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Author(s):	John (Jack) Whippen
Contractor:	Black & Veatch Special Projects Corp.
USAID Agency:	USAID Office of Infrastructure, Energy, and Engineering - Afghanistan COR: Massoud Orya
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Kandahar City Distribution Planning Study Results

Kandahar Helmand Power Project

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COTR: Thomas Bauhan P.E.
Office of Infrastructure, Energy and Engineering (OIEE)
U.S. Agency for International Development (USAID)
Great Massoud Road
Kabul, Afghanistan

Name of Submitting Party: Black & Veatch Special Projects Corporation

Organization: Federal Services Division, Kandahar Helmand Power Project (KHPP)

Address: Highway 4, Across from Kandahar Airfield, c/o AMTEX Village, Kandahar Afghanistan

Telephone: 93 (0) 799 620 012

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1.0 EXECUTIVE SUMMARY

Using data gathered by a previous USAID assessment, a high-level system analysis was performed on the Kandahar City 20 kV distribution system, including an assessment of 20 kV/400 V stepdown transformer stations' loading. The system analysis reported was undertaken in order to identify the 20 kV system (medium voltage) system improvements which will be required to serve all the presently connected customers, the customers connected but not to available generating capacity, and the customers desiring to be connected to the electric system.

System medium voltage feeders were modeled using loadflow simulation software. Known actual loads for existing customers were used. Estimates for new customers' loads were made and added to the system loads. System peak loading was analyzed assuming all connected customers at their peak demand. No contingency switching or loading was analyzed. The additional feeders planned to be obtained by the rebuilding of Breshna Kot substation were modeled.

The summary of findings includes:

1. The 20kV feeders will require little reconductoring due to overall loading or voltage issues. Feeder backbones do not need to be upgraded above 120mm^2 ACSR conductor.
2. Voltage regulation can be achieved on the 20kV system by utilizing fixed capacitor banks.
3. Full utilization of generation at Bagh-e-Pol and SIPD can be gained by some moderate facility expansion on the 20kV system.
4. The most significant 20kV feeder work will be for
   a. establishing the nine feeder backbones out of the new Breshna Kot substation.
   b. transferring some loads between feeders to balance loads on the nine feeders.
   c. building and reconductoring some line sections to facilitate the transfer of loads between feeders to utilize the full generation capacity at Bagh-e-Pol and SIPD.
   d. installation of approximately nine 1200 kVar fixed capacitor banks.
5. A significant number of additional replacements and upgrades of 20kV-400V transformers will be needed.
6. For a complete study of the load flow, a follow on study of the extensive 400V networks will be warranted when substation, transformer, and customer load data is available.

Additional work could also be completed for recommendations detailed 20 kV feeder work and 20 kV/400 V step down transformer station (T/S) upgrades and additions required to serve all the known and anticipated customers at full load. Additional work recommendations include guidance for conductor sizing for 400 V secondary and service extensions.

A System Planning Criteria and Guidelines Manual should be prepared and provided to DABS and MEW, along with training on data maintenance and system planning to build system planning capabilities within the DABS Kandahar organization.

The MEW material and design standards should be translated into Pashtu and provided to DABS along with training on the use of the standards, both for design and for construction.

2.0 BACKGROUND

Presently, the electric power distribution system in Kandahar City is currently distributing all available generation energy to the city. The load requirements in the city cannot be met by the existing transmission system infrastructure or generation capabilities. The local utility operator must impose rotating generation outages in order to provide part-time service to all the connected customers. Furthermore, many customers are not connected who desire to be connected are not, either because no electric system infrastructure exists in their neighborhood or because generation is not available to support their requirements.

These conditions result in a social and economic burden on this community and have been identified as a priority for ISAF COIN objectives. Funding is now available to rebuild the Kandahar electrical distribution systems, upgrading its physical condition, connecting new customers, and optimizing the overall system.

Improvements are planned for generation, transmission, and substation infrastructure. The existing Breshna Kot substation is being rebuilt. Breshna Kot currently receives energy from the Kajaki Dam Hydroelectric Facility in northeast Helmand Province using a 110 kV transmission line. The substation transforms the power to 20 kV and distributes it throughout the city on five (5) 20 kV feeders. In addition, local generation is present at the substation using two sets of generators. Fourteen KTA-50 generators provide alternating service to two (2) feeders. Due to the poor performance of the 110 kV transmission line, six QSK-60 generators provide backup energy to the 110 kV service. The KTA-50 generation condition and remaining life is being evaluated and the substation is being replaced. With the new Breshna Kot substation, eight 20 kV load feeders and four local generation 20 kV feeders are being installed.

In addition to the substation improvements, local generation is being added. At Breshna Kot, the KTA-50 generators are being replaced with fourteen 1.5 MW units. The QSK-60 generators will remain as backup to the 110 kV transmission line until the transmission line reliability improve. At Bagh-E-Pol, eight (8) generating units have been recently installed on Feeder 511. At Shurandam Industrial Park, USACE has installed eight (8) 1.8 MW generating units (SIPD – DABS) and USAID has installed ten (10) 650 kW generating units. The sizing these two generating facilities have been de-rated from their nameplate values due to the site conditions (ambient temperature and altitude).

These generating facilities are connected to feeder 514. Feeder 514 has been divided into the North Feeder 514 and South Feeder 514 outside of the industrial park. Both Feeders 511 and 514 are isolated from the Kajaki and KTA-50 generation at the existing 20 kV switchgear in Breshna Kot substation.

During 2009-2010, a USAID project, AIRP Task Order -22 (TO-22)[1], visually assessed the condition of the electrical infrastructure in Kandahar City. This study is referred to as the “Kandahar Existing Distribution System Technical Condition and Expansion Assessment. (EDSTCA).” For this condition assessment, electrical system data was gathered and mapped on a geographical basis. Then, replacement work was identified and system expansion work was identified, both based on a visual assessment of present condition.

TO-22 also modeled feeder and transformer loading based on field investigation of customer connections. This modeled load data provided the basis for this Planning Study. This modeled data

[1] Afghanistan Infrastructure and Rehabilitation Program, Contract Number 306-I-22-06-00517-00, Task Order 22, Kandahar Existing Distribution System Technical Condition and Expansion Assessment, 30 September 2010.

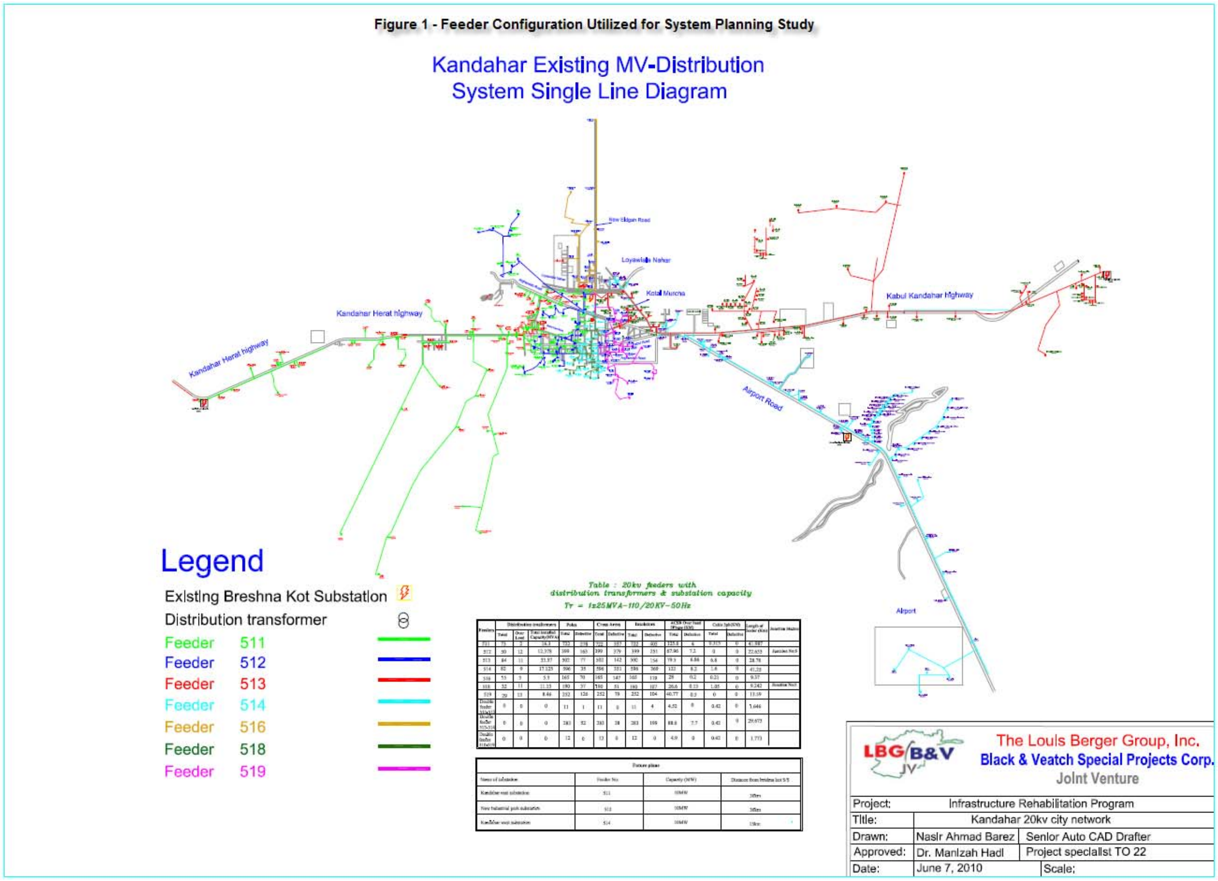
has not been verified with actual measured values for two primary reasons: 1) the substation metering instrument transformers do not have calibration records and 2) the distribution transformers do not have metering information. The scope of TO-22 does include the installation of boundary metering at the distribution transformers; however, the work has not been completed at this time.

3.0 METHODS AND ASSUMPTIONS

3.i Feeder data

The feeder configurations identified by TO-22 were utilized as the base data for this planning study for feeder lengths, wire sizes, structure configuration, and transformer sizes. The overall layout and extents of the feeders are shown in Figure 1 - Feeder Layouts and Extents.

Figure 1 - Feeder Layouts and Extents



3.ii Load data

The quantity of loads to be served was modeled using a seasonal analysis, load balancing and power factor assumptions, and the TO-22 transformer station data. Next, existing loads were escalated recognizing that the current usage is limited by generation capacity, not customer requirements. To these load levels, the estimated loads for the customers that are planned to be connected by this Contract and the customers who are ready to be served when the generation in this Contract were modeled. The assumptions and approaches for the load data estimates are as follows:

Seasonal Analysis: Based on historical loading data compiled, the winter season was determined to be the critical system peak load season. The study was modeled using conductor and equipment ratings are for the winter season. Winter peak loads were entered into the model.

Load phase balance and power factor: A system wide native power factor of 90% was used in modeling all existing and future loads. Furthermore, all unbalanced phase loads were averaged per transformer and were modeled as balanced three phase loads.

Feeder loading for existing customers: The loading data was taken from the stepdown transformer station tables from TO-22. For modeling the 20 kV feeders, <u>no diversity factor was</u>

used in this analysis. All the transformers were modeled with their individual peak loads occurring at the same time. This assumption is a conservative approach, ensuring adequate capacity is available. The true feeder coincident peak loads will be less due to diversity. This will allow for some increase in individual loads.

Transformer loading for existing customers: Existing connected individual 20 kV/400 V step-down transformers' peak loads were reviewed. On an individual transformer basis, loads were up-scaled by 15% to account for forecasted load growth when a constant supply of power is readily available as shown below.

Table 1 - Existing Transformers' Loading by Feeder

Feeder	Present Load (MW)	Existing Customers' Potential Increased Loading (MW)
511	7.9	9.0
512	7.7	8.8
513	7.1	8.1
514	6.0	6.9
516	4.0	4.6
518	7.0	8.1
519	6.8	7.8
Total	46.5	53.3

Future loading for new customers: The additional 16,822 customers that are to be served were reviewed at a transformer level, resulting in the following potential loading on the existing feeders.

Table 2 - Potential Transformers' Loading by Feeder

Feeder	Present Load (MW)	Potential Future Loads Additions 16k Additional Customers (MW)
511	7.9	1.9
512	7.7	0.6
513	7.1	14.7
514	6.0	6.8
516	4.0	0.6
518	7.0	0.4
519	6.8	0.5
Total	46.5	25.5

3.iii Modeling

The 20 kV electric distribution system was modeled using ETAP 7.5 using the basic software package. The distribution lines were modeled with standard single circuit configuration with no neutral.

The following general criteria and assumptions are:

- Breshna Kot 20 kV bus regulated at 102% Voltage
- Conductors loading limits at rated ampacity. (see Appendices)
- For these preliminary findings, a 98% voltage criteria on the 20 kV feeders was utilized. In the final report, a more robust voltage criteria could be used, factoring in voltage drop across 20 kV-400 V transformers and on the 400 V system.

The analysis method:

- Is limited to normal peak load with no diversity.

- Does not include contingency analysis

4.0 PRELIMINARY RESULTS, FINDINGS, AND RECOMMENDATIONS

Table 3 - Breshna Kot Loading for Existing Customers shows system modeling resultant statistics expected at the existing Breshna Kot Substation before the addition of new customers, without any local generation. The supporting loadflow models to support this summary is included in Appendix D – Loadflow Data.

Table 3 - Breshna Kot Loading for Existing Customers

Feeder	Number of T/S	Main Branch	Peak Amps	Peak MVA	Main Branch Loading	T/S <98%	Lowest Voltage
511	73	120 mm²	222.7	7.9	54.3%	45	96.45%
512	50	120 mm²	215.7	7.6	52.6%	0	99.26%
513	82	120 mm²	196.6	6.9	47.9%	22	97.74%
514	82	120 mm²	164.7	5.8	40.2%	57	96.38%
516	15	95mm²	115.5	4.1	33.0%	0	101.17%
518	32	120 mm²	202.9	7.2	49.5%	0	99.39%
519	28	120 mm²	193.5	6.8	47.2%	0	99.78%
			Total MVA	**46.3**			

<u>20 kV Feeders</u>

Assuming that the condition of the conductors and their hardware are in adequate condition to meet the designated capacity rating, Table 3 - Breshna Kot Loading for Existing Customers illustrates that the 20 kV feeders need no reconductoring due to overload or voltage drop. The two additional feeder positions will allow connection of new customers without overloads, and will be allow diversions to minimize individual feeder loading. During normal conditions when local generation on 511 and 514 is operating, average feeder loading could be further reduced. With the additional two feeder positions, the additional 16,822 customers that are to be connected will not create loading problems on the feeders.

The operating limitation for the 20 kV feeders is the existing switchgear feeder breakers limited to 150 Amps. The new Breshna Kot switchgear should have breaker and relay limits of at least 400 Amps to fully utilize the capacity of the 120 mm^2 conductor. No conductor larger than 120 mm^2 will be needed on any of the 20 kV feeders.

Voltage regulation concerns were noted which can be addressed with 20 kV capacitor bank installations. A preliminary estimate is that the feeders with the worst voltage concerns could be addressed by installation of no more than a total of nine 1200 kVAR "fixed" capacitor banks.

With the additional two outgoing feeders for the new Breshna Kot configuration, resulting in a total of nine outgoing distribution feeders, and further assuming installation of some capacitor banks, loading and voltage on the 20 kV system will not be an issue. The recommended 20 kV feeder work will be exclusively for establishing the new feeder routes, balancing the system loads on the resulting nine feeders, and possibly some additional tie switches for operating flexibility.

<u>Local distributed generation sources</u>

The new generation will be placed in the main branches of feeders 511 and 514. Little or no reconductoring will be required to utilize the distributed generation. Generation at Bagh-e-Pol can supply the entire load on feeder 511 and possibly some on an adjacent feeder. A good candidate is feeder 516. Generation at SIPD will be under-utilized without system changes to allow more load to be served by it. The SIPD generation far exceeds loads on feeder 514. One promising option to be studied further is connecting part of feeder 513 to 514. This approach will require some reconductoring work.

Distribution 20 kV/400 V Stepdown Transformer Station Loading

Several of these distribution transformers will need to be upgraded, and several new will need to be installed. Below is a very high level summary of the preliminary findings:

Table 4 - Overloaded Transformers by Feeder

Feeder	Overloaded Transformers	Total Overload (MW)
511	2	0.02
512	7	0.5
513	5	0.5
514	8	1.2
516	2	0.2
518	7	0.5
519	10	0.4
Total	41	

Secondaries, Services and Metering (400 V)

In this preliminary phase of the study, the 400 V systems were not modeled; however, based on reviews of the facility maps and field conditions, modeling and analysis will likely identify a significant quantity of voltage drop and overloaded conductor issues. Any 400 V modeling work will require load data from both the individual transformers and from customer meter data.

Customer Loads, Mapping, and GIS

New transformer stations since the TO-22 are believed to have been connected, energized, and in-service and not included in the information for the system. Given some of these installations have been identified, a modeling gap may exist depending on with how many have been installed and not identified on mapping or GIS system.

System Condition

Field reviews of existing system material and equipment condition indicate that general condition of the facilities on the 20 kV and 400 V system are impacting service availability and reliability as much or more than system design. This impact of condition on reliability will certainly be true after the recommended system expansions have been placed in-service. Getting the system to an operable, reliable condition should involve not only system planning, but must also include attention to design standards, construction standards and practices, and maintenance programs.

Illegal connections are an important part of this as they are typically connected in a manner that will negatively impact reliability.

5.0 FURTHER STUDY / FINAL REPORT / NEXT STEPS

As noted above, the findings of this study are highly dependent upon the data provided by TO-22 and may be different if the all installed facilities are known. Future study work should be put on hold until additional field data is obtained from the new substation metering, new transformer station metering, and/or customer metering data is obtained (at least two of these three sources of data).

With additional data, the models could be refined to to confirm these preliminary recommendations, and use the further refinement to look more precisely at system needs.

A System Planning Criteria and Guidelines Manual should be prepared and provided to DABS and MEW, along with training on data maintenance and system planning to build system planning capabilities within the DABS Kandahar organization.

The MEW material and design standards should be translated into Pashtu and provided to DABS along with training on the use of the standards, both for design and for construction.

On a parallel path with the infrastructure improvements is the requirement to develop additional distribution system planning capabilities (capacity building) with the local utility. With system improvements and planning capability improvements, DABS will be able to plan and develop the electric power delivery system, in concert with industrial and economic development, to achieve social and economic stability in the region. Part of the training will include providing loadflow modeling software and models, along with hardware for the same.

A work plan for executing the recommended system improvements could be prepared.

6.0 APPENDICES

APPENDIX A

EXISTING AND PLANNED SUBSTATION 20 KV CONFIGURATION

The current substation configuration utilizes 7 outgoing feeders (511, 512, 513, 514, 516, 518 and 519) each connected to a circuit breaker with a current carrying capacity of 150 amps. Due to this ampacity rating, each feeder has maximum operating capacity of 5.19 MVA with the load settings on the protection relays set at 5 MVA.

The current substation configuration also utilizes uses 3 incoming generation feeders (581, 582, and 583) each connected to a circuit breaker with a current carrying capacity of 800 amps. At the time of this report, circuit breaker 582 is out of service.

Figure 3 - Existing Kandahar Breshna Kot Substation Configuration illustrates the existing configuration. Figure 4 - Existing Switchgear Lineup illustrates the physical lineup of the feeders within the control building switchgear.

Figure 3 - Existing Kandahar Breshna Kot Substation Configuration

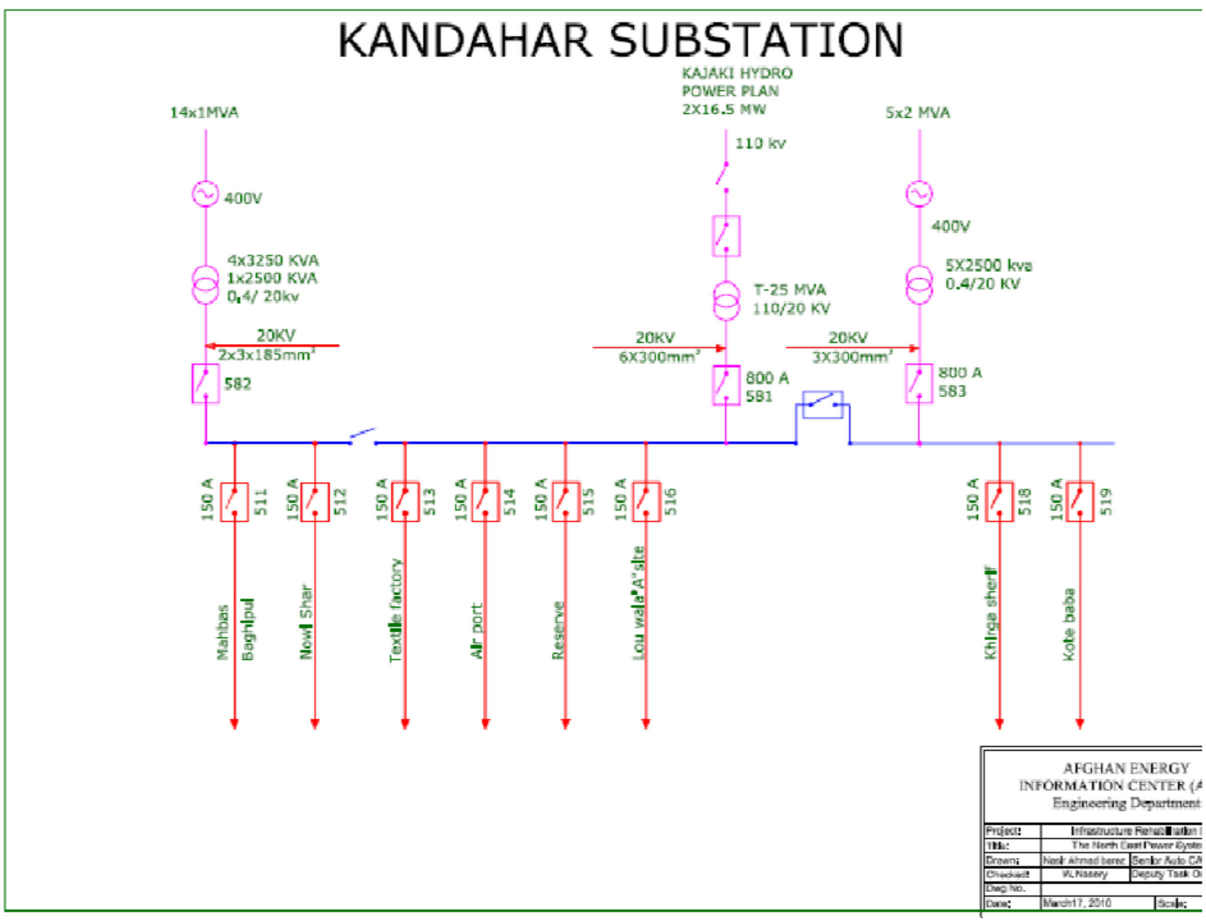


Figure 4 - Existing Switchgear Lineup

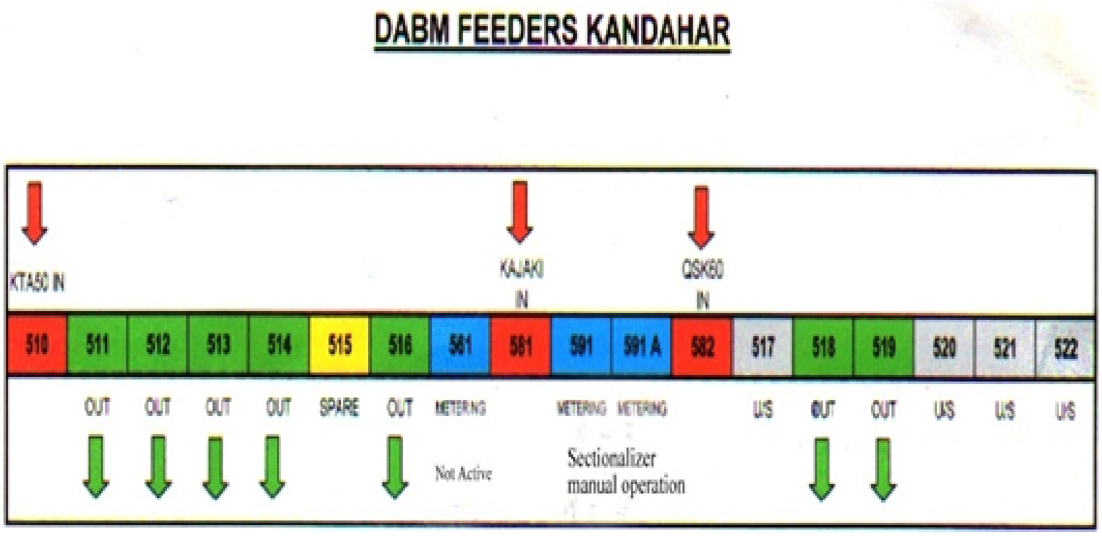
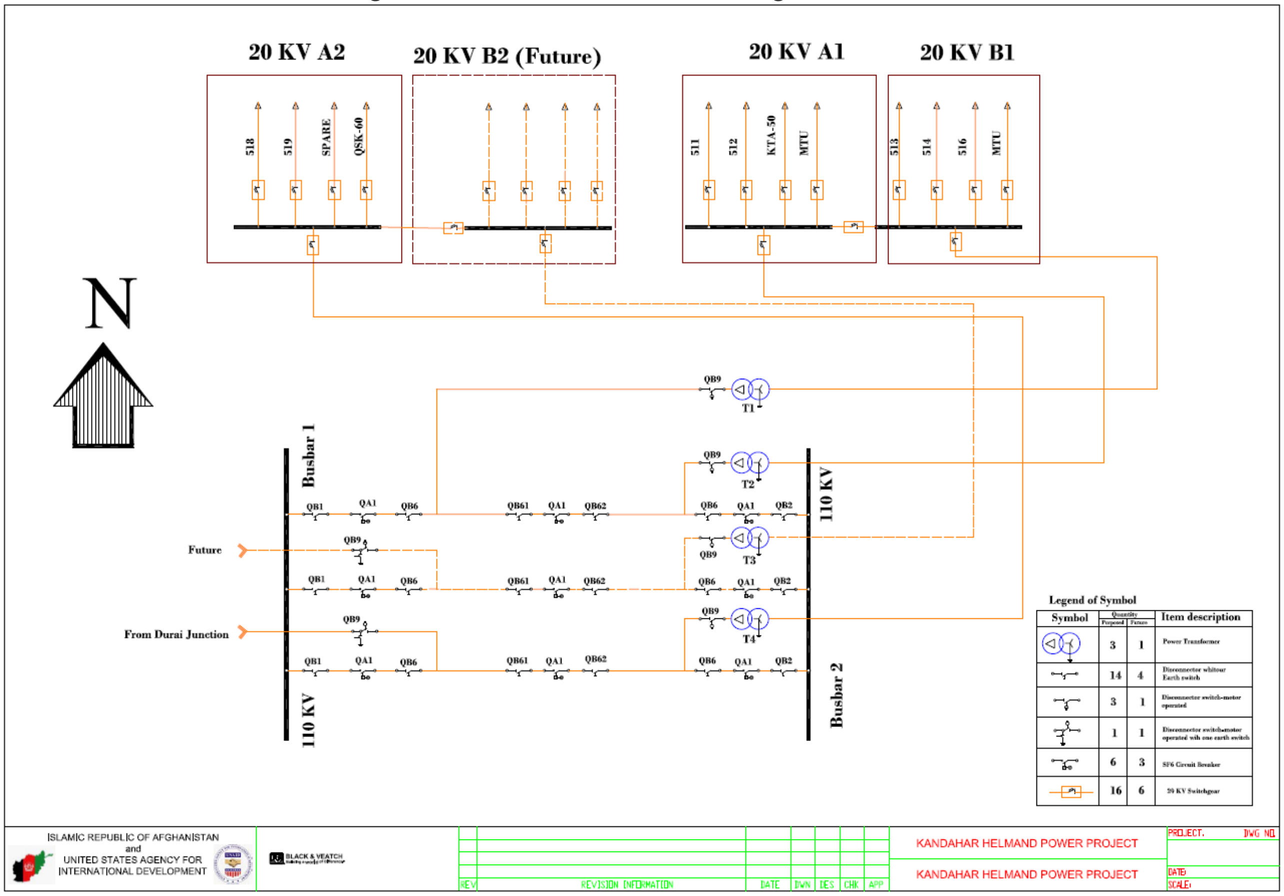


Figure 5 - Planned Substation Configuration



APPENDIX B

RATINGS FOR AVAILABLE CONDUCTOR SIZES FOR MV AND LV

Standard Conductor Sizes

In the following table there are the ACSR conductors that are either existing or proposed for new feeders with corresponding ampacity according to DIN 48204, and apparent power with 20 kV without accounting for voltage drop.

Table 5- Ampacity of DIN 48204 ACSR conductor sizes

Conductor Size	Ampacity (Amp)	Apparent Power (MVA)
25 mm^2	125	4.3
35 mm^2	145	5.0
50 mm^2	170	5.9
70 mm^2	290	10.0
95 mm^2	350	12.1
120 mm^2	410	14.2
185 mm^2	535	18.5
240 mm^2	645	22.3
300 mm^2	740	25.6

APPENDIX C

REFERENCE DEFINITIONS (Standards Committee of IEEE)

Term	Definition
Diversity Factor	The ratio of the sum of the individual maximum demands of the various subdivisions of a system to the maximum demand of the whole system.
Load Factor	The ratio of the average load over a designated period of time to the peak load occurring in that period.
Power Factor	The ratio of total watts to the total root-mean-square- (RMS) volt-amperes. For this system, the ratio of Active Power to Apparent Power. The lower the power factor, the more power is required to be produced to support the loads. Power factor reduction is typically associated with industrial load additions.

APPENDIX D

LOADFLOW DATA

Adobe Acrobat
Document

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