Siemens PTI in Peru to Present Recommendations to Electric Sector Stakeholders Regarding Transmission Interconnection Solutions

Siemens PTI (in association with Quantum Andes, a Peruvian firm) delivered several presentations last November in Lima to Peruvian electric power sector stakeholders. These presentations included recommendations with respect to transmission interconnection reinforcement solutions between the central and southern regions of Peru. The recommendations were developed as part of an assignment performed by Siemens PTI and Quantum Andes for Osinergmin (the energy and mining regulatory entity in Peru) entitled “Risk Analysis of the Transmission Interconnection between the Central and Southern Regions.” Among the attendees at the presentations were representatives from the Ministry of Energy and Mines, Osinergmin, COES (the system operator) and REP (a transmission service provider). The presentations also included Siemens PTI’s independent assessment of the current transfer capacity between the central and southern regions, and the results of our analysis of the Peruvian regulatory framework for electricity relative to the implementation of new transmission projects.

The assignment started in June of 2007 and was completed in November of 2007. The Siemens PTI project team included Ramón Nadira, Nelson Bacalao, Carlos Dortolina, Paloma De Arizón, Yuriy Kazachkov, Arthur Pinheiro, and José Daconti. The Siemens PTI team that traveled to Lima for the final presentations included Carlos Dortolina, Nelson Bacalao and Yuriy Kazachkov. This project was a follow on to a previous assignment entitled “Expansion and Planning Model of the Peruvian Transmission System, 2006 – 2016,” carried out between July 2006 and March 2007.

In both of these projects Siemens PTI applied a planning under uncertainty methodology known as trade-off risk, or TOR [1, 2]. TOR has been proven to be very effective in multi-objective optimization problems such as transmission planning. With multiple conflicting objectives, the traditional concept of optimization is of limited use since there is usually no plan which is “best” in terms of all of the objectives or attributes of concern. Further, TOR is able to explicitly consider structural uncertainties (e.g., those associated with both the location and size of new generating power stations) to produce robust transmission plans.

Key to the successful application of TOR is the correct definition of options (choices or possible decisions available to the planner), uncertainties (quantities or events which are beyond the decision makers' foreknowledge or control), and scenarios. This is shown in Figure 1. Scenarios are assembled by combining specific options with futures (and the latter are specific materializations of the modeled uncertainties.) Scenarios are evaluated in terms of defined attributes.
The central and southern regions of Peru are currently interconnected by means of an approximately 610-km, series-compensated, double-circuit (on the same tower) AC transmission line operating at 220 kV. The line runs from the Mantaro substation in central Peru to the Socabaya substations in the southern region of Peru. Series compensation (and switching) are applied at Cotaruse, a mid-point substation. Siemens PTI determined that the nominal transfer capacity of each of the circuits was 550 MW. However, because of thermal limitations on the series compensation devices - as well as dynamic stability and other considerations - the double-circuit line is reported to be operated only at a maximum transfer capability of 246 MW (123 MW per circuit). Significant additional transfer capability from the central to the southern regions is anticipated to be needed, in light of the projected development of the generation resources and the load demand in the country.

In order to increase the transfer capability between regions, numerous transmission expansion options were considered, including several based on HVDC or HVAC technologies. After significant discussions about the merits of each postulated option (including the required timeframe for implementation), a total of six plans were agreed upon, as follows: (i) Plan A: increase the capacity of the existing line by enhancing the thermal capability of its series compensation devices (hereafter this is referred to as “additional series compensation”, (ii) Plan B: build a new AC 220 kV line plus additional series compensation, (iii) Plan C: build a new HVDC line plus additional series compensation, (iv) Plan D: install thyristor-controlled series compensation (TCSC), (v) Plan E: install a new AC 500 kV line plus additional series compensation (this plan also required the installation of a flow control device, such as a phase-shifter), and (vi) Plan F: install a new HVDC Back-to-Back (“B2B”) converter station at the Cotaruse substation. Plan F was eliminated in the next stage of the analysis, as it was found to be very much inferior to the other plans.

As alluded to above, these plans were combined with uncertainties to form scenarios. The uncertainties that were considered in the analysis included, size, timing and location of future generating power plants, load demand growth ratios (by region), fuel costs, cost of energy not served, and hydrology. Uncertainties were modeled using an unknown-but-bounded approach [1, 2], which assumes upper and lower limits on the uncertainties, with no presumption about their probability distributions.

A total of 135 scenarios were modeled and compared in terms of the following attributes: (1) capital investment costs, (2) operations and maintenance costs, (3) cost of unserved energy, (4) system losses, (5) system-wide locational marginal prices of energy, (6) final end-user price, and (7) NDH and MIF, two non-traditional probabilistic planning criteria defined by Siemens PTI as part of the previous transmission expansion project performed for Osinergmin. NDH, or Hours of Non-economic Dispatch, measures the number of hours the transmission system constrains the economic dispatch of generation. MIF, or MWh of Interrupted Flows, measures the MWh of flows that are interrupted due to limitations in the transmission system. Numerous system simulation runs were performed to determine the value of each of these attributes for each scenario. These simulations were made using PSS™E – Siemens PTI’s proprietary program for simulating, analyzing, and optimizing power system performance – as well as a market simulation program developed by Osinergmin specifically for the Peruvian system (known as PERSEO).

Below we present a sample of the graphical results of our analysis. Figure 2 shows several scenarios (not all) plotted for two attributes: Net Present Value (NPV) of total costs and NPV of final end-user prices (all in USD/MWh). Even though there are some scenarios very close to the origin (0,0), further analysis
showed that the corresponding plan (i.e., Plan A) is robust for some materializations of uncertainties, but it is extremely volatile in case different materializations of uncertainties occur. This can be better explained through Figure 3, which shows the results obtained for the NPV of total costs for several materializations of the uncertainty associated with load growth (i.e., high, average, and low). This figure shows that Plans A and D can potentially have either the lowest or highest regret levels. For example, if one chooses Plan A and the load grows at a high rate, then the level of regret is extremely high. On the other hand, if one chooses Plan C and the load grows at a low rate, then the level of regret is relatively low.
outcome one would obtain for a given future. Hedging strategies were also designed for protection in case certain credible futures would materialize the "wrong way."

The solution recommended in this study was to immediately reinforce the existing double circuit line by enhancing the thermal capability of its series compensation devices, and to initiate the development of a parallel high voltage circuit between Mantaro and Socabaya whose optimal timing was recommended to be a function of the evolution of the generation and load demand in the country in the next few years.

During the presentations, Osinergmin and the various other stakeholders focused intensely on short term concerns relative to the existing interconnection. These concerns, and equally importantly, the long term concerns, were shown to be properly addressed by our methodology. All in all, the stakeholders were very vocal regarding their satisfaction with the depth and thoroughness of the analysis performed by Siemens PTI.

Finally, it is important to mention that as a direct result of the two projects described earlier, Osinergmin is reportedly considering to issue orders to the effect that: (1) TOR is the preferred methodology to be applied for planning transmission expansions in Peru, and (2) CIM/XML is the basis for the standard data base of power system simulation data to be adopted in Peru.

References.