DESIGN AND MASS PRODUCTION OF MEDIUM VOLTAGE SPACERS

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ABSTRACT

This paper presents design and mass production procedure of 20 and 33 kV spacers of overhead spacer cable distribution systems. All mass production steps including the initial design, making the prototype, tests and mass production are presented. The proposed mechanical, lightning strike, power frequency dry/wet discharge/withstand voltage tests procedure and limiting values are presented and used on mass produced spacers.

1- INTRODUCTION

Spacer cables (SC) overhead electrical distribution line is a messenger wire supported system using covered conductors in a closed triangular/delta configuration.

Spacer cables have some advantages compared with Covered Conductors (CCs) as follows:

(a) Possibility to use all aluminum conductors (AAC) instead of all aluminum alloy conductors (AAAC) (that is important from mass production ability point of view in developing countries),
(b) No need for additional protection equipment against lightning (such as arc horns),
(c) No need for porcelain insulators,
(d) Reduction of right of way corridor,
(e) Simpler and possibility for installation of more than one circuit on common pole,
(f) Possibility to install longer spans.
(g) Lower voltage drop
(h) Balance phase impedance
(i) Higher capacitance and lower inductance

Also, using spacer cables have some advantages compared with Aerial Bundled Cables (ABCs) as follows:

(a) Troubleshooting of ABCs is difficult because of their wrapping around a messenger wire,
(b) Lower initial cost,
(c) Easier T-off and connection to pole mounted transformers

Above-mentioned advantages are the main reasons for developing SC in different countries.

The first 20 kV SC in Iran is in operation since July 2010. Since that time, there has been a great deal of attention and also a good market for SC system in Iran [1].

Almost all tools and apparatuses of SC were made in Iran except spacers [2]. The material of spacers is HDPE and they may have different shapes such as lozenge, cross and vertical. Also, they may be in single or three-phase forms.

This paper presents design and mass production procedure of 20 and 33 kV spacers of overhead spacer cable distribution systems. All mass production steps including the initial design, making the prototype, tests, and mass production are presented. The results of paper may be useful for other manufacturing companies to produce this key equipment for spacer cable distribution systems.

2- SPACER DESIGN PROCEDURE

The spacer cable overhead distribution lines configuration mainly consists of three separate three-layer CCs which are hanging from a messenger wire by using some spacers in each span. It is necessary to use stranded alumuweld aluminium or steel messenger wire Spacers hang from messenger wire in almost 10 meter spans. Indeed, three phase conductors hang from messenger wire by spacers [3, 4]. Fig. 1 shows first fully Iranian made spacer cable four feeder 20 kV overhead line.

To design and manufacture of lozenge spacers, available information obtained and analyzed. These information were about Hendrix Co. and some Thailand made spacers [5]. The Hendrix Co. which is the first producer of spacer cable system, is an American company which has published a limited information about its spacers. Thailand made spacers imported to Iran for installation of first 20 kV spacer cable systems in Iran. Table 1 shows the main specifications and technical characteristics of analyzed American and Thailand made samples.

All samples have a main body, three arms for holding the spacer cables and a hanging arm on the top to be hanged from messenger wire. The main difference between the

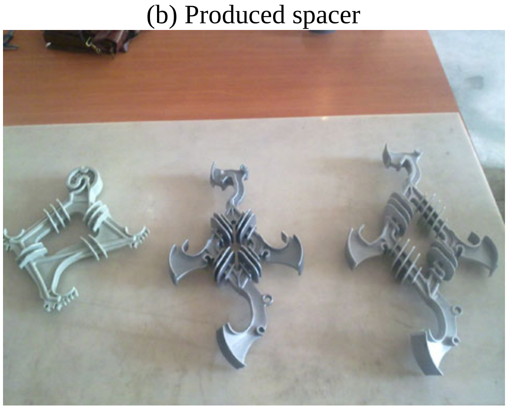
Fig. 1. First fully Iranian made 20 kV spacer cable line

arms design relates to their cables holding type. In Thailand sample, snap ties are used to wrap the spacer cables on spacers while in USA samples there were locking handles to fix the spacer cables on spacers.
The mentioned samples used for getting primary mechanical and electrical information. The results matched with Iran temperature, humidity and air pressure interval condition. There were so many experiences in Iran reference laboratories on used custom insulators which helped to extend them on new made samples. Finally, first sample which had considerable different with foreign samples from dimension and shape point of view, produced.
Fig. (2) show the mould of spacers, a produced prototype, a photo of mass produced spacers and a comparison between Thailand, Iran and USA made spacers.

(a) Mould of spacers

(b) Produced spacer

(c) Mass production of spacer



(d) From left, Thailand, Iranian, USA samples

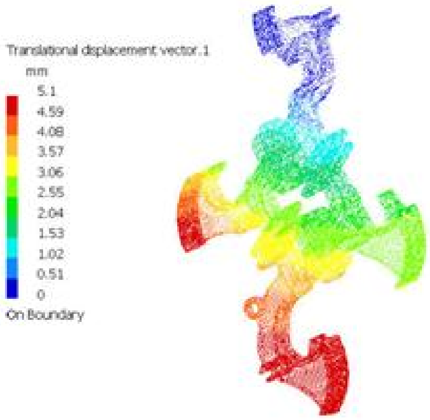
Fig. (2) Production steps of spacer.

Mechanical strength of new designed spacer analyzed using simulation results in design stage. Fig. 3 shows some selected results. The new spacer is UV resistant high density polyethylene.
As a result of this analysis, the maximum stress is equal to 7 MPa, while the standard ASTM D638 has a tensile strength of that material about 13 MPa, then new spacer will withstand the desired forces.
The prepared Iranian sample passed tensile test (according to IEC 61284 and manufacturer proposals) and in comparison with the best foreign designs. Fig. 4 shows that mechanical strength of the Iranian sample was higher than foreign samples with almost same amount of material.

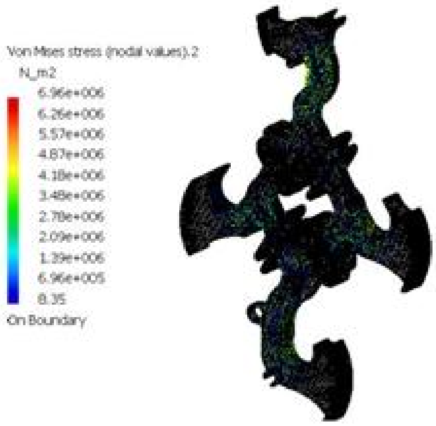
Table 1) Main specifications and technical characteristics of the samples

Code	**Voltage**	**Phase to phase distance**	**Phase to earth distance**	**Ultimate Strength**
T01	35	250	250	10
A1-01	15	176.26	165.1	10
A1-02	35	269.24	246.38	10
A1-03	15	203	203	10
A1-04	46	381	368.3	10
A2-01	15	203.2	215.9	10
A2-02	46	292.1	304.8	10

(a) Mechanical design

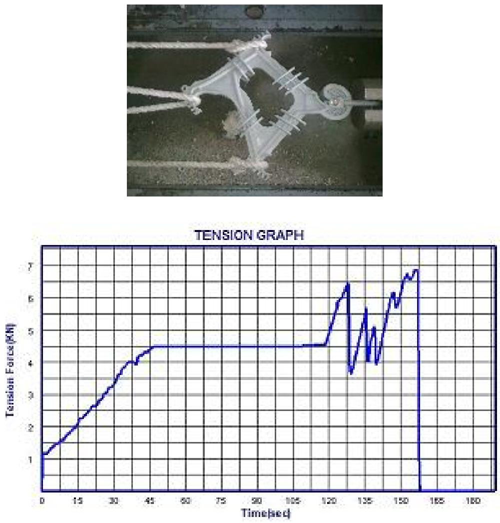


(b) Transitional displacement vector

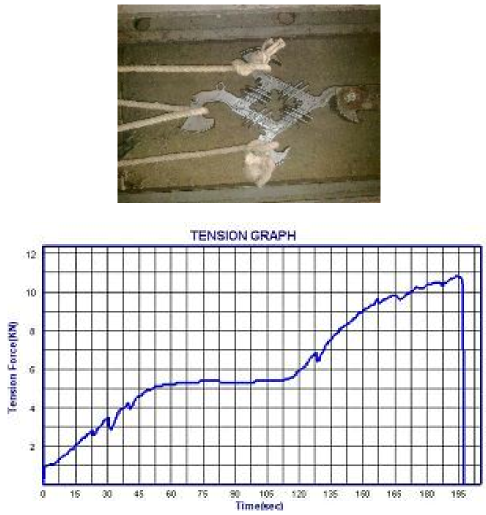


(c) Nodal stress vector

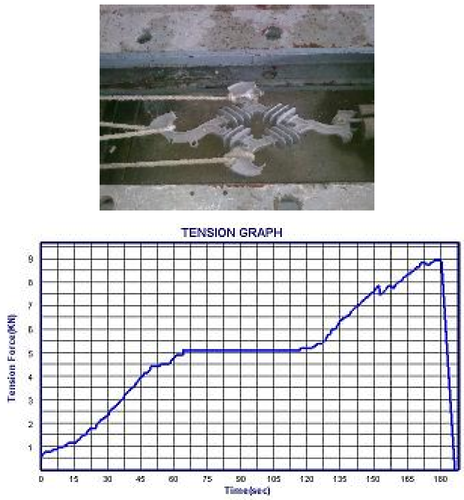
Fig. 3. Mechanical strength simulation results



(a) Thailand



(b) Iranian



(c) American

Fig. 4. Tensile Force (kN) against time (sec) test

3- TEST RESULTS

There is not any international test procedure for medium voltage spacers. Also, it is so difficult to find any national or factory designed test procedure for spacers. The authors proposed the following tests to be done in a reference laboratory:

a) Mechanical,
b) Lightning strike test,
c) Power frequency dry discharge voltage,
d) Power frequency dry withstand voltage,
e) Power frequency wet discharge voltage,
f) Power frequency wet withstand voltage.

It seems these tests and their procedure and limiting values may be useful for other producers and also distribution companies.

Mechanical test is done on two samples. A force equal to 30 times of three spacer cable weight is applied by the rate of 100 kg/sec. The mentioned force is kept on spacer sample for one minute. The sample should withstand without any deformation. The force increased up to first deformation of sample.

Tests results for above-mentioned (b) to (f) tests are shown in table 2. For example column (b) shows Lightning strike test results. The spacer sample hanged in test media and three spacer cables each with 10 mm diameter and 200 mm length fixed to each of spacer phases place.

In tests (b) and (c) the ambient temperature of test media in laboratory was 24.2 °C, humidity was 27.5% and air pressure was 852.4 hPa. Lightning and discharge voltages were modeled by SGE-400kV-20MJ Haefely Trench Co. test system.

Test voltage for power frequency dry discharge voltage ((d) test) was 70 kV. The ambient correction factor was 0.89 which results in 62.3 kV for implementation of test.
For tests (e) and (f), the temperature, humidity and air pressure were 22.1 ^{o}C, 29.3% and 850.3 hPa, respectively. The tests were according to IEC60060-1 (2010). Water disposal in vertical and horizontal directions were 1-2 mm/min and water specific resistance was set on 100 +/- 15 (μs/cm) and water temperature was +/- 15 ^{o}C compared with ambient temperature. Spacer should be sink in water for 15 minutes before test.
For all tests, there was not any visible breakdown on sample spacers.

Table (2) Test results on sample spacers

Tests Code >			Test (b)		Test (c)		Test (d)		Test (e)		Test (f)	
Sample Code	Powered Phase	Grounded Phases	Breaking voltage (kV)	Average (kV)	Breaking voltage (kV)	Average (kV)	Voltage (kV)	Time (s)	Breaking voltage (kV)	Average (kV)	Voltage (kV)	Time (s)
1	A	B, C	117.4	117.7	75.7	75.6	62.3	60	53.2	53.9	47	60
2			118.8		77.9				55.9			
3			117.9		74.3				54.7			
4			116.3		73.1				51.6			
5			118.1		76.8				54.3			
1	B	A, C	120.2	120.4	74.6	74.2	62.3	60	51.4	51.8	47	60
2			121.9		76.3				53.9			
3			120.8		73.2				52.8			
4			119.3		71.3				50.1			
5			119.9		75.6				50.8			
1	C	A, B	119.2	119.6	73.4	73.2	62.3	60	52.3	52.2	47	60
2			120.9		75.8				54.6			
3			119.8		73.1				51.3			
4			118.3		71.2				50.2			
5			119.7		72.6				52.8			

4- FUTURE STUDY

Using bundle configuration is known as a good solution to considerable reduction of voltage drop in transmission lines. It seems, using lozenge spacers may make it possible to use bundle configuration for spacer cable systems, too. In this case, it is necessary to design and produce two conductors per phase spacers. Fig. 5 shows reactance values versus bundle distance for a two conductors per phase spacer. This kind of overhead distribution lines will have a good market for heavily loaded long distribution lines with limited regulating voltage value and is under research by authors.

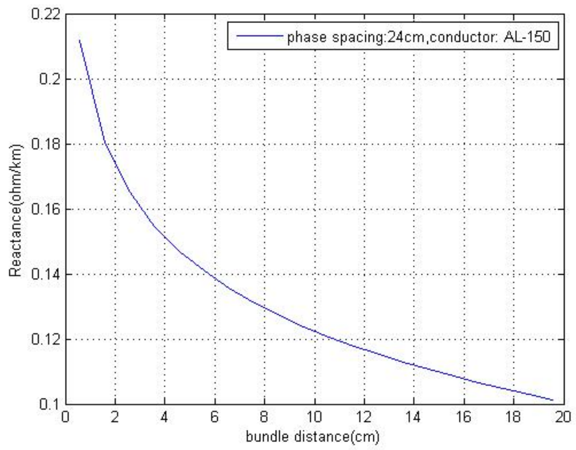


Fig. 5. Reactance versus bundled distance

5- CONCLUSION

This paper presents the procedure of mass production of HDPE spacers for using in spacer cable medium voltage overhead distribution lines in Iran. Production steps including getting information, their analyse, making spacers mould, tests procedure and their limiting values and tests results on produced spacer samples are presented. The future study for production of bundled spacers is presented, too.

6- REFERENCE

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