Paper accepted for presentation at 2009 IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania

A Novel Method to Test the Quality of ADSS Fiber Optic Cables Installed in Transmission Lines

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Abstract**—Dry-band arc resistance determines the quality of fiber optic cable insulation materials. Three different brands of ADSS fiber optic cable qualities are determined with IEEE 1222 standard test method. Results give a ranking of the cables. During the experiment, it is noticed that randomly spread water droplets are a factor for the results. Therefore, the same cables are tested with another standard method, the well-known ASTM D2303 standard inclined plane test method. The duration of the test is shorter than IEEE 1222 standard test method and results show the same high ranked cable. However, this method does not represent the actual filed conditions. A new test method is proposed, which is the combination of the two standard test methods. Test uses the circuit parameters of IEEE 1222 standard and it uses the test environment of ASTM D2303 standard. After testing one type of cable, the test is interrupted since the duration of the test is much longer than the other two methods. All the three test methods show that the wetting process of the samples is not the point of determination for dry-band arc resistance. Major determination is the current limitation.**

Index Terms**-- ADSS, dry-band arcing, fiber-optical cable, inclined plane tests.**

I. Introduction

ALL-DIELECTRIC self-supporting (ADSS) fiber optic cables have been installed in power transmission lines for almost 30 years now [1]. As time passed, ADSS cable failures started to occur since ADSS cables, placed under transmission lines, have been subjected to a high electrical field. Dry band arcing is one of the electrical phenomena that causes most of these failures and it is a common problem in industry. In order to investigate the reasons of cable failures, several studies have been carried out [2-6] and a new testing method was developed for the IEEE 1222 standard [7]. This new method simulates the actual field conditions for ADSS cables, and at the same time, it determines the dry band arcing resistance. Rather than defining the insulation strength of the cable, the IEEE 1222 method decides the quality of the cable insulation material.

In this regard, in order to determine the quality of three fiber optic cables, a test was performed at Arizona State University's high voltage laboratory according to the IEEE 1222 standard. During the test, it was noticed that water droplets were scattered around randomly due to the fact that the fiber optic cable samples were not completely horizontal and straight. This random spread of water droplets affected the dry band arcing process, and changed the test results. As a result, a new method, free of randomly spread water droplets, was being searched, in order to determine the arc resistance of insulation material. The ASTM D2303 inclined plane test [8] is considered as a potential method to be applied since it is a well-known standard method for investigation of high voltage insulation materials' quality. This is questionable; however, whether this well-known method, with its different design, would be able to decide the quality of the ADSS fiber optic cable insulation material as the IEEE 1222 did. While in IEEE 1222 standard method the cable gets wet as water is sprayed by nozzle, ASTM D2303 method uses full water droplets to wet the cable. IEEE 1222 method limits the leakage current with R and C elements that represent the pollution level in the actual field conditions. On the other hand, ASTM D2303 method does not limit the leakage current. However, cables are horizontal and straight in ASTM D2303 method unlike the other method.

In this paper, the dry-band arc resistances of three (3) ADSS fiber optic cables, manufactured by various companies, are determined with IEEE 1222 standard. Afterwards, ASTM D2303 standard is used to determine the dry-band arc resistances of the same cables. The failure time of each cable is recorded for each test method and results are compared. In addition to the two standard test methods, a new testing method is proposed. This method is an inclined plane test, yet it is different from the standard inclined plane tests, with a limiting resistance and capacitance added to its circuit. This limiting impedance is also used in the IEEE 1222 standard method and it reduces the leakage current. The new proposed method removes the problems that were faced in the IEEE 1222 standard method. This method is an inclined test with straight alignment of samples, and fine spraying of samples by water droplets.

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978-1-4244-2235-7/09/$25.00 ©2009 IEEE

II. Experiments with IEEE 1222 Standard

A. *Test Setup*

The dry-band arc resistances of cables are tested according to the description given in IEEE 1222 standard. Three cables are suspended in a chamber as three channels and are sprayed salt water occasionally. Fig. 1 shows the test facility.

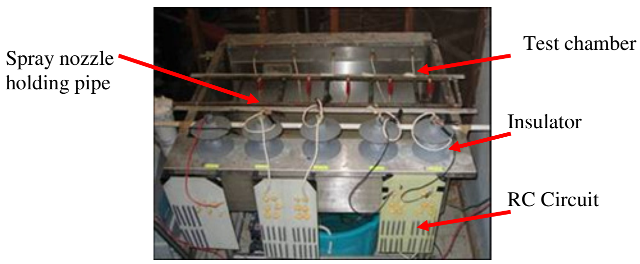

Fig. 1. ADSS cable test facility based on IEEE 1222 standard

18" long samples are prepared from each of the cable samples. Totally 15 samples are prepared. The two ends of the samples are covered with a waterproof coating to prevent water penetration. Two electrodes, made of aluminum foil are placed 4" apart from each other. Fig. 2 shows a cable test sample.

Fig. 2. Test sample

The samples are energized with 25 kV by a high voltage transformer. The current that flows through each sample is limited by a RC circuit. One RC circuit is connected in series for each test sample. The pollution level is selected as "medium" and the circuit parameters are:

TABLE I
Circuit Parameters

Parameters	Actual value	Unit
Voc	25	kV
Isc	1.363	mA
R	13.1	MΩ
C	200	pF

Water that is used for spraying has 1% salinity and the flow rate of the spraying water is 0.5–0.8 gpm per nozzle. After samples are energized with 25 kV, they are sprayed by salt water for 2 minutes then they are allowed to dry for 28 min. The total 30-minute time period is called as one cycle and the measurement of the arc resistance is defined by the number of cycles needed to puncture the jacket.

When the cables are new, water forms droplets on the surface of cables and the high voltage creates sparking between the water droplets. After a number of cycles, the surface of the cables becomes hydrophilic, and a conducting layer forms dry bands. Hence, flashover produces dry-band arcing that damages the cable.

B. *Test Results*

Test is run for three samples simultaneously and the failure time is observed. Some of the cables catch fire during the test. Once the cable is ignited, the test is interrupted and the destroyed cable is removed from the setup. Experiment is continued with the remaining cables. Each cable is tested 5 times. Each time the number of failure cycles for each cable sample is recorded. The average number of failure cycles, the failure in minute, and standard deviation are calculated and presented in Table 2.

TABLE II
Test Results

	Cable 1		Cable 2		Cable 3	
	Cycle	Minute	Cycle	Minute	Cycle	Minute
Set # 1	27	810	32	960	19	570
Set # 2	44	1320	61	1830	2	60
Set # 3	57	1710	15	450	5	150
Set # 4	55	1650	78	2340	13	390
Set # 5	64	1920	76	2280	7	210
Average	49.4	1482	52.4	1572	9.2	276
Standard deviation	14.4	432.9	27.8	835.3	6.8	203.9

The test results are plotted in Fig. 3. It shows the failure time in minutes for each set, average number of failure times in minutes, and standard deviation of the failure times for each cable.

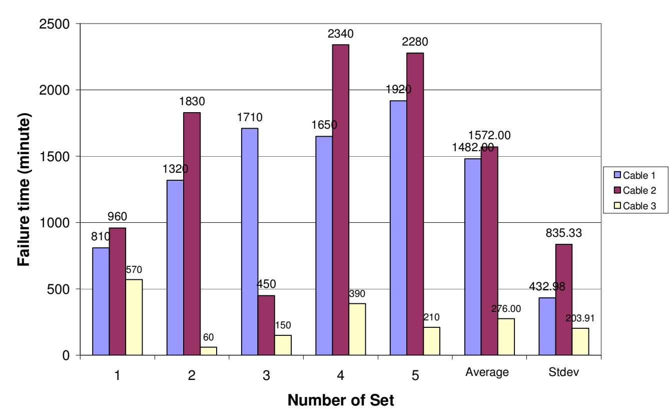

Fig. 3. Test Results

Fig. 4 shows a failure cable sample. It is seen that a channel cut and a hole are produced by the arc in the jacket.

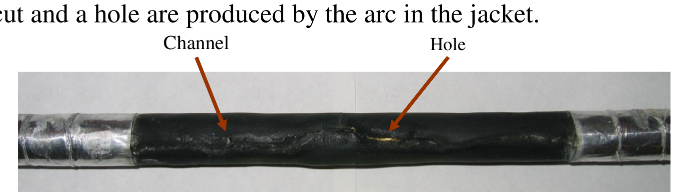

Fig. 4. Test Results

Test results show that dry band arcing is a statistical phenomenon. It changes rapidly through the wetting and drying cycles. For this reason, the result shows a significant difference between the maximum and minimum number of cycles. Hence, the cable arc resistance must be determined as the average of at least 5 tests. The quality of the insulation materials of the cables has the following order: Cable 2, cable 1 and cable 3.

III. Experiments with ASTM D2303 Standard

A. *Test Setup*

The dry-band arc resistances of the same three ADSS fiber optic cables are tested with ASTM D2303 standard inclined plane test. Test is conducted according to the procedure described in the standard. One cable is placed at one time to the plane test setup and the test is run. Fig. 5 shows the test setup.

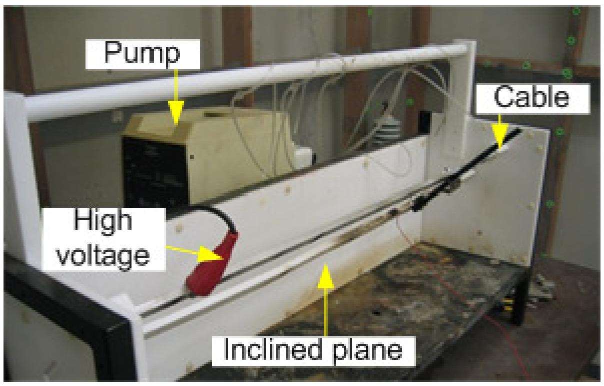

Fig. 5. ADSS cable test facility based on ASTM D2303 standard

10 cm long samples are prepared from each cable sample. The two ends of the samples are covered with a waterproof coating to prevent water penetration. The two electrodes, made of aluminum metal, are placed 50 mm apart from each other. The bottom ground electrode is mounted to the plane with a screw. The glass and coating materials inside the fiber optic cable are conducting materials and they shorted the two electrodes internally. Therefore, the lengths of the cables are increased to 12'' long in order to eliminate this problem. Fig. 6 shows a cable sample.

Fig. 5. Test sample

An electrolyte solution of 0.1 % by weight of sodium chloride and 0.2% wetting agent, TritonTMX -100, is prepared and applied through a peristaltic pump with a constant flow rate of 36ml/h. 'Time to track method' that uses a constant voltage and flow rate is used and the time of failure is recorded. The samples are energized with 4 kV constant high voltages.

Initially, the solution is applied to ensure that sample is wet before applying the high voltage. Afterwards, high voltage is applied until the cable is punctured and it catches fire. The failure time is recorded for each sample.

B. *Test Results*

Test is run for all the three cable samples separately. When the sample catches fire, it is considered as failed and the failure time is recorded. The failure cable is removed and replaced with a new sample. The failure time of each cable, the average failure time in minutes and standard deviation are presented in Table 3.

TABLE III
Test Results

	Cable 1	Cable 2	Cable 3
Set # 1	1.33	19.47	1.00
Set # 2	1.83	71.33	1.55
Set # 3	0.75	54.75	1.42
Set # 4	1.83	53.83	47.42
Set # 5	1.17	18.58	15.58
Average	1.38	43.59	13.39
Standard deviation	0.46	23.49	20.00

The test results are plotted in Fig. 6. It shows the failure time in minutes for each set, average number of failure time in minutes, and standard deviation of the failure times for each cable.

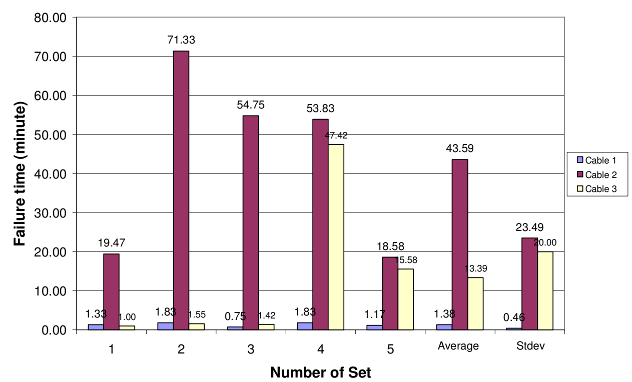

Fig. 6. Test sample

Results show that the inclined planed test successfully determines the quality of the cables. The cable arc resistance is determined as the average of 5 tests. The total duration of the test is significantly lower than the IEEE 1222 test method. The quality of the insulation materials of the cables has the following order: Cable 2, cable 3 and cable 1. Fig. 7 shows a failure cable sample. It is seen that the insulation material punctured and burned.

Fig. 7. Test sample

IV. Proposed Test Setup

The dry-band arc resistances of the three ADSS fiber optic cables are tested with two well-known standards. In IEEE 1222 standard test, it is noticed that water droplets are scattered around randomly because the fiber optic cable samples are not completely horizontal and straight. On the other hand, ASTM D2303 defines the quality as well as the dry-band arc resistance of cables successfully in a very short period of time compared to the IEEE 1222 standard. However, it does not represent the actual field conditions very well. The new proposed test method is the combination of the two standards. Inclined plane test setup is used as the test environment and RC circuit is added to the circuit. Fig. 8 shows the proposed test setup.

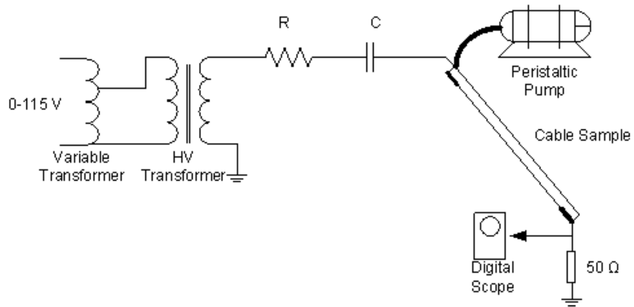

Fig. 8. Schematic of proposed test setup

One of the cable samples is placed at the inclined plane and the solution that is used for ASTM D2303 is used to wet the sample with the same flow rate. The RC circuit that is used for limiting the current at IEEE 1222 standard is connected in series. Initially, the solution is applied to ensure that sample is wet and then a 25 kV voltage is applied. The pump is run without stop as in the ASTM D2303 test. However, it is seen that when the solution continues to flow at the cable surface, it becomes conductive and the current in the circuit is zero. No destruction happens on the cable sample. Therefore, pump is run for 2 minutes then the cable is allowed to dry for 28 min., same as it is done in the IEEE 1222 test. This drying process is different from the one in IEEE 1222 test since the solution contains 0.2% wetting agent, TritonTMX -100. It stays on the cable surface for a while and then all the water droplets become drain. During the drain process, arc occurs between the electrodes but not as much as it occurs in the IEEE 1222. Hence, this increases the failure time of the cable. Only one sample is tested and it is noticed that the failure time is much longer than in the IEEE 1222 standard. The experiment is interrupted.

V. Conclusion

This paper presents a series of test results to identify the dry-band arc resistances of three ADSS fiber optic cables. The two standard methods are used to test the quality of cables and a new test method is proposed. The test results are:

- Dry-band arc resistance is a statistical phenomenon and is the major factor determining the quality of cable insulation. The duration of failure is determined by taking the average of test results.
- IEEE 1222 standard test method determines the dry-band arcing resistance and simulates the field conditions successfully.
- ASTM D2303 standard inclined plane test is used to test the quality of the same cable insulation materials. The total duration of the test is shorter than the IEEE 1222 standard method test duration; yet ASTM D2303 does not represent the actual field conditions.
- Both experiments' test results show the same cable to have the highest rank. The difference in results shows that more number of samples is needed for testing.
- A new test method is proposed. This method eliminates the problem of randomly spread water droplets. However, it is not as short as the inclined plane test duration, it takes longer time.
- All the test methods show that wetting progress is not the point of determining the quality of ADSS cable. Major determination is current limitation.

VI. References

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VII. Biographies

Sadik Kucuksari was born in Burdur, Turkey. He received his B.Sc. and M.Sc. degrees in Electrical Engineering Department from Yildiz Technical University, Istanbul, Turkey in 2000 and 2002 respectively. Currently, he is a graduate student in Electrical Engineering PhD program at Arizona State University, Tempe, AZ.

Ibrahim Gunes, was born in Edirne, Turkey. He received his B.Sc. and M.Sc. degrees in Electrical and Electronics Engineering from Istanbul University in 1999 and 2005, respectively. Currently, he is a Ph.D. student at Istanbul University at Electrical-Electronics Engineering Department. Since 2001, he is working at Istanbul University Engineering Faculty as a research assistant. His research interests are high voltage insulation materials and high voltage technology.

George Karady received his BSEE and Doctor of Engineering degrees in electrical engineering from the Technical University of Budapest.

Dr. Karady was appointed to Salt River Chair Professor at Arizona State University in 1986. Previously, he was with EBASCO Services where he served as Chief Consulting Electrical Engineer, Manager of Electrical Systems, and Chief Engineer of Computer Technology. He was Electrical Task Supervisor for the Tokomak Fusion Test reactor project in Princeton. Dr. Karady is a registered Professional Engineer in New York, New Jersey, and Quebec. He is the author of more than 100 technical papers.