by anti government elements along the transportation route. Some components were airlifted to the site; many of the large components were delivered by convoy in September 2008. Due to lack of warehouse space at Kajaki Hydropower Plant, the Unit 2 components as well as other CMIC equipment supply are in storage under tarpaulins and inside shipping containers. These have been stored this way since their delivery. Initial site preparation and civil work for the installation of Unit 2 started March 2008 with a small construction crew from CMIC. In November 2008 CMIC employees withdrew from the Kajaki work site due to security concerns, without performing any significant work.

In December 2010, US Agency for International Development ("USAID") awarded a contract to Black and Veatch Special Projects Corporation ("BVSPC") to execute the Kandahar Helmand Power ("Project"). Component 5 of the Project entails rebuilding the Kajaki dam 110 kV substation and the local distribution system.

# 4 GENERATOR BUS FAULTS

Nuisance tripping has been an ongoing issue at the KHPP. Both units 1 and 3 were observed to trip for various faults on the distribution and transmission networks. This Section will outline assessment of the generator trips and possible solutions to mitigate the problem.

## 4.1 ORIGINAL DESIGN OF THE 13.8KV BUS AND 13.8 KV LOAD CONNECTIONS

The plant 13.8kV bus configuration and how the loads are fed from this bus impact the tripping. These two conditions are described below.

### *4.1.1 Internal Plant Bus Configuration*

The existing configuration consists of two overhead 13.8 kV feeders leaving the powerhouse and directly connected to an extension of the 13.8 kV generator bus-duct feeding the 13.8/110 kV generator step-up (GSU) transformers as shown below in Figure 4-1

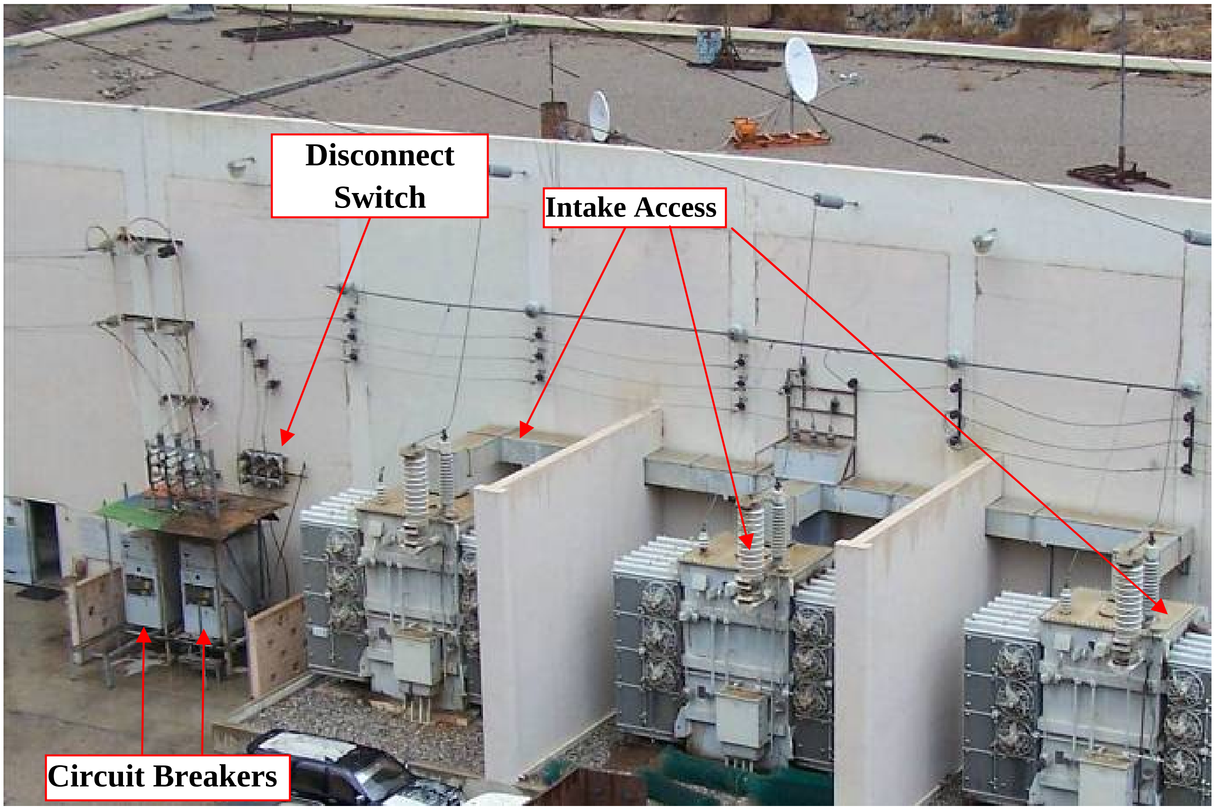



**Figure 4-1 Existing Configuration at KHPP**

The two overhead circuits were originally protected via the two indoor-rated circuit breakers, housed outdoors under only a shed roof, with a non-load break gang-operated switch. One of the circuit breakers is inoperable and the remaining circuit breaker is bridged to both feeders and is providing limited protection for all of the 13.8 kV bus.

The non-load break gang-operated switch, connecting cables and insulators are in extremely poor condition and subject to arc flash-over during even the lightest precipitation.

### *4.1.2 External Loads*

Local distribution load being served out of the KHPP is shown below in Table 4-1. Load sizes were estimated and provided by the local KHPP staff. The size of these loads and the distances that the feeders extend are believed to be above the original basis of the design. To meet these load requirements, rotating service outages are implemented. Electric service is available on alternate days.

| Load ID | Value (MW) | Circuit |
|---|---|---|
| West of Tangi | 5 | OH Kajaki-Tangi |
| LerKand | 3 | OH Kajaki-Tangi |
| Konjak | 3 | OH Kajaki-Tangi |
| South Kajaki | 3.5 | OH Kajaki-South Kajaki |
| Kajaki Construction Camp | 1 | OH Kajaki-South Kajaki |

**Table 4-1 KHPP 13.8 kV Local Distribution Load**

## 4.2 CAUSE OF FAULTS

Nuisance tripping of KHPP units 1 and 3 was investigated by the assessment team and a review of the station's trip log book revealed the following trip flags:

- 13.8 kV Over-current Relay Trips
- 110 kV Over-current Relay Trips
- Neutral Ground Relay Trips
- Unit Over-speed Trips
- Unit Under-speed Trips

An outline of each trip scenario is detailed in the following Sections.

### *4.2.1 110 kV Over-current Relay Trips*

The 110 kV Over-current relay trips are the result of fault events on the 110 kV line to Sangin due to various issues including lack of maintenance, environmental impacts, and damage due to hostile activities. The 110 kV distance relays were found to be inoperative, which further degrades 110 kV operation and the ability to localize faults on the transmission line.

### *4.2.2 Generator Neutral Ground and 13.8 kV Over-current Relay Trips*

The Generator Neutral Ground trips and 13.8 kV Over-current trips are directly attributable to the extension of the KHPP 13.8 kV generator electrical bus as an overhead distribution circuit around the local KHPP service area. Isolation of the generator bus from local distribution lines is non-existent and protection of the 13.8 kV generator bus from local distribution line faults is virtually non-existent.

Presently, current from an external ground fault has a return path that is sensed by the 64G relay, generator ground protection device. The 64G relay mistakes the fault for an internal generator fault and trips either unit offline. Isolation and protection of the 13.8 kV generator bus from the distribution circuit is critical to achieving or maintaining a more reliable operation of the KHPP facility.

### *4.2.3 Unit Over-speed and Under-speed Trips*

Existing governors for both units 1 and 3 do not respond fast enough to handle load rejection. A loss of load, due to 13.8 kV or 110 kV trips noted above, causes a unit to trip on over-speed, then cascading to the remaining unit which trips due to under-speed.

Faults on both the 110 kV transmission and 13.8 kV distribution lines result in rapid load changes which the KHPP units cannot handle resulting in unit trips, rather than reverting to full speed-no load conditions.

## 4.3 RECOMMENDATIONS TO MITIGATE FAULTS

### *4.3.1 13.8 kV Distribution (In Scope – Short Term)*

The current distribution system local to the KHPP area is in a degraded state and needs a significant overhaul to reach proper reliable operation. Additionally, the numerous distribution faults experienced on the local 13.8 kV circuit are sensed at the generator neutral voltage relays and thus tripping KHPP units 1 and 3.

The 13.8 kV distribution circuit leaving KHPP should be isolated from the generator bus via an R-MAG magnetically actuated dead tank outdoor vacuum circuit breaker show below in Figure 4-2. The medium voltage vacuum circuit breaker is relatively small in size and has the following features which adequately fit the application at the KHPP:

- Rated for 10,000 full load operations, a valuable feature due to the number of faults on the distribution circuit which can be multiple times per day.
- Utilizes a one moving part mechanism which leads to less maintenance.
- 0.3 Second reclosing time for minimal distribution interruption.
- No maintenance required on magnetic actuator.
- No spring charging motors or trip/close coils to replace.


**Figure 4-2 R-MAG Vacuum Circuit Breaker**

The R-MAG breaker will be equipped with the REF615 feeder protection relay. The 59G ground voltage relay element will be set to operate faster than the 64G relay to provide coordination with the generator ground fault protection so as to protect better units 1 and 3 against ground faults. As part of the 13.8 kV isolation, it is also recommended the existing disconnect switch be replaced due to its extremely poor condition.

A protection one line diagram depicting the R-MAG and REF615 design is shown below in Figure 4-1. This recommendation will not address the issue of the generator governors not responding to load rejection and tripping on over/under speed. Recommendations addressing governor response is included in the *Kajaki Dam Unit 2 Hydro Inventory and Condition Assessment Report-DRAFT* study previously submitted to USAID.

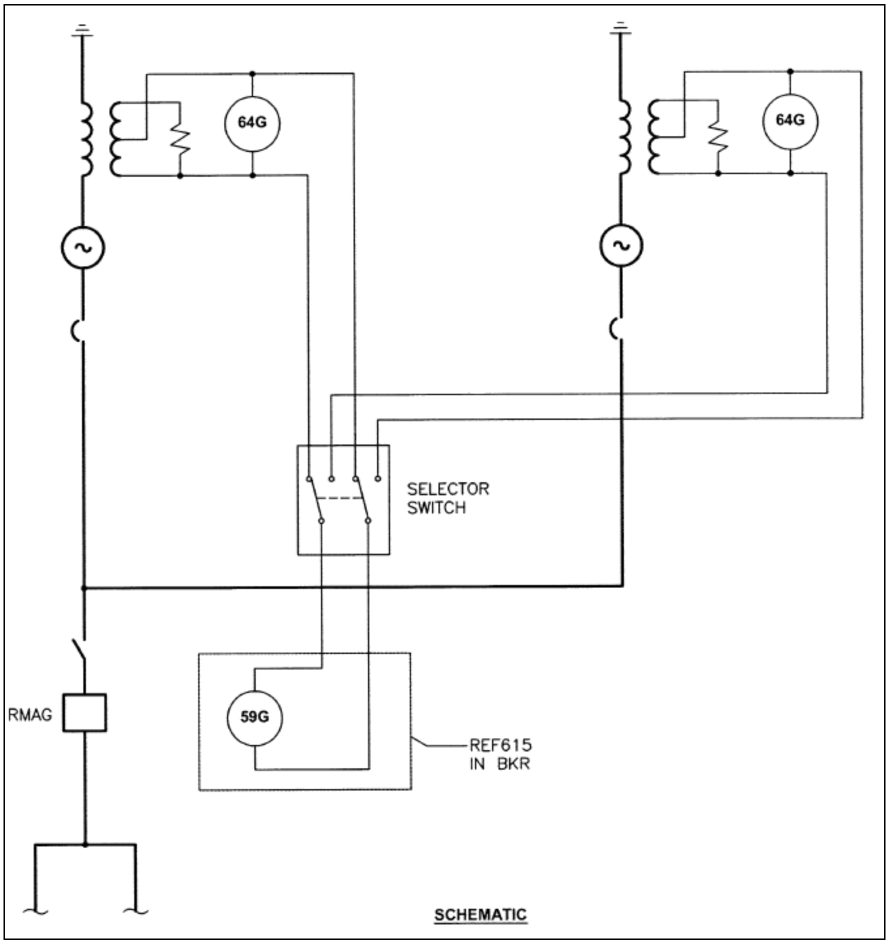



**Figure 4-3 R-MAG and REF615 Protection One Line Diagram**

*4.3.2 Governors (Out of Scope – Medium Term)*

Slow responding governors for KHPP units 1 and 3 is a critical issue resulting in nuisance tripping at the plant due to faults on the 13.8 kV distribution and the 110 kV transmission systems. Trips on the 13.8 kV and 110 kV systems cause a loss of load on the generators. The purpose of the governors is to control the speed of the turbines under this scenario so that their speed will stay within operating parameters.

The governor controls for KHPP Unit 1 and Unit 3 should be repaired as part of the Component 6 scope of work to provide improved response to load rejection scenarios or replaced with digital controls as part of the Unit 2 construction which includes Unit 1 and Unit 3 control systems upgrades. This recommendation is further detailed in the *Kajaki Dam Unit 2 Hydro Inventory and Condition Assessment Report-DRAFT* study previously submitted to USAID.

*4.3.3 13.8 kV Distribution (In Scope – Medium Term)*

The medium term solution to mitigate units 1 and 3 tripping due to faults on the local distribution system entails converting the 13.8KV distribution circuit leaving KHPP to a 20KV operation by commissioning the GFE Inventory 16 MVA 13.8/20KV transformer in a new 20 kV substation to be located next to a new 110/20 kV transformer as indicated in the Project's contract document. This reconfiguration will eliminate the KHPP generator neutral ground relay trips due to the Delta-Wye isolation provided by the newly commissioned 13.8KV/20KV transformer.

#### *4.3.4 Re-insulate Existing Distribution Lines (Out of Scope – Medium Term)*

To implement the recommended solution presented in section 4.3.3 above, the distribution lines "Tangi 2 Line" and "Tangi South Line" shown on Attachment 9 – Diagram D-7 Kajakai Substation Single Line included in the Contract will need to be upgraded from the 13.8 kV system voltage insulation level to a 20 kV system voltage insulation level. If this recommendation is accepted, the work scope should recognize that the switchgear provided by CMIC does not meet current industry standards for arc resistance and should not be installed. Either new switchgear or new open air insulated substation is recommended. Also, if this recommendation is accepted, the scope of the Tangi substation work should be revisited to ensure it meets the load and feeder requirements clarified by DABS during this assessment.

#### *4.3.5 110 kV Transmission (Out of Scope – Long Term)*

Trips sustained on the 110 kV transmission line accompanied by slow responding governors at KHPP cause units 1 and 3 to trip offline. Overhauling and the continued maintenance of the 110 kV transmission line leaving KHPP will mitigate a significant amount of trips observed. The effort to improve the 110 kV transmission line conditions will reduce transmission line trips islanding the KHPP. Additionally, repair or replacement of the distance relays at the KHPP is recommended.

#### *4.3.6 Recommendation for Mitigating Faults*

In the short and medium term, the replacement of the circuit breaker and the addition of improved protective devices will reduce the nuisance tripping. Combined with the improved response provided by new governor controls, notable generator output performance and system reliability will be achieved.

In the medium to long term, continue the transmission system upgrades downstream of the generation, both the local loads and towards Durai Junction and Kandahar.

# 5 TANGI DISTRIBUTION TRANSFORMER

The government furnished Tangi distribution transformer was stored in the Kajaki lay-down yard in a shipping container with ID TY01/145. Transformer technical data is shown below in Table 5-1.

| **GFE Transformer Data** | | | | |
|---|---|---|---|---|
| Rating (MVA) | Impedance | HV Tap | LV Tap (Generator | Cooling Class |
| 16 | 7.49% | 20 kV | 13.8 kV | ONAN |

**Table 5-1 Tangi Distribution Transformer Technical Data**

## 5.1 EXTERNAL DAMAGE ASSESSMENT

The transformer's shipping container has signs of small fire arm damage as shown below in Figure 5-1 and Figure 5-2; however, none of the fire arm damage penetrated the transformer's tank.


**Figure 5-1 Tangi Distribution Transformer External Damage #1**

**Figure 5-2 Tangi Distribution Transformer External Damage #2**

## 5.2 INTERNAL DAMAGE ASSESSMENT

Inspecting the transformer's physical body showed damages to drain valve and auxiliary piping. These damages are illustrated below in Figure 5-3, Figure 5-4 and Figure 5-5.

**Figure 5-3 Tangi Distribution Transformer – Bent Drain Valve**

**Figure 5-4 Tangi Distribution Transformer – Bent Auxiliary Piping**

**Figure 5-5 Tangi Distribution Transformer – Damaged Flex Conduit**

## 5.3 MEGGER TESTING RESULTS

Testing of the winding insulation resistance was performed and the results were positive. Testing results are shown below in Table 5-2.

| Winding insulation resistance at 5 kV dc for 1-minute | | |
|---|---|---|
| H-Gnd | H-X | X-Gnd |
| 185.5 GΩ | 133.4 GΩ | 174.7 GΩ |

**Table 5-2 Tangi Distribution Transformer Megger Testing Results**

## 5.4 OIL TESTING RESULTS

An oil sample was extracted from the transformer and was sent to the laboratory for analysis to determine contamination, if any. The lab results will show if the oil has been contaminated with outside air during the long storage period at the Kajaki site.

Due to the lack of an oil gauge on the transformer, the oil level was determined by installing a temporary external sight glass of plastic tubing from the bottom radiator to the top fill valve. This was accomplished without admitting any outside air into the transformer tanks. The oil level was found to be approximately 5.5inches from the bottom of the cover. The oil level was found to be sufficiently high to ensure that the internal core and coils are entirely submerged in oil, a requirement for transformers in extended storage.

## 5.5 CONCLUSION

The GFE Tangi distribution transformer has sustained damages while in-transit to the Kajaki area; however the damages don't deem the transformer inoperable. Provided the oil tests are positive, all the accessories are accounted for and a suitable oil processing unit is available, the transformers should be able to be successfully installed and commissioned.

# 6 110 KV TRANSMISSION SUBSTATION TECHNOLOGY AND SITE ASSESSMENT

As part of this assessment, the technology to be utilized and the site location for the substation were investigated.

## 6.1 TECHNOLOGY ASSESSMENT

Gas insulated switchgear (GIS) technology is typically specified for utility substations where limited space is available or where high currents at low voltages require added insulation due to clearance limitations. In addition GIS equipment costs are greater than air insulated equipment, particularly for instrument transformers, buswork, and switches. The gas utilized for GIS is sulfur hexafluoride, ($SF_6$). This gas depletes ozone from the atmosphere, potentially a hazardous situation. In addition, this gas and the equipment both require specific monitoring and handling.

Importantly, GIS technology has not been used in either of the DABS Helmand Province or Kandahar Province electrical systems.

An assessment of the use of gas insulated switchgear (GIS) technology for placing a substation on the roof of the existing hydro facility building was performed. The roof and structure of this building are of insufficient design to accommodate roof-mounted equipment. Placing the substation on the roof of the powerhouse will also require installing 110 kV insulated cable or compressed gas insulated bus to get to the 110 kV transmission line. In addition, the roof was not designed to accommodate personnel working on it (safety guard rails, tie off points, ingress/egress, etc.).

Since land is available for an air insulated substation in the vicinity of the generating plant, the use of air insulated technology is recommended for the new Kajaki substation. Using this technology will also allow similar equipment (circuit breakers and transformers specifically) and bus configurations (breaker and a half) to be utilized as is planned for Kandahar City Breshna Kot substation and Kandahar City East substation.

## 6.2 POTENTIAL SITE LOCATIONS

Due to the location of the hydro facilities and the area's engineering geology, a limited number of potential sites were identified.

### *6.2.1 Site Selection*

Three sites located above and south of the existing switchyard and powerhouse were assessed for the new 110 kV substation. Access to the three sites is from the main road located near the Tangi bridge. The dam access road and intake access road fork off of the main road. The military path, road branching off the intake access road, is only passable using heavy duty 4-wheel drive vehicles. A layout of the three assessed sites with respect to the KHPP area is shown below in Figure 6-1.

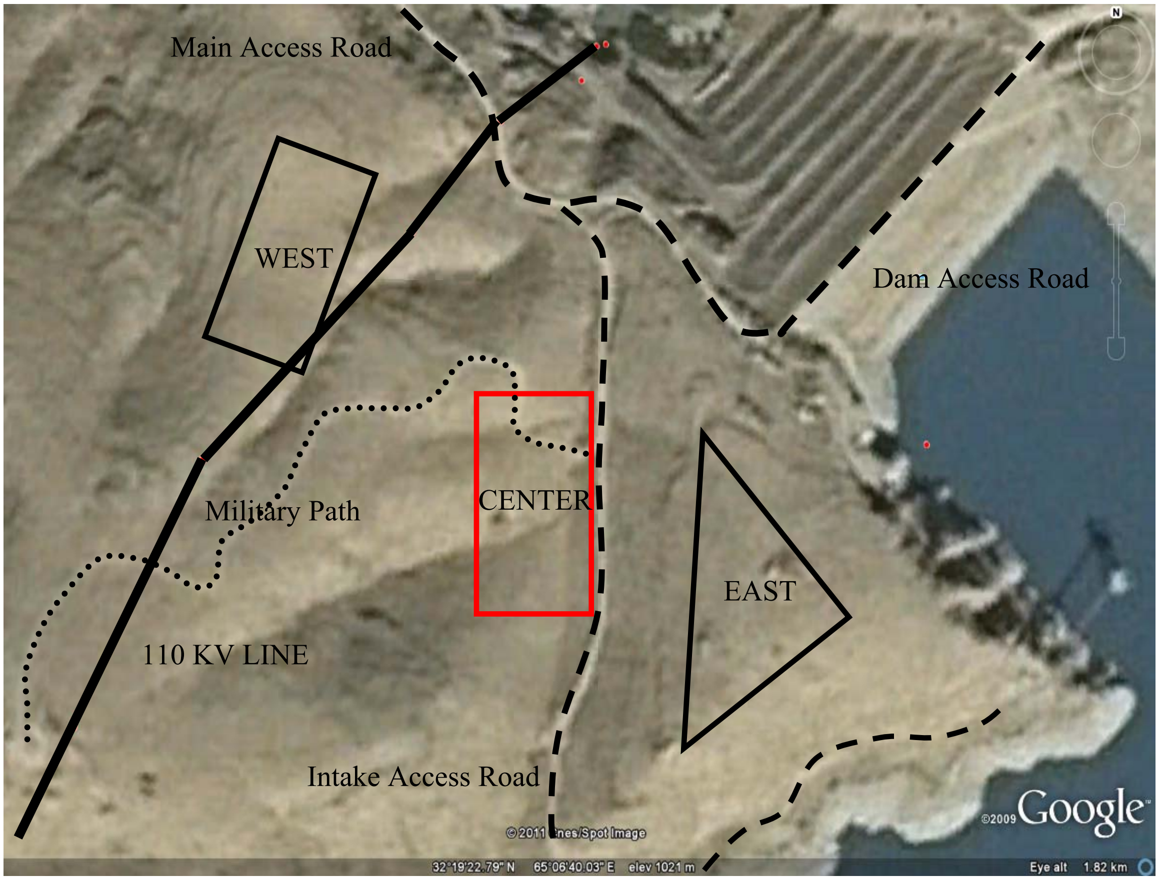



**Figure 6-1 Layout of Assessed 110 kV Substation Sites**

The west site is located west of the existing 110 kV lines on a relatively flat lying bench below the Military outpost. The site has the advantage of requiring minimal cut and fill, and is the largest of the three sites. Disadvantages of the west site are access and its location west of the 110 kV line. An access road will have to be built roughly following the exiting path and travelling under the 110 kV lines to the site. Access from the west, north and southeast would be prohibitive.

The east site is located on a hilltop immediately south of the Kajaki dam. The east site location should not be considered as a substation site since it is located on an irregularly shaped triangular hilltop which will require significant blasting or rock removal in order to increase the size of the site to the minimum size required. Also, access to the east site will be extremely difficult, requiring a long ramp cut into the hillside approaching from the north, and wrapping around the south side. The intake road wraps around the site, just above the lake shoreline which may subject the intake road and structure to rock falls during blasting and grading operations.

The center site, proposed, is located along the existing intake access road. The center site has the best access of the three sites, low visibility and is positioned on the preferred side of the 110 kV lines. The disadvantages include the presence of three drainage pathways through the site, and a large net fill requirement that will have to be brought in to level the site. An access loop could approach the site from the north, extend along the west side, and return to the intake road on the south side of the site giving trailer loads ample turning room. An illustration of the proposed 110 kV site is shown below in Figure 6-2.

### *6.2.2 Engineering Geology*

The proposed site is located in a saddle/valley south of the existing powerhouse 110 kV substation. The entire site is located over exposed Triassic limestone dolomite bedrock. The limestone and dolomites are expected to have unconfined compressive strengths in excess of 150 MPa. An illustration of the proposed 110 kV site is shown below in Figure 6-2.


**Figure 6-2 Kajaki New 110 kV Substation Proposed Site**

## 6.3 SITE CHOICE CRITERIA

The proposed substation site is located east of the existing 110 kV transmission line. The following factors were considered in determining the proposed site:

- New transmission line construction for both the existing and new power houses will not have to cross over existing transmission lines.

- The site is located in a topographic low point, approximately 70 meters below the easternmost military outpost at Forward Operating Base Zeebruge.
- The site's elevation is approximately 60 meters above the existing powerhouse.
- The low profile location and favorable location east of the existing transmission lines will allow construction without interference with plant operations.
- The site is located immediately adjacent to the dam/intake access road. The road was used to support construction of the original intake structure, and will be sufficient for construction of the substation with minor grading and maintenance.
- The road slopes at approximately 10% adjacent to the substation site and originates about 100 meters southeast of the Tangi bridge. The road may require some safety improvements due to the steep section.

## 6.4 KAJAKI SUBSTATION ENGINEERING AND CONSTRUCTION CONSIDERATIONS

For the site selected, significant amount of site preparation work will be required, including site grading, managing the borrow material, and obtaining appropriate aggregate for site grading and substation surfacing for electrical insulation, and road construction.

### *6.4.1 Site Grading*

The site is located at the intersection of three intermittent stream channels, which will require significant filling to create the substation platform. The site slopes approximately 14 meters over a distance of 180 meters. Assuming only minimal excavation, the site will require a minor amount of fill at the south end, and thicken to roughly 12 to 14 meters at the north end. . A substantial amount of shot rock fill is available north of the dam, originating from the spillway excavation. Drainage from the three intermittent streams will be routed around the platform in open ditches.

### *6.4.2 Borrow material*

Borrow material for the site will be excavated using a conventional excavator (track-hoe), and loaded into local tandem dump trucks. Spreading will require a large tracked bulldozer. Some excavation at the site may be necessary, using a hoe-ram excavator attachment. Alternatively, hand-held air drills/jackhammers powered by an air compressor may be used.

### *6.4.3 Aggregate*

The stockpile of shot rock from the spillway is entirely composed of hard limestone and dolomite. This material is suitable for use as aggregate for a wide variety of construction applications, including concrete aggregate and substation surfacing aggregate. Crushing and screening equipment will be required to process the shot rock into suitable gradations.

# 7 20 KV DISTRIBUTION LINE ROUTE

Similar to the substation, due to the location of the hydro facilities, Tangi village, and the area's engineering geology, a limited number of potential routes were identified. The preferred 20 kV route through Tangi Village was discussed with local DABS staff prior to our assessment.

## 7.1 DESCRIPTION OF THE PREFERRED ROUTE

The new 20 kV line will leave the power house and follow the existing 13.8 line along the river road/plant access road. The line will run due south from the bridge, avoiding existing buildings and olive trees, before heading southwest across a hillside. The route along the hillside will attempt to keep a relatively constant elevation before travelling down slope to an area just south of the southern most structure in the village. The line will take a small turn to the south west and traverses a broad open relatively level area before turning northwest at a main road. The line will travel along the northwest road, past the Afghan National Police Station, then turns west into the Tangi Substation. A preliminary line routing drawing is included in Appendix-A

## 7.2 ENGINEERING GEOLOGY

Three geologic units are along the 20 kV alignment; Triassic limestone and dolomite; Quaternary alluvial fans; man-made fill. The steep hillsides are typically exposed hard bedrock composed of limestone and dolomite with estimated unconfined compressive strengths greater than 150 MPa. The bedrock jointing is very wide, meaning the joints not spaced closely enough to provide any help with excavation. Rock beds are massive, meaning they are greater than 600 mm, also making conventional excavation methods very difficult. The alluvial fans are broad and gently sloping areas of unconsolidated fine grained silty clay, and coarse grained sand and gravel. The man-made fill is generally shot rock (blasted limestone rubble).

The river crossing points are located in a sandy river alluvium with intermixed cobbles and boulders. Both the north and south end appear to be within an area subject to flooding. North of the river, the 20 kV line will stay east of Tangi Village, and the olive tree orchard, and stay on the northern edge of the developed area as it turns to the west. The line will intersect a northeast/southwest trending road, just north of the Afghan National Police station, where the line will follow the road to the Tangi Substation. The hillside between the north end of the Tangi bridge to the northeast most village building is predominantly exposed limestone bedrock with small areas of thin colluvium. From the northeast corner of the village to the Substation, the route is underlain by unconsolidated alluvial fan deposits.

## 7.3 TANGI ROUTE AND SUBSTATION ENGINEERING AND CONSTRUCTION CONSIDERATIONS

For the route selected, several key design factors need to be considered: existing interferences, the need for a river crossing and its associated design requirements, and obtaining appropriate equipment to construction the line.

### 7.3.1 *Construction Interferences*

- An olive orchard is located just beyond the north end of the Tangi bridge which will need to be avoided. No more than 4 to 6 trees will need to be removed at either end of the river crossing. Beyond the olive orchard, there is no significant vegetation along the alignment.
- The preferred alignment extends around the north side of the uninhabited Tangi village. Buildings or structures do not interfere with the route alignment.
- The existing 13.8 kV line occupies the route from the powerhouse to the Tangi bridge. The 13.8 kV line splits and crosses the bridge on the east and west sides, then runs down the main street through Tangi village to the substation. The new route avoids the village, traversing north of the developed area.

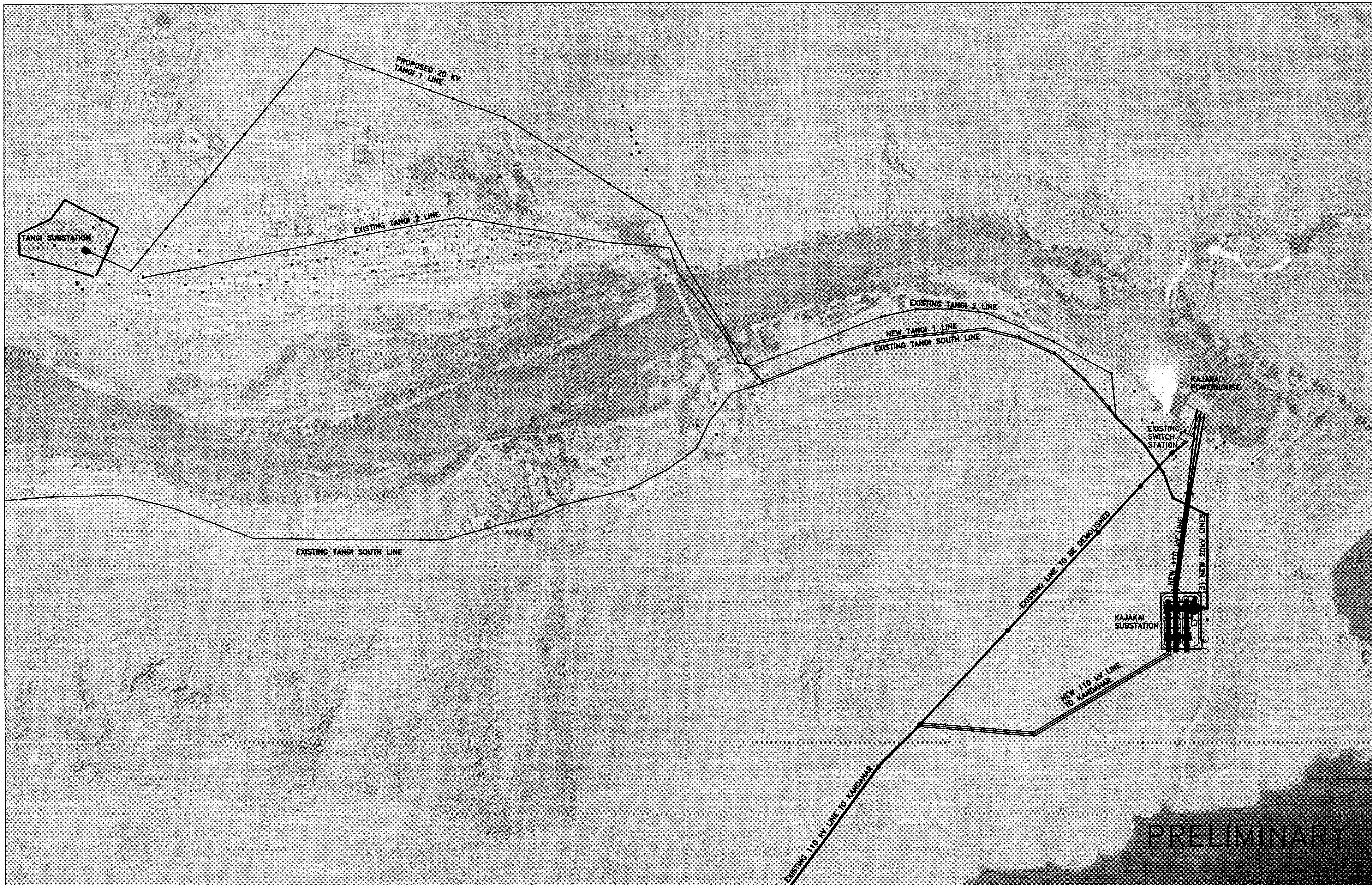
### 7.3.2 *River Crossing Observations*

- The Helmand River crossing will require a span length of 125 to 130 meters. Appropriately sized structures are required to span the river.
- Two (2) 13.8 kV existing distribution lines are running parallel to the bridge. The existing lines are located adjacent to the east and west sides of the bridge. The new distribution line can be located immediately east of the existing 13.8 kV line.
- The existing 13.8 kV lines do not impact air operations. Air operations typically operate between the lower LZ and the Reservoir. Occasional medical evacuation flights will fly below the canyon walls, therefore the new 20 kV distribution line should include markers where spanning the river.

### 7.3.3 *Anticipated equipment required to build the line*

- An auger truck for drilling foundations
- Crane with basket for setting poles and for use as a man-lift for installing hardware
- Tensioner to hold conductor reels while stringing
- Puller to pull conductor through string blocks
- Stringing blocks
- Flat bed truck for transporting poles and materials.

# 8 APPENDIX A – PROPOSED 110 KV STATION AND LINE ROUTING

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KANDAHAR HELMAND POWER

KAJAKAI
PROPOSED 110 KV INSULATED & 20 KV TANGI ROUTE

PROJECT. DWG NO.
042246-KJKI-C0003
DATE: 11/MAR/11
SCALE: NONE