Demonstration of the Sagging Line Mitigator On a San Diego Gas and Electric line at Escondido, CA

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ABSTRACT

Following comprehensive testing of the sagging line mitigator (SLiM) device at the Kinectrics Labs and the Material Integrity Solutions (MIS) facilities, the device was installed on the bottom phase of San Diego Gas & Electric's (SDG&E) TL696 line – a 69kV line in Escondido, California – on May 4, 2004. The installation of the SLiM was "straight forward" according to the SDG&E linemen who installed the device. Along with the SLiM device, an ultrasonic monitoring system was installed in June 2004 to measure line sag for the bottom (Test) phase and an untreated (Control) phase. The results so far indicate the device is performing as per design reducing line sag during high conductor temperature conditions. The current demonstration at SDG&E will continue for the remainder of 2004.

BACKGROUND

Conductor line-to-ground clearance dictates transmission line loading levels in many key situations. Excessive sag from high conductor temperature operations is the limiting condition making line capacity an issue. The Sagging Line Mitigator (SLiM) is a new class of transmission line hardware that fixes the problem at just the right time. In response to high conductor temperatures, SLiM decreases the effective length of conductor in the span. This mitigates the natural thermal expansion experienced by the conductor and reduces or eliminates excess sag.

Earlier, the functionality and reliability of the SLiM device was tested and demonstrated at Pacific Gas and Electric (PG&E) and MIS testing facilities [1]. Reliability of the device was further shown by a series of tests at Kinectrics Labs and MIS facilities. Finally, to demonstrate the functionality and usefulness of the device in an actual application, it was installed on an SDG&E transmission line.

This paper summarizes the reliability test results and provides a status report on the on-going demonstration at SDG&E.

RELIABILITY TESTING AT KINECTRICS LABS

A SLiM device was shipped to Kinectrics Labs (Toronto, Canada) for fault current and mechanical tension testing in January 2004 [2]. The following summarizes testing and results:

Fault Current Testing

SLiM device was tested at the Kinectrics High Current Lab and was subjected to a number of fault current events ranging from 21 kA to 40 kA (rms) for a minimum of 10 cycles (Fig. 1). Resistance measurements before and after these tests, visual examination of the device, and subsequent functionality testing proved that SLiM suffered no damage under the fault current conditions.

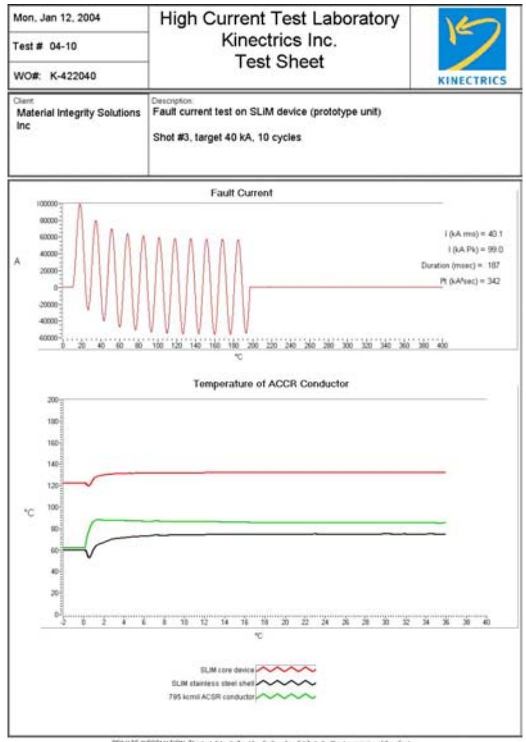

Figure 1: SLiM at the Kinectrics High Current Lab & sample of applied fault current.

Mechanical Tension Testing

After the fault current testing, the SLiM device was moved to the Kinectrics Mechanical Test Lab and installed in a MTS machine (Fig. 2). The device was subjected to increasing load until its safety links failed at about 49 Kips exceeding the target range (breaking load of the conductor). After the failure of the safety link, however, it was noticed that the device is still capable of carrying the full line tension. Testing continued on the device (without the safety link) by increasing tension. The device supported the full load until testing was stopped at ~60 Kips (near the machine load capacity). These tests demonstrated that the device has built-in redundancies and is fail-safe. In fact, it was argued that the device is practically indestructible.

Figure 2: SLiM at the Kinectrics mechanical testing lab.

DEMONSTRATION AT SDG&E

Demonstration Location – TL696

The SLiM device was installed on the west side of pole Z214903 on the bottom phase of line TL696, in SDG&E's service area in Escondido, California (Fig. 3). The line is a 69kV transmission line conductored with Rook/AW. The monitoring equipment was installed on pole 713831, which is part of a 12kV distribution section.

Figure 3: View of the test span, looking West (left photo) and looking East (right photo). Distribution pole is also evident.

Installation of the SLiM Device

Using site specific conditions (line tension, span, operating currents, contingency conditions, etc.), a SLiM device was manufactured and prepared for installation in MIS facilities in Berkeley, California. It was then shipped to SDG&E's Kearny Yard in San Diego on April 22, 2004 (Fig. 4). A one day outage was scheduled for May 6, 2004 such that the installation could be completed on a "cold" line. Additional safety precautions involved grounding the 69kV line at both ends of the span, and placing covers over the 12kV distribution line passing below the installation.

Figure 4: The SLiM device prepared for installation.

A two man crew working from a bucket truck performed the actual installation of the device. The length of the SLiM device, including SDG&E's end attachments, was used to determine the amount of conductor to be removed. A hoist anchored to the pole was attached to the conductor and tension was relieved from the insulator string. The old ceramic insulator string was removed as was a section of conductor from the marked location. A new composite insulator string was attached to the pole followed by a turnbuckle and the SLiM device. This equipment was temporarily supported by ropes.

The next step measured the tension and sag in the span. Enough tension was released from the hoist such that the bottom phase returned to its original sag based on the measurement made between the pole and the cut mark on the conductor. A survey crew measured elevations of the bottom and middle phases at mid-span and at a location directly above where the monitoring equipment had been placed. The cross-hairs of the surveyor's transit were then fixed on the bottom phase. A second hoist was placed on the conductor, and a dynamometer was placed between the conductor and the pole. Tension was placed on the dynamometer which was then adjusted until the conductor was again aligned in the cross-hairs. Tension on the bottom phase was 1500 lbs. The dynamometer was removed.

Figure 5: Completed installation of the SLiM device.

The mechanical installation to the device was completed by crimping a compression dead-end to the cut end of the conductor and attaching the SLiM device (Fig. 5). The hoist was released, allowing the SLiM device to support the full tension of the line. The turnbuckle was then adjusted until the bottom phase was pulled into the cross-hairs of the surveyor's transit. A new jumper with a 4-bolt pad at one end was constructed to straddle the pole. The flexible jumpers on the SLiM device were then connected, one to the pad on the compression dead-end, and the other to the pad at the end of the jumper straddling the pole. Ground wires on the 69kV line and covers on the 12kV line were removed, and power to the 69kV line was resumed.

Installation of Monitoring Equipment

The Siemens monitoring equipment consists of two ultrasonic transducers (Milltronics XPS-30) controlled by a microprocessor based level monitor (Milltronics Airanger DPL+). The level monitor outputs milliamp data directly to a stand-alone data logger (HOBO Microstation). The data logger also records ambient temperature through an external temperature transducer. A remote telemetry unit (Smartlink Modbus RTU) integrated within the level monitor also sends transducer and other site information to a Levelwatch connection hub, which transmits data to a remote server via satellite modem (Wireless Matrix SDX 1100). All components were mounted in a NEMA enclosure commonly used for mounting SCADA equipment on a utility pole (Fig. 6). The box was mounted approximately 10 feet above ground on the distribution pole located directly under the 69kV transmission line about 100 feet from the pole on which the SLiM device was installed.

Figure 6: Controls for the Siemens monitoring


Figure 7: Monitoring equipment on the pole

The ultrasonic transducers and the antenna for satellite communications were mounted on a 10 foot cross-arm 26 feet above ground (Fig. 7). Power was dropped to the control box from existing service on the distribution pole, and a ground rod was planted at the base of the pole for grounding all equipment. The ultrasonic transducers were then aimed using a laser to center each transducer's line of site on their respective targets – the bottom phase for transducer 1 (Test), and the middle phase for transducer 2 (Control). The monitoring system was energized, and proper operation of each piece of equipment was verified.

<u>*Sag Measurements*</u>

Sag and line current data are currently being collected at the site at preset intervals and evaluated by MIS. Preliminary results (Fig. 8 for June, Fig. 9 for July and Fig. 10 for 3rd week of July data) show that the SLiM device has been partially active reducing sag in the Test line. Full capacity of the device has not been recognized since conditions of high ambient temperatures, low winds and high currents have not yet taken place.

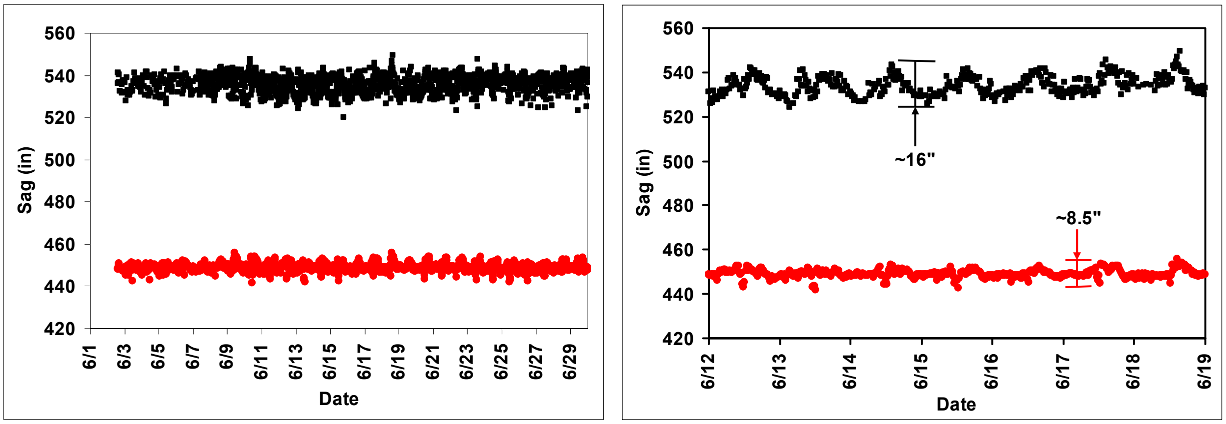

Figure 8: June sag data (left) and one week of data (right) showing sag differences in Control (top curve) and Test (botom curve) lines (from Levelwatch.com)

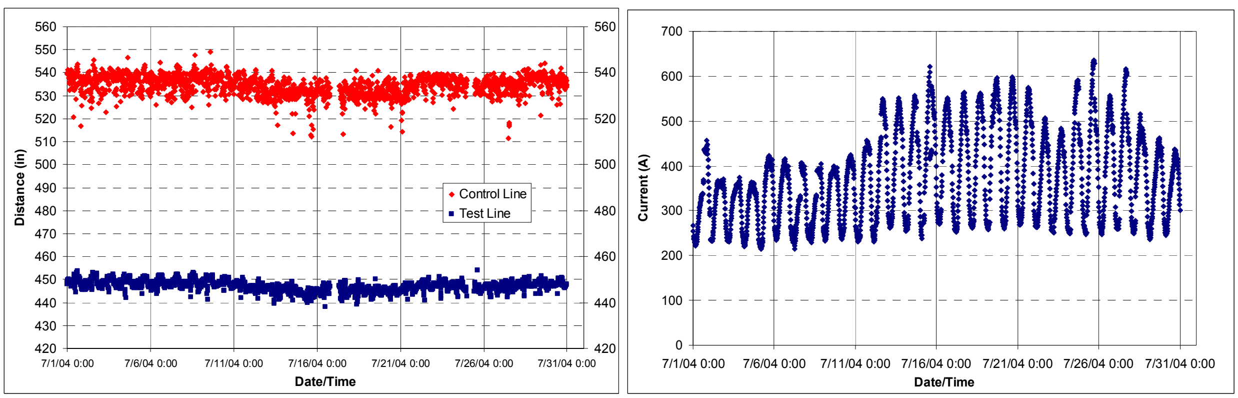

Figure 9: July sag data (left) and current (A) data (right)

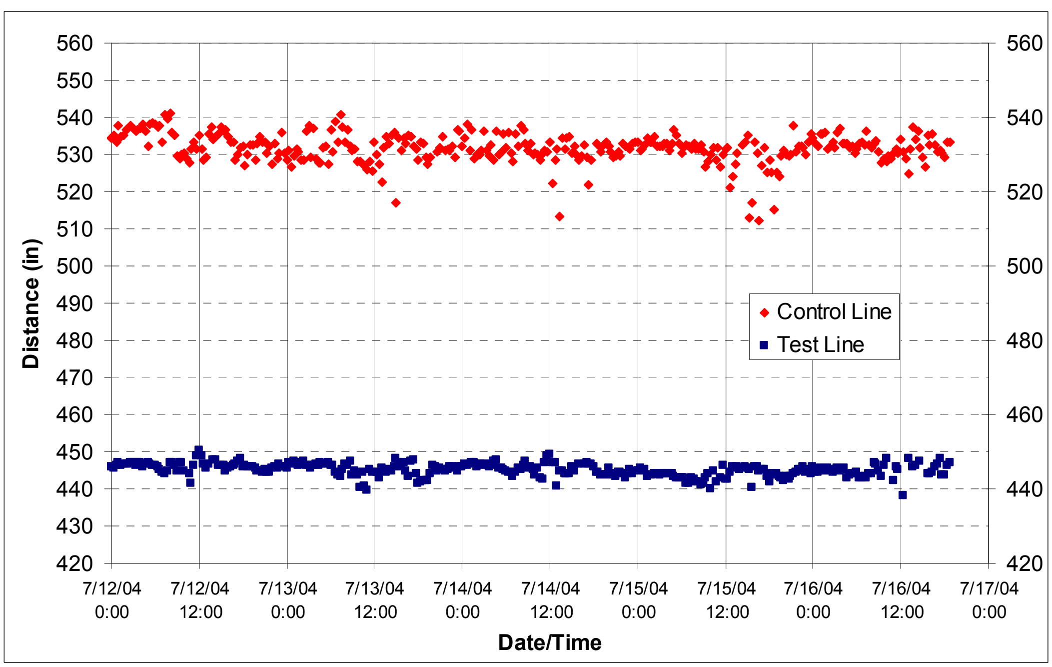

Figure 10: July 12-17 Sag data for Control and Test lines. Notice large sag reduction on Test line.

CONCLUSIONS

Following conclusions are made:

- Fault current and mechanical testing of the SLiM device, in addition to earlier tests [1], indicates the device's ruggedness and reliability for transmission line applications.
- The construction crew provided positive feedback, indicating that the installation was relatively easy and straightforward.
- The device has shown no sign of distress over the time it has been installed.
- Sag measurement data from the demonstration site shows the device is performing as designed – i.e. reducing the Test line sag during high conductor temperature conditions. The SLiM device was designed to start activating (reducing sag) at a conductor temperature of about 110^{0}F and go through its full range of motion (maximum sag reduction of ~2.5') during "contingency" conditions (current of ~900A and a hot day). As of end of July no contingency conditions have been reported on the line. Accordingly, the SLiM device acted through a portion of its range (as designed). Maximum sag reduction during the June-July period was about 1.5'. This observation confirms that the device does not "over-act", that is, it only reduces the targeted excess sag when needed.
- Data collection/analysis will continue and upon encountering of contingency conditions, the results will be reported.

Based on the above, we believe the demonstration program at SDG&E has been successful and that it demonstrates the ability of the SLiM device in reducing excessive sag on actual transmission lines. The demonstration program will continue for the remainder of 2004.

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