CONNECTOR PERFORMANCE ON NEW VS. SERVICE AGED CONDUCTOR

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Abstract - Pacific Gas and Electric Company has been experiencing problems with both overhead line tension splices and non-tension connectors. We believe that a number of factors are contributing to these failures; circuit loadings, connector redesign based on ANSI C119.4 parameters, and PG&E's application standards. Evaluations of the events indicate that most have occurred on service aged conductors. The results of the evaluations raise concerns about the effectiveness of ANSI C119.4 for electric connectors. We question whether the current test specifications adequately "prove" the connector for the wide variety of field conditions that are encountered.

A series of tests was initiated to compare the performance of splices and connectors on new conductor versus the same splices and connectors installed on service aged conductor. The result of the first test, on automatic line splices, has resulted in PG&E discontinuing the use of All-aluminum automatic splices, and using ACSR automatic line splices exclusively in all applications on both All-aluminum and ACSR conductors.

The purpose of this paper is to present results of tests conducted on automatic line splices and a variety of other connector designs. From these early results PG&E has changed its connector practices to require compression tap connectors on all applications involving tensioned conductors. We are currently engaged in a series of ANSI C119.4 tests on a wide assortment of non-tension connectors and conductor conditions using the same test protocol on both new and service aged conductor under the identical test conditions and loop configurations. The conductor conditions that will be used in the tests are; new, cleaned; service aged, cleaned; service aged, uncleaned. The tests will compare various connector designs from bolted to powered wedge. Future papers will present in-depth evaluations of the results of the ANSI C119.4 test on electric connectors, on both new and service aged conductors. From these tests PG&E plans to recommend changes in the ANSI C119.4 to better reflect field conditions.

INTRODUCTION

A good connection is comprised of three basic elements: selection of the proper connector for the job, proper preparation of the conductor to accept the connector, and installation of the connector in accordance with prescribed methods. In addition, other factors that can affect the ability to make a good connection are: climatic conditions, time of day, age and condition of the conductor, calibration of installation tools, construction methods, etc.

Some of these field related conditions are difficult if not impossible to control. The connector design is easier to control and must be capable of compensating for differences in the field conditions. From a user's standpoint many of the connectors, while having passed the C119.4 laboratory tests, are failing in the field.

The purpose of the tests being conducted by PG&E are to determine which connectors, if any, that are currently available will provide a good connection under less than perfect conditions. The tests will be conducted using the ANSI C119.4 standard for electric connectors, with the following differences; in addition to new cleaned conductor, service aged conductor, both cleaned and uncleaned will be used. The same type and number of connectors will be used on all three conductor loops and the tests run simultaneously with identical equipment and instrumentation.

During the investigation into the failures of All-aluminum automatic line splices on critical circuits, many of which occurred on service aged conductor, the design of the automatic splice, size of the jaws and mass of the connector, appeared to be contributors to the failures. It was decided to test both All-aluminum and ACSR automatic on all aluminum conductor in accordance with the ANSI C119.4, standard for electric connectors. In addition to the new conductor, service aged conductor was removed from service and used in the test. The tests were conducted in the spring of 1990. Both sets of conductors and splices were prepared and the tests conducted in accordance with the specifications of the standard. The results of the test with new 397.5 kcmil conductor can be seen in Figure 1.

The average temperature of the All-aluminum automatic splices used in the test approximates the control conductor temperature, with the temperature of the ACSR automatic splices running at 67% of the control conductor. The difference in performance was attributed to the larger size of the jaws and the larger mass of the ACSR automatic splice.

The results of the service aged conductor tests are shown in figure 2. The All-aluminum automatic splice samples failed within the first 25 cycles. The ACSR samples while running at a higher temperature than the new conductor samples, completed the test at approximately 80% of the control conductor temperature.

The reason for the failure of the all-aluminum automatic splices at the beginning of the test cycle can be attributed to the high resistance of the connection, due to the corrosion on the inner strands of the conductor and the small jaws and mass of the connectors. The resultant performance of the ACSR automatic splices on service aged conductor was attributed to the lower current density because of the larger cross sectional area of the jaws and the larger mass of the connector allowing for faster transfer of heat from the connection.

These tests, as well as the number of failures that have been experienced led to the decision by PG&E to use ACSR automatic line splices for application on All-aluminum conductor as well as on ACSR conductor. The results of these tests have also raised questions about the performance of all connectors on new versus service aged conductor.

As previously indicated, PG&E has been experiencing some non-tension tap connector failures. We currently use the bolted parallel groove clamp as the standard means of making non-tension connections.

To address this problem, a second series of ANSI C119.4 heat run tests was planned and initiated to determine if any changes should be made to our current connector practices. An additional driving force behind this second series of tests is our plan to institute Rubber Gloving as a construction option to our present Hot-sticking methods. Our intention is to evaluate many different connector types and installation systems to insure we are providing adequate connection options for our Divisions. Options are necessary for the wide range of operating and field conditions that can be encountered.

Three different conductor sizes and types were selected for the tests: 397.5 kcmil aluminum, #4 ACSR and #6 copper. The 397.5 kcmil was selected because it represents the midrange of our standard large aluminum conductor, the #4 ACSR because it is our standard conductor size for minor tap extensions and the #6 copper because we presently have approximately 22,000 circuit miles in the air.

For each conductor size, we will have three concurrent loops; new conductor - cleaned, with inhibitor; service aged conductor - cleaned, with inhibitor; and service aged conductor - uncleaned, with no inhibitor. In our judgement, these three conductor configurations represent the broad range of conditions that could be encountered in the field. The new clean conductor loop, which was prepared to the ANSI C119.4 requirements, will act as a control loop for the tests.

Connectors to be tested include dieless non-tension compression barrel sleeve, standard non-tension compression barrel sleeve, compression "H" frame, compression figure "6", fired wedge, bolted wedge, bolted parallel groove, bolted vise, formed wire, and hot line clamps.

Figure 3 shows a typical loop configuration that will be used for the tests. All three conductor sizes will be tested using this configuration. Figure 4 shows the typical control and measurement schematic diagram that will be used.

The 397.5 kcmil aluminum was selected to be the first conductor size tested because of concerns about maintaining adequate room ambient temperatures during the cooler winter and spring months. Figure 5 shows the pretest resistances for the various connectors used in the three different conductor loops. With the exception of the formed wire connector, the pretest resistances on the new conductor are approximately the same for all connector types. In the service aged - cleaned configuration, again with the same exception, the overall resistance begins to increase with a bit more variation between connectors, as the conductor/connector interface deteriorates. Finally, on the service aged - uncleaned configuration, there are dramatic differences in the levels of pretest resistance for the various connector types. It will be interesting to observe the performance of the connectors as the heat cycle test progresses and what the test results will reveal about the ability of these types of connectors to provide long term reliable connections for PG&E.

<u>Conclusion</u>. Conductor loading practices at PG&E as well as throughout the electric utility industry are changing. Circuits are expected to carry more load than in the past. At PG&E the emergency rating of circuits have been increased to approximately the same level as is necessary to achieve the 100°C temperature rise called for in the ANSI C119.4 test standard. Also, the economic redesign of connectors have pushed the connector closer to the limits allowed by the standard. The result of the evaluation of the failed automatic splices, as well as the preliminary results of the connector tests currently underway have raised questions about the ability of some of the connector designs to provide effective long term connections. Also, similar concerns have been expressed about the effectiveness of the specifications of the ANSI C119.4, standard for electric connectors, to reflect the ability of the connector to perform under varied and adverse field conditions.

The goal of Pacific Gas & Electric Company is to answer as many of these questions as possible and to recommend changes to the ANSI C119.4 test specification as supported by the results of our tests. Additionally, we will be making recommendations for changes in PG&E's connector standards and policies taking into consideration current and proposed construction practices while maintaining the highest levels of safety and reliability for our employees, customers, and the public.

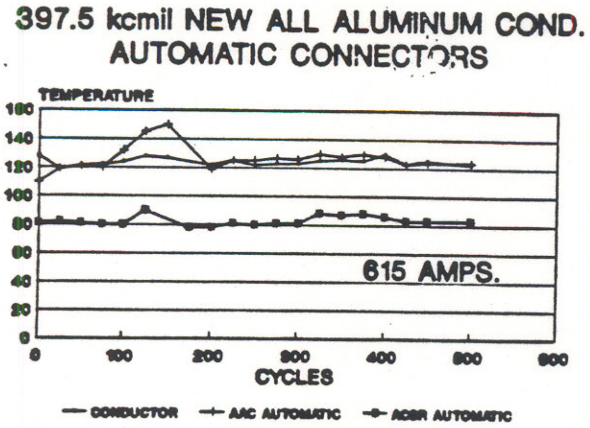


FIGURE 1. Automatic connectors on new 397.5 kcmil All aluminum conductor

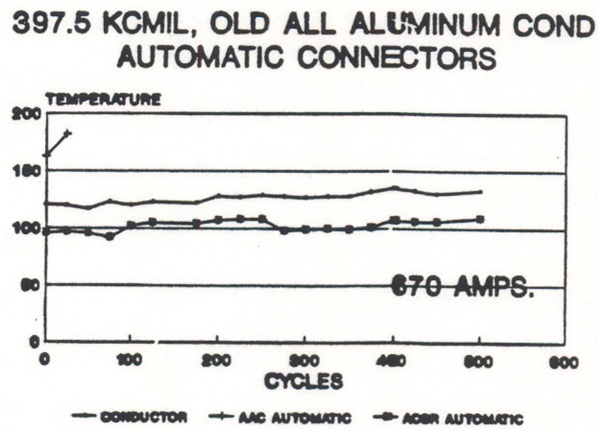


FIGURE 2. Automatic connectors on service aged 397.5 kcmil All aluminum conductor

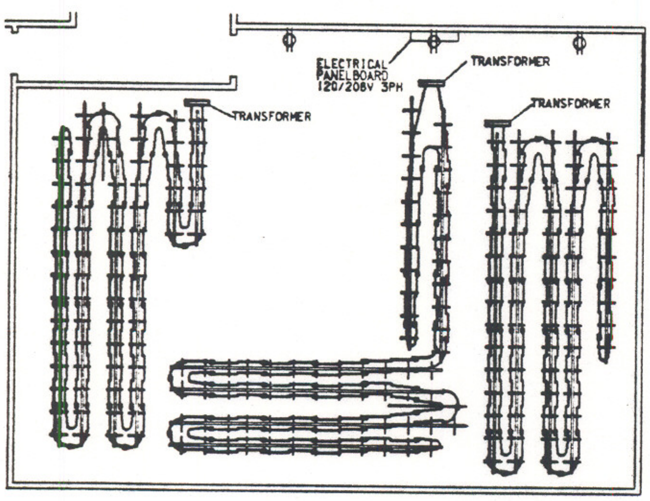


FIGURE 3. Typical test loop configuration

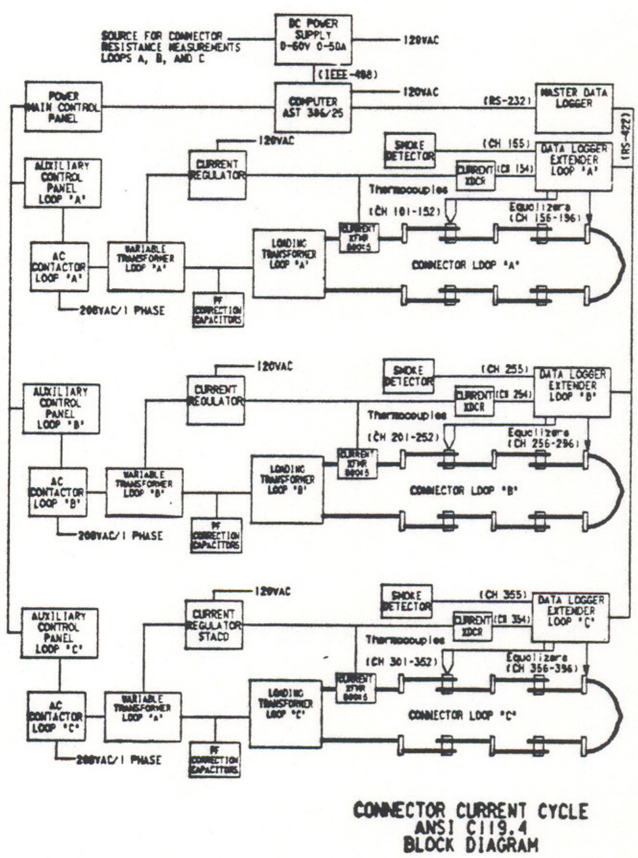
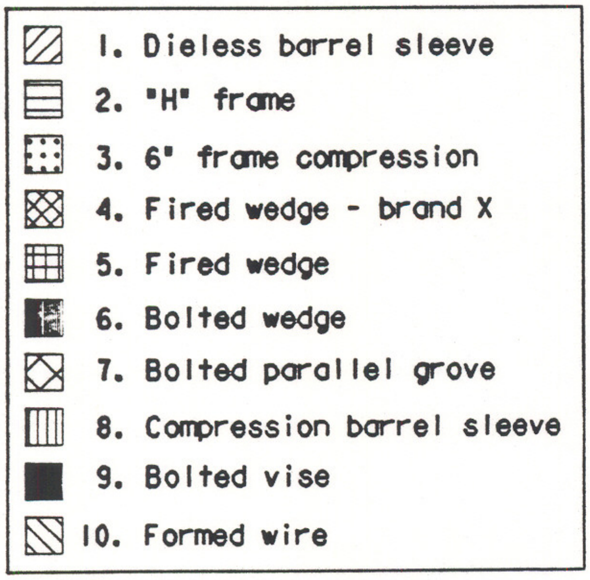


FIGURE 4. Measurement and control schematic diagram

Connector Pretest Resistance on 397.5 Al
(Avg of 4 connectors)



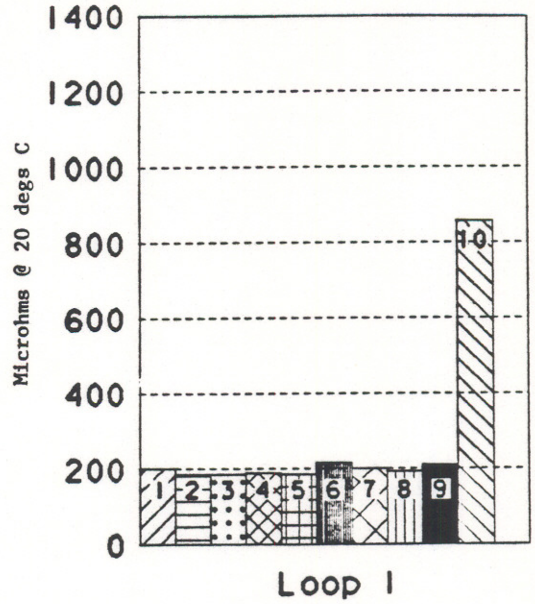


FIGURE 5. New conductor cleaned-with inhibitor

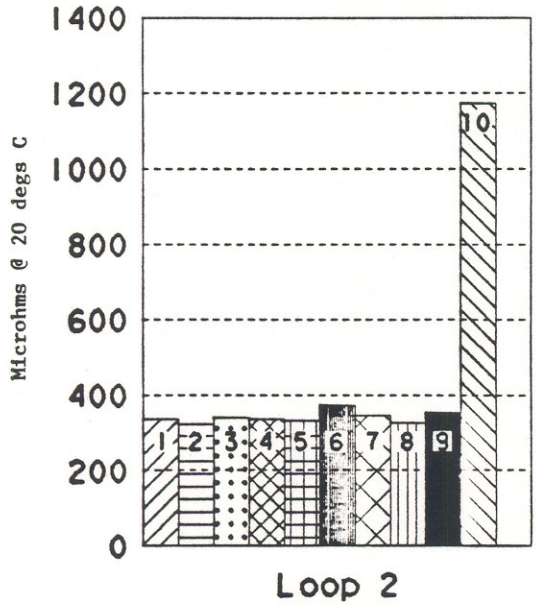


FIGURE 6. Service aged cleaned-with inhibitor

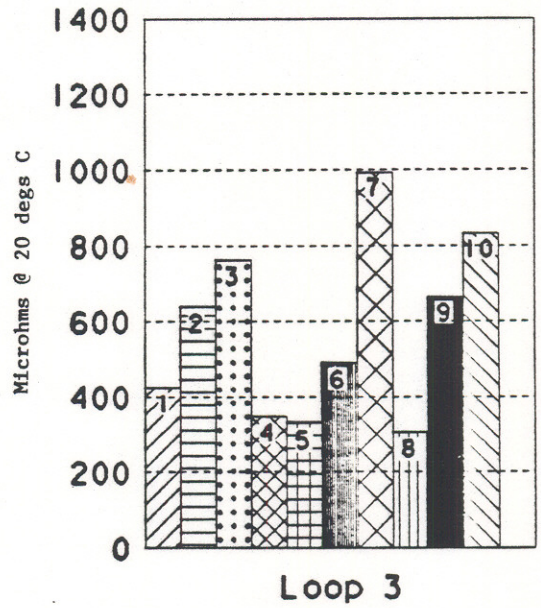


FIGURE 7. Service aged uncleaned-without inhibitor

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