Global
Sustainable Electricity
Partnership

Galapagos San Cristobal Wind Project

VOLT/VAR Optimization Report

Prepared by the General Secretariat

May 2015

Foreword

The GSEP 2.4 MW Wind Park and its Hybrid control system was commissioned in October 2007, along with a 12 kW grid connected Solar PV system on the San Cristobal Island of the Galapagos Archipelago. Since that date, both systems have successfully generated and delivered electricity to the San Cristobal customers, meeting approximately 30% of the whole Island demand and displacing about the same percentage of fuel consumption (over 7.6 million litres or close to 48,000 barrels of diesel as of December 2014), avoiding more than 18,000 tons of CO2 in the atmosphere. EOLIC SA, the company created to own and operate the assets has performed its duty with great success and steadiness, keeping the business financially viable over that period and paying all debts, thanks to its dedicated and professional General Manager and staff.

The purpose of the project was to sell the wind energy generated output to the grid system reducing the amount of diesel fuel currently used in power generation, to assist in promoting a more sustainable energy future for the Galapagos Islands and to contribute to climate change mitigation efforts. The project also helps to reduce the ever-increasing demand and supply gap of electricity.

Benefits of the project activity as can be reported today:

- The provision of valuable experience for the global promotion of small-scale, power generation and distribution systems with renewable energies;
- The opening of a path for future wind projects in the Galapagos Islands.
- The increase in access of local population to non-conventional energy;

Today, this project is a row model for other Renewable Energy projects that have been and are being developed on other islands of the Galapagos.

Recent development in the Government Energy Policy aims at promoting the use of electricity for eating and cooking (induction) to replace gas. This will accelerate the load growth on the distribution grid.

In the footsteps of this successful project and taking advantage of the experience, know-how and relationship developed with the different local stakeholders during the Wind Park and solar PV construction and operation, the Project Leader AEP offered investigating grid energy efficiency improvements by the use of the most recent technologies such as Volt/Var control systems. The objective of the Project Leader initiative is to optimize the grid operating characteristics to help reduce the energy consumption without impacting the customer or requiring more power on the generation side, hence reducing the existing customer bill and providing access to more productive uses with the same amount of generated electricity.

VOLT/VAR Optimization (VVO) Concept

Volt-VAR is a dual objective concept:

- Conservation Voltage Reduction (CVR): In general, a reduction in voltage results in a reduction in energy consumption.
- VAR Optimization: By optimizing the reactive demands of the feeder the line flows are minimized and less reactive power must be supplied through the substation transformer. Additionally, this should “flatten” the voltage profile allowing for greater voltage reductions.

A recent Report from the US Department of Energy (*Application of Automated Controls for Voltage and Reactive Power Management - Initial Results,* Smart Grid Investment Grant Program*,* December 2012*)* states that:

"Advanced VVO is made possible through recent improvements in sensors, communications, control algorithms, and information processing technologies that for monitor voltage levels throughout the distribution system. This information is sent to devices that can adjust voltage regulating equipment and capacitor banks on distribution feeders in near□real time enabling quick adjustments in response to constantly changing load and voltage conditions. Adjustments to individual devices and systems can also be coordinated so that voltage levels can be optimized along feeder lines.

… These strategies are meant to achieve one or more of the following objectives:

(1) lowering voltage levels during peak periods to achieve peak demand reductions,

(2) lowering voltage levels for longer periods to achieve electricity conservation, and

(3) reducing energy losses over feeders. Generally speaking, utilities applying VVO technologies expect to see 1% reductions in electricity consumption for every 1% reduction in voltage levels.

Achieving these VVO objectives results in the following benefits:

- Deferred capital expenditures and improved capital asset utilization Reduced electricity generation and environmental impacts
- More efficient utility operations, greater flexibility to address resiliency,

  And
- More opportunities to keep rates affordable."

Application to the EEPG San Cristobal Grid

Step 1 (Pre-Feasibility): Data collection and preliminary assessment of potential VVO Optimization on the San Cristobal Distribution Grid

In a first attempt to assess the potential of VVO on the San Cristobal Grid and at the request of AEP, EOLICSA in collaboration with the local Utility EEPG provided the readily available information on the distribution grid such as the grid single line diagram, grid components physical and electrical characteristics.

Based on the provided data, AEP was able to understand the current circuitry. The information about the loading and wire sizes was also helpful. However, some critical information were still required, namely the voltage profile of the circuits as they operate today. The voltage profile includes knowing what the voltage is just outside the station and how it drops at the far end of each circuit including the drop to the customer's meter.

Through simulations, this information would indicate if (and how much) the voltage could be lowered without going outside the required range. The fairly light loads and decent wire size was an indication that the existing voltage profile could be pretty good but actual voltage information would be necessary to validate this assumption. Without actual voltages during operation it is not possible to not know if the system is using the full range with no ability to lower further or if there is some margin to lower.

The other important information is how the voltage will be adjusted. This is achieved through an adjustment of the transformer load tap changers (LTCs) or voltage regulators on the 13 kV level. The San Cristobal grid does not have LTCs or voltage regulators. So the question was: can the voltage of the generation system be effectively adjusted via SCADA or will there be a need to add voltage regulators? As a first assessment, AEP had assumed that the addition of voltage regulators would be required to control the voltage level.

Conclusion of Step 1 and recommendation: Based on the available information and EOLICSA/EEPG first estimates, it was concluded that there could be some potential for VVO Optimization and that further investigations and data gathering was required to be able to confirm the viability of the concept, define the scope of work, provide cost estimates for detailed engineering, labor and equipment where necessary and define an implementation schedule.

Step 2 (Feasibility): Data collection and further assessment of potential for VVO Optimization on the San Cristobal Distribution Grid

For Step 2, EOLICSA worked with EEPG to gather all the available information on voltage profiles on different feeders:

Voltage registers available at the following points of the San Cristobal distribution system were provided for analysis:

- Three (3) medium voltage feeders (13.2 kV) registered at the starting point on the substation side;
- Two (2) distribution transformers – urban area;
- Two (2) final users – urban area.

Based on this data and previous information obtained in Step 1, AEP conducted additional assessment of the San Cristobal grid operating conditions and commented their findings as follows:

1. Voltage data provided are from the feeders at the station and from some end users at the end of the circuits. Since power quality meters were used, AEP assumed that the measurements were the actual voltage readings at the customer.

2. It is also assumed that the transformers are 7620/120 volt rating. In this case and with a bus voltage at the feeders averaging 7600 volts, the voltage at customers just outside the station is probably around 120 volts. In the U.S. most utilities start at the station with about 125 volts (on a 120 volt basis). When running VVO the voltage at the station is lowered by 3 – 5 % so the voltages just outside the station range from 120 to 122 V. Based on this data it appears that the low voltages are already below 110 volts and that any further lowering of the voltage would be too low for efficient operation of the customer's equipment. It appears that the San Cristobal system with lower voltage at the station (120V versus 125V) is already providing voltages close to the design voltage of the customers' equipment and in effect is already operating in a voltage optimization mode.

3. The magnitude of the voltage drops on the circuits is quite significant. Given the relatively light loads, the short length of the circuits, and the fairly large conductor size, one would expect less voltage drop.

In order to validate the assumptions and data provided by EEPG, it was suggested that further data and a measurement campaign be conducted on the San Cristobal network. EEPG agreed to conduct this activity and with the support EOLIC SA General Manager provided further readings and information for analysis by AEP Engineering.

Data provided includes additional readings on sample circuits, and information on equipment and circuit configuration such as network connections (3-phase grounded wye), transformer ratings and tap position, conductor sizes, circuit loads, etc.,

Based on this additional information, AEP was able to perform additional assessment and came to the conclusion that the San Cristobal Grid was operating under conditions (voltages) that could not justify further energy efficiency by investing in Volt/Var Optimization technology.

San Cristobal Distribution Grid VVO Optimization Feasibility Study Conclusions and Recommendations

1. AEP's assessment of the potential for Volt/Var Optimization concluded that the San Cristobal Grid is already operating at the lower end of the voltage range and cannot be further optimized without the risk of voltage drops below the authorized minimum level.
2. From the information provided so far, the extent of the voltage drop between the substation feeder and the end customer could not be explained without ambiguity.
3. It would be advisable to investigate the voltage profile while focusing on potential reading errors or loads/losses unaccounted for in the current grid circuits.
    - Check metering accuracy
    - Consider energy balance between substation feeder(s) and customer calibrated meters (customer billing data base?) as a validation tool.

Additional Recommendation:

1. EOLIC SA to share the outcome of this VVO assessment with EEPG so that they can consider investigation Volt/Var Optimization on other Galapagos Islands' Distribution Grids.

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