DECEMBER 2006

TRANSMISSION & DISTRIBUTION WORLD™

www.tdworld.com

# High Capacity, Low Sag

## SRP puts a new high-temperature ACCR conductor to the test.


Deadend structure for ACCR test line. Note the installation of the CAT-1 system and weather instrumentation below the conductors.

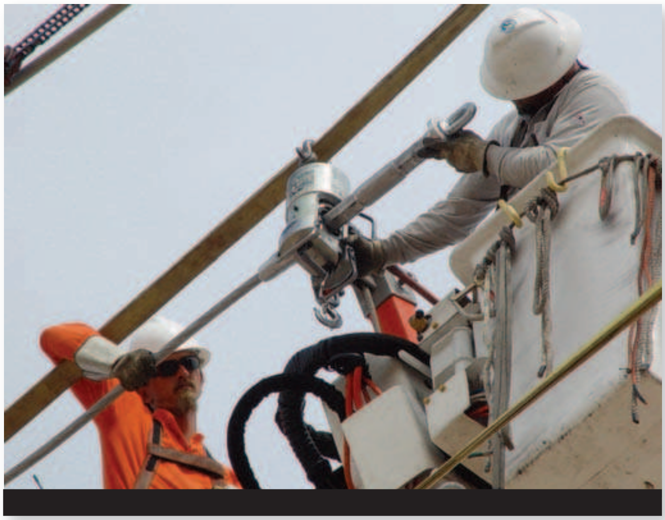
*by* **Jim Hunt**, *Salt River Project, and*
**Stephen Barrett**, *Barrett Research*

**THE 3M ALUMINUM CONDUCTOR COMPOSITE REINFORCED (ACCR) CONDUCTOR** is a new high-temperature, low-sag conductor designed to significantly increase the thermal capacity of overhead transmission lines without violating existing clearances. The Salt River Project (SRP; Phoenix, Arizona, U.S.), with the support of the U.S. Department of Energy (DOE), decided to put ACCR to the test. SRP built a transmission line with 795-kcmil ACCR to deliver the entire output of the Santan Unit 5b generator to the 69-kV switchyard.

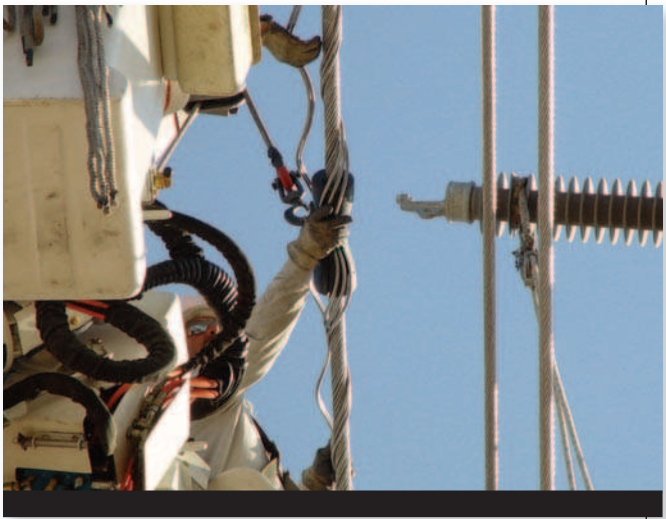
With the extreme desert-southwest climate and a high load factor, the line was a good candidate to monitor the ACCR sag (temperature response under high thermal loads and significant temperature swings). Testing by the manufacturer has demonstrated that the conductor can be operated continuously at 210°C and up to 240°C under emergency conditions.

### INSTALLATION DETAILS

An SRP line crew was responsible for the construction of the line, with consultation from the conductor and accessories manufacturers. The SRP crew primarily installs aluminum conductor steel supported (ACSS), but it also works with all-



Linemen Matt Peek and Scott Rindal installing an ACA Conductor Accessories compression deadend.



Linemen installing rods on a THERMOLIGN Suspension from Preformed Line Products.

aluminum conductor (AAC) and aluminum conductor steel reinforced (ACSR). With that experience base, the fundamental skill set to install ACCR was solidly in place and only modest adjustment of standard practice was needed.

The test line consists of two deadend poles that are approximately 500 ft (152 m) apart and a suspension pole between them. The installation of the 795-kcmil ACCR followed the IEEE 524 installation guideline for overhead transmission conductors. Particular care was given to the stringing operation to avoid damage to the ACCR core. SRP selected 28-inch (0.71-m) stringing blocks and 54-inch (1.37-m) bullwheels to keep the bending radius within manufacturer guidelines. The sagging procedure used for ACCR conductor is similar to that used to install ACSR. Two types of conductor accessories were installed: compression deadends made by ACA Conductor Accessories terminated the line and THERMOLIGN Suspension Assemblies made by Preformed Line Products support the line.

A CAT-1 Transmission Line Monitoring System from The Valley Group Inc. (TVG; Ridgefield, Connecticut, U.S.) was installed on one of the deadend structures to monitor the conductor tension and weather conditions (solar net radiation temperature, wind speed and direction) at 5-minute intervals. A 10,000-lb (4536-kg) load cell was installed and is used to measure the line tension. Line current data also are acquired at 15-minute intervals.

## ENERGIZED LINE

During the two and a half years since energization, the highest line current reached has been 1330 A. Conductor temperature was estimated to be around 140°C to 143°C at that current level using the TVG Rate Kit, emissivity 0.8 and IEEE STD 738-1993 for the computation method. SRP selected a rating of 1540 A for continuous operation at 200°C, somewhat more conservative than the manufacturer's nominal capability. The ampacity rating is based on 45°C ambient temperature, 2-ft/sec wind velocity at a 70-degree wind angle to the conductor, emissivity and solar absorption of 0.5, and 1200-ft (366-m) elevation above sea level. Given the network configuration, no emergency rating is needed. The measured current (1330 A) represents about 85% of the conductor rating of 1540 A. An example of predicted conductor surface temperature versus line current is given in Fig. 1. When it is dispatched, Santan Unit 5b goes through a daily cycle from off-line to full output. The line has experienced approximately 400 cycles of going from 0 A to 1300 A.

As of the end of August, the conductor has been operated at or above 1200 A for about 2210 hours and at or above 1300 A for 160 hours. It has been running above 100°C for more than 2800 hours, as illustrated in Fig. 2, which displays the total number of hours the conductor has been at or above specific current values. In addition, the conductor has operated at currents above 1000 A for several thousand hours.

## LINE SAG AND TENSION

The initial conductor line tension was less than 10% of conductor rated breaking strength. The mechanical tension was computed using STESS software and a compressive stress of -1.45 Ksi and it agrees with data measured using the CAT-1 load cells under no load and at high current load. The STESS model, developed by Ontario Hydro Research for the Canadian Electrical Association, differs in some details from the commonly used SAG10 software, but both are used to predict sag and tension.

The tension-temperature relationship is in agreement with STESS results computed before any current above 800 A was experienced. The correction factors were needed to account for the weight of the end fittings and slight deflection and twisting of the poles with tension changes and variation in loading on the ACSS circuit on the west side of the poles.

The CAT-1 data for the energized line from 2005 to early 2006 is plotted in Fig. 3 as tension versus predicted temperature. The temperature is predicted from the thermal model. The data are corrected for end fittings and a compressive stress of -1.45 Ksi was used for aluminum strands. There is some scatter in the data because wind-speed measurements were taken at only one location and were not averaged over each 15-minute cycle. A single measurement does not repre-

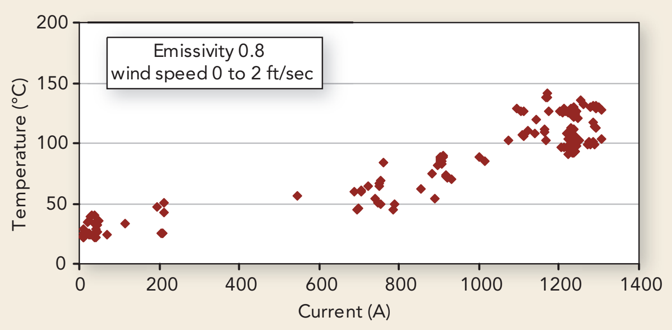



Fig. 1. The effect of current on computed conductor temperature at steady state and low wind speeds (0 ft/sec to 2 ft/sec).

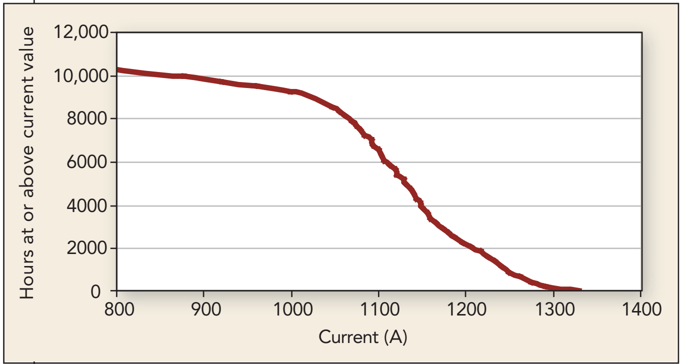



Fig. 2. Cumulative ACCR current exposure duration from February 2004 to August 2006.

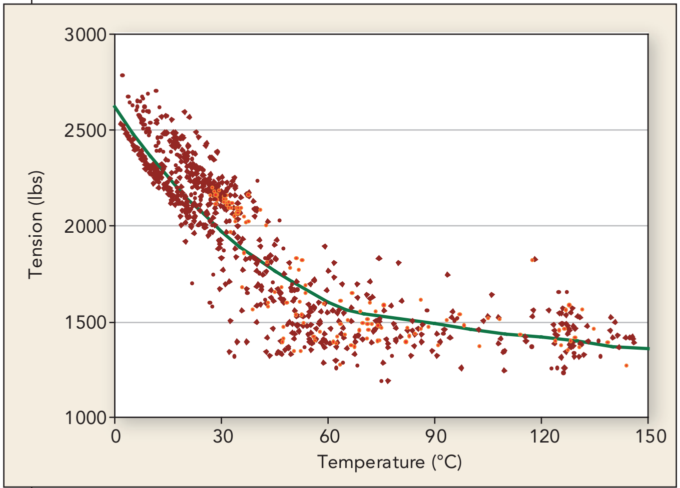



Fig. 3. Conductor surface temperature calculated using IEEE 738 method. The computed temperature values have scatter because of the significant variability in wind velocity as a function of time and because wind velocity is measured at a single point.

sent actual conditions on the whole span and does not take into account the time constant of the conductor as it reacts to short time wind deviations.

As an example, predictions from the thermal model show that around 1227 A, the conductor temperature is about 124°C with 0.6 ft/ sec wind speed (at a 90-degree wind angle). When the wind speed increased to 9 ft/ sec, the predicted temperature dropped to 46°C. The corresponding measured tension values were 1454 lbs (660 kg) and 1673 lbs (759 kg), respectively. These values agree well with the TVG Rate Kit temperature predictions at emissivity of 0.8.

The line has functioned as expected for the last 2.5 years with more than 6000 hours logged at current levels greater than 1100 A. The conductor and accessories behaved as expected under the large thermal loads for extended times. TDW

## ACKNOWLEDGEMENTS

The authors acknowledge the support of the U.S. Department of Energy under Award No. DE-FC02-02CH11111 to this project. The authors also acknowledge the 3M Composite Conductor team, especially Drs. Kamal Amin and Herve Deve.

**Jim Hunt** is a principal engineer in transmission engineering at Salt River Project (Phoenix, Arizona, U.S.). He develops transmission standards and specifications, is a company spokesman on EMF issues, and consults on line engineering issues such as conductor ratings, audible noise, radio and TV interference, induction effects and NESC clearances. Hunt coordinates support for industry and university research on transmission issues. Originally a transmission planning engineer, his checkered past includes management positions in transmission planning, substation apparatus and line design. He earned his BSEE degree from Brigham Young University and his MSEE degree from The Ohio State University. Hunt is a registered professional engineer in Arizona.
**jim.hunt@srpnet.com**

**J. Stephen Barrett** has spent more than 28 years in the power industry. Since 2000, as Barrett Research, he has provided consulting services to the industry. With more than 30 published papers, his area of expertise is in the modeling of the electrical, mechanical and thermal properties of conductors and insulators. Much of his work involves the operation of conductors at high temperatures, including the development of a state-of-the-art sag-tension program (STESS) for the Canadian Electrical Association.
**barrett.s@sympatico.ca**

**High Capacity**, **Low Sag**

**High Capacity**, **Low Sag**. Deadend structure for ACCR test line. **....** with permission from the December 2006 issue of Transmission & Distribution **World ...**

solutions.3m.com/3MContentRetrievalAPI/BlobServlet?assetType=MMM_Image&loca..