BELIZE ELECTRICITY LIMITED

REPORT ON ASPECTS OF THE POWER 2 PROJECT COMPONENTS POW2-1 TO POW2-4

CARILEC'S ENGINEER'S CONFERENCE
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BRIEF DESCRIPTION OF TRANSMISSION LINES

A 115 kV line was built from West Substation running north to interconnect with Mexico at the Xulha Substation.   The length of the main 115 kV line is 82.5 miles long with a short 3.75-mile section from the Belize-Mexican border to the Mexican Substation Xulha.

A 34.5 kV line was built at Mile 31 on the Western Highway to Dangriga Substation just outside of Dangriga Town, from the existing 115 kV that extends from the Mollejon Hydro Plant to West substation and then to Belize City. This 34.5 kV line is 39.5 miles long.

The existing Mollejon 115 kV line is 88.9 miles long with the Belmopan Tap being 2.17 mile long.

And a 34.5 kV line was built from Maskall Tap Substation to the coastline to interconnect with the submarine cable and another 34.5 kV line was built from the other end of the submarine cable to San Pedro Power Town. The 34.5 kV line to the coastline is 7.9 mile long and the section on San Pedro is 6.0 miles long.

In general the lines were built to REA standards for 115 kV and 34.5 kV lines.

The three new lines mentioned completes the National Grid that supplies all major load centers except four small areas.

The locations of the various lines are shown in Figure 1.

DESIGN FEATURES OF THE LINES

Wind Speed

The three lines were designed to meet the loading criteria of both the REA and NESC.

Design Condition	*Wind Velocity*	*Temperature*
Maximum wind gust	265 km/h = 73.61 m/sec	$30^{o}C$

An overload factor of 1.0 was applied to the loading from the maximum wind gust. This overload factor of 1.0 was considered suitable for the specified hurricane winds with a maximum gust of 265 km/h because:

- The maximum wind gust recorded from 1962 to 1992 at Philip Goldson International Airport near Belize City is 68 knots that equals 126 km/h (35 m/sec). This wind velocity has a return period of approximately 200 years.

An overload factor of 4.0 was applied to the vertical load on wood crossarms.

Lightning Protection

This led to the shielding angle from the overhead shield wire to the outer phases to be 30 degrees. A typical A – Frame structure is shown in Figure 2.

In addition each 115 kV transmission line pole was grounded using No. 5 solid galvanized steel wire attached to the OHGW and extending the full length of the pole and wrapped around the butt.

Pole Protection

The poles in the Carmelita to Santa Lucia section of the 115 kV transmission line (through sugarcane fields in the Northern part of the country) are protected from the effects of fire from sugarcane burning by means of rock caissons around the bases. This design is shown in Figure 3.

Vibration Damping

Stockbridge dampers provide vibration damping on the conductors and OHGW of the 115 kV line, one damper per span. For long spans (i.e., river crossings), two Stockbridge dampers per span are installed. Stockbridge dampers were not installed on the 34.5 kV lines because of the reduced every day tension limits. Armour rods are installed on both the 115 kV and 34.5 kV lines.

Foundation

The soil type encountered along the line route varied from good to swamp or technically classified as Type A, B and C. The classification according to ASTM is:

Soil Type	A	B	C
Visual Classification to ASTM D2487 & D2488	SC & MH	CH & CL	OL
Description	MARLS	FAT & LEAN CLAY	ORGANIC BLACK CLAY
Vertical Bearing Capacity – Long Term Loads	400 kN/m^2	200 kN/m^2	25 kN/m^2
Vertical Bearing Capacity – Short Term Loads	1200 kN/m^2	600 kN/m^2	50 kN/m^2

To design each structure the soil type for the 115 kV line was determined at every fourth structure and the 34.5 kV line at every mile. During construction the foundation was also adjusted to actual site conditions. The various designs are shown in Figure 4.

Because of the difficult terrain and the type of foundation, primarily because of the need to transport backfill for those structures requiring Type C foundation, the cost per structure in swamp varied to as much as 4 times the cost in Type A soil.

SPECIAL CHARACTERISTICS OF EACH STRUCTURE

Because of the design the following special design features were used:

1. For those Type A structures in type C soil side guys were used as shown in Figure 5.

2. In the cane fields porcelain insulators were used instead of the polymer insulators.

3. An overhead shield wire was used on the 115 kV line but not used on the 34.5 kV line that instead was insulated to 69 kV.

CONTAMINATION STUDY AND CORROSION STUDY

Because, as shown in Figure 1, the line traverses close to the coastline and in fact the 34.5 kV line traverses within the coastal zone a corrosion study and a contamination study was done. The first was done to choose the type of conductor and fittings and the amount of galvanizing and the second study was done to choose the leakage distance in mm/kV.

Corrosion Study

Based on the CLIMAT test results, the corrosion severity for the transmission lines can be summarized as follows:

LINE SECTION	***MCI Index***		***Classification***
	Maximum	***Minimum***	
115 kV line West substation to Maskall	3.5	1.4	Moderate
115 kV line Maskall to Mexican border	2.3	0.8	Negligible
3.4 kV line Maskall to mainland coast - Section from Maskall to within 2 km of coast - Section from 1 km of coast and coast	 3.5 10.6	 1.4 7.6	 Moderate Severe
34.5 kV line on Ambergris Caye	4.8	5.4	Moderately Severe
34.5 kV line to Dangriga	3.5	1.4	Moderate

Based on prices obtained from conductor suppliers it was determined that AAAC conductor was between 7% and 12% less expensive that the equivalent ACSR in addition to having better corrosion resistance and, considering the CLIMAT study results, all aluminum alloy conductor (AAAC) was used for all lines.

AAAC conductor (without grease) was used for the length of the Maskall to San Pedro line within 1 km of the mainland coast because it was not considered practical to purchase a short length (3 km) of greased conductor.

Insulation

Based on the findings of the insulation test program and the site pollution level, the criteria for pollution levels was based on the recommendations provided in Table II of IEC 815, which is:

Pollution level	Minimum nominal specific Creepage (mm/kV- LL)
I - Light	16
II- Medium	20
III - Heavy	25
IV - Very Heavy	31

The insulation requirements for the transmission lines and substation equipment were then determined to be:

System Component	***Pollution Level Classification***	***Minimum Creepage Distance (mm)***	***Type of Insulator Recommended***	***Remarks***
115 kV line excluding sugarcane fields	II-Medium	2460	Polymer	Equal or better than porcelain, lightweight, easy construction, standardization (similar to existing line).
115 kV line in sugarcane fields	III-Heavy	3075	Porcelain 8 units in suspension 9 units in strain	Higher creepage distance to account for additional pollutants from the sugarcane fires and higher temperatures.
Maskall to San Pedro 34.5 kV line	IV-Very Heavy	1116	Polymer	Equal or better than porcelain, lightweight, easy construction.
Dangriga 34.5 kV line (values estimated)	II-Medium to III-Heavy	1116	Polymer	For this voltage class, there is no significant difference in insulation among the various pollution levels. Therefore, for standardization and simplicity, the same insulator unit is proposed for both 34.5 kV lines.

LESSONS LEARNED SO FAR FROM EXISTING 115 KV LINE

1. The longer lines now mean that location of failed insulators is difficult, so fault-locating equipment are now installed at West Substation using Schweitzer 321 relays. The 321 relays also provide distance protection.

2. The number of damages due to woodpecker holes have increased and BEL has investigated and are using an epoxy based product manufactured by OSMOSE to fill each woodpecker hole. The procedure is that the hole is first cleaned and then wooden dowels are inserted along with the epoxy. The hole is then taped and left to dry. This then returns the pole to its original strength. But this does not eliminate woodpecker holes so fine wire mesh is then also installed on the pole all the way from the top to about 1/3 from the bottom.

3. The type of studies mentioned above are usually done for large projects where, in order to protect the investment, comprehensive engineering is required. BEL subsequently found out, for example, that changing the distribution voltage for the island of San Pedro from 6.6 kV to 22 kV was a costly mistake because the insulators used were porcelain and only had a creepage distance of 381 mm. To correct the problem, the voltage was reverted to 6.6 kV. But because of a possible need for future voltage upgrade a small section of line was left at 22 kV for further study.

SWITCHING ARRANGEMENTS – WEST SUBSTATION

The Power II Project expanded the original grid from the West substation to the Mexican border for interconnection with the Mexican power system via Xulha substation with a total of 82.5 miles of main 115 kV transmission line and three tap substations (Dangriga, San Pedro and Buena Vista) as well as expansion of the West substation at 115 kV voltage level. West substation is now a major 115 kV switching station with a ring bus-switching configuration. This ring bus configuration along with an overall single line for the National Grid is shown in Figures 6 and 7.

115 kV West Substation – Xulha Transmission System

Circuit breakers are installed at both ends of the transmission line

- Any fault on the 115 kV transmission line will trip the appropriate circuit breakers at both Xulha and West substation. Re-energization can then take place from either the West or Xulha substation depending on the location of the fault. Both transmission line terminals are equipped with synchronization facilities. This tripping scheme also serves to allow the Belize side generation (if on) to supply the Western part of the grid should the islanded system be stable (generation matches load).

- The protection features as the main protection a communication assisted Transfer Tripping Scheme using Directional Comparison Blocking (DCB), this scheme is able to provide a fast clearing of all phase and ground faults inside the line section. For external faults the fast trip is blocked and only delayed backup will be provided.

- The DCB scheme is implemented using a Schweitzer SEL-321 Relay which has the zones 1 and 2 looking forward and the zone 3, at West Substation say, looking backward and farther than the over reaching zone 2 from Xulha. The Phase and ground zones 1 (M1P and Z1G) and the level 1 Ground Directional Overcurrent 67N1 will trip instantaneously their own breaker and send a DTT (Direct Transfer Trip signal via PLC to Xulha). Alternatively, if the fault is detected by the zones 3 relays (M3P and Z3G) and level 3 Ground Directional Overcurrent 67N3 it means that the fault is external to the West to Xulha Line section, then a BT (Block Trip signal) will be sent to Xulha via PLC, to block the zones 2 short time

- In addition, the scheme features breaker failure logic to detect failure to trip during fault conditions or during load conditions. If this condition is asserted and detected by the Schweitzer SEL-352 Relay a transfer trip is sent to the adjacent circuit Breaker in the ring and also a BF (Breaker Failure signal) is sent to Xulha via PLC.

- Further a Schweitzer SEL-267 and MCND -GEC Relays are installed as back up protection.

- There is an interesting feature of the transfer trip scheme that prevents overloading of the Mexican Chetumal Area system. If XUL-73230 (115 kV Circuit Breaker - Transmission Line Link to Polyuc Substation) or the XUL-73240 (115kV Circuit Breaker- Transmission Line Link to Tikul Substation) trips a Direct Transfer Trip signal is sent to 52-3 and 52-4 (115kV Circuit Breakers - Belize to Xulha Transmission Line). This is so because the two mentioned Mexican lines are the links for the Chetumal Area to the Yucatan Grid.

TWO MAIN CONSEQUENCES

Voltage Characteristics

The impedance of the 115 kV transmission line is approximately z = (0.196 + j 0.76) ς/mile and the shunt admittance is Y = j5.504 μS/mile or x_c = 0.181 Mς/mile/phase

The 115 kV line has a distributed capacitance characteristics with the charging kVAR/mile given by:

$$kVAR_{charging} = \frac{kv^2}{k\Omega}$$

Therefore, the charging kVAR/mile is 73 kVAR. For a 175 miles long transmission line the total vars generated by the line is 12.8 MVAR.

If a transmission line is loaded below the null point a situation develops where the inductive losses, I^2X_L, are less than the capacitive vars generated resulting in elevated voltages. This situation is mitigated if generators or reactors absorb the excess vars. At present the excess vars are absorbed by Mexico because of the excitation limits on the Mollejon generators and BEL's own diesel units. However, BEL will have to consider the need for reactors because the nighttime load is only 20 MW.

Frequency Response

To be stable under normal operating conditions, the torque-speed characteristics of a turbine should have a "droop characteristic". That is, an increase in load results in a reduction in turbine speed. A 5% droop or speed regulation, for example, means that "a load pickup from no load (power) to full load (power) would result in a speed drop of 5%, assuming a linear speed-load characteristics".

When the Mollejon Plant was first synchronized with the Western portion of the grid along with the diesel units, the droop setting was set at 5%, the same as BEL's diesel generators. This slow response from the hydro plant governors meant that the Mollejon Plant did not respond adequately (quickly) to load changes and faults. This resulted in instability and total grid outage because the smaller diesel units could not handle the load swings. The droop was reduced to 2% thus significantly increasing the response time of the Mollejon hydro units and thus reducing outages. BEL diesels and the Mollejon plant operated until the Northern link to Mexico was completed in this mode.

Now that the Mexican system can better respond to load changes and faults because their system represents a more stable source of power, it was decided to increase the droop from 2% to 3%. This improves the performance of the hydro plant units that are better suited for the higher droop meaning that that are less sensitive to load variations and have resulted in significantly improved operations.