DESIGN AND INSTALLATION OF FIRST 20 kV SPACER CABLE IN IRAN

Mehrdad TARAFDAR HAGH
University of Tabriz – Iran
tarafdar@tabrizu.ac.ir

Karim ROSHAN MILANI
East Azarbaijan Dist. Co. – Iran
kr_milani@yahoo.com

Mohammad Reza OSOOLI TABRIZI
East Azarbaijan Dist. Co. – Iran
osoolitabrizi@ezepdico.ir

ABSTRACT

This paper presents designing, installation and mass product of necessary components procedure for first 20 kV spacer cable overhead distribution line in Iran. Electrical and mechanical design procedure for spacer cable distribution networks are presented. A user-friendly software is developed for mechanical design. Mechanical analysis of produced metallic components is done by ABAQUS software. The three-layer covered conductor with 150 mm^2 cross section is produced, too. Also, the paper presents the results of installation of first 20 kV spacer cable overhead distribution line in Tabriz, Iran.

INTRODUCTION

Electrical power consumption is increasing with an average annual growth equal to %2.4. This number is %3.7 in developing Asian countries and a little more in Iran. These numbers justifies high amount of investment in developing countries in the field of electrical energy production. After "availability", the consumers talks about reliability and power quality of electrical energy. So, it is possible to say that, the main responsibility of electric power distribution companies is supplying reliable electric energy with high quality. To response these requests, the electric distribution companies search for economical solutions.

Using covered and insulated overhead distribution lines instead of bare conductors is an economical solution for increasing reliability of electric power supply. Covered and insulated overhead distribution lines can be categorized as follows:

(a) Covered Conductors (CCs)

(b) Aerial Bundled Cables (ABC) (Self supporting cables)

(c) Spacer Cables (SC)

Covered conductors use one or two insulation layers over conductors [1-3]. The ABC may use same CCs which are wrapped on a supporting messenger wire in low voltage (LV). Each mono-phase medium voltage (MV) ABC cable has more layers than its LV type mainly because of higher voltage, electric and magnetic fields [4]. Spacer cables overhead electrical distribution line is a messenger wire supported system using covered conductors in a closed triangular/delta configuration [5-10]. Spacer cables have some advantages compared with 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 ABC 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. In Iran, production of CC started since 2005. Now, MV and LV CCs, most of their accessories and installation tools are producing in Iran and some hundreds of kilometers of CC lines are in operation.

Mass production of LV ABC started since 2006 in Iran. The MV ABC (generally, metallic screen type) is in production since the end of 2006. All necessary sizes of ABCs, their clamps and tools are producing in Iran.

The first 20 kV SC in Iran is in operation since July 2010. This paper presents some explanation on designing, installation, production of necessary components and future attempts in this field.

SPACER CABLE CONFIGURATION

The SC 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 in addition to spacers because, the conductor part of three-layer CC is aluminium. The rated tensile strength (RTS) of aluminium conductor is not enough to support itself. The

exact distance between spacers in each span should be computed by considering the RTS of three-layer CC. Indeed, the three-layer CCs are hanging from spacers in a very shorter distance compared with span of poles.
The messenger wire supports all mechanical loads such as CCs weight, wind and ice. The messenger wire ties to the brackets which are bolted to the poles by themselves. Such structure is one of the main attractive features of SCs. Indeed, it is possible to design the SC from electrical and mechanical points of view, independently. The above mentioned loads determine the specifications of messenger wire. For example, for crossing a wide river, it is enough to know the distance between the poles on both sides of river. Then, by considering all horizontal and vertical loads on CCs, messenger wire and spacers, RTS of messenger wire and a suitable safety factor, it is easy to choose the suitable messenger.
The brackets may be made through galvanized steel or aluminum alloy. The installation procedures of SC make it necessary to use some specially designed parts which will be explained later in detail, too.
The conductor which is stranded and compacted AAC, is surrounded by a semiconductor layer to dissipate the electrical stresses. Also, there is a LDPE layer as the first insulation layer around semiconductor. The outer insulation layer consists of black HDPE.
The spacers are HDPE and may have different shapes such as lozenge, cross and vertical three-phase form.

PROJECT SPECIFICATIONS

Fig. 1 shows the configuration of first 20 kV SC in Iran that has four circuits per pole. This project started in June 2009 by financial supporting of East aZarbaijan province Electric Power Distribution COmpany (EZEPDICO) as a research project in faculty of electrical and computer engineering of university of Tabriz. The line length was 650 (m). Cross section of AAC three-layer CCs was 150 mm^2. The project installed in foreign investment town of Tabriz, an industrial area with high electrical energy demand rate and considerable air pollution due to a nearby large cement factory. The installed project is capable to transmit 36 MW. All designing process is done in university of Tabriz and installation is done by EZEPDICO. The CC, aluminum alloy brackets, dead-end heliforms and some of other fittings are made and tested for first time. Also, installation tools are designed and made after passing test process. These procedures are explained in following sections in brief. Only spacers are imported from abroad because of economical aspects in this stage.

(a) route of pilot project (b) one of suspension poles
Figure 1- First 20 kV SC system configuration in Iran

DESINING PROCEDURE

The main designing procedure can be categorized as follows:
(a) Electrical
(b) Mechanical
(c) Fittings and tools

Electrical design

The necessary electrical power demand according to EZEPDICO request was 36 MW. Technical specification s of 150 mm^2 SC that is standardised by Western Power, shows that the current carrying capacity of this conductor is 389 (A) in 75 ^{0}C conductor and 25 ^{0}C ambient temperatures and 0.61 m/s wind speed with sun. It was possible to use this conductor with 67% of its current carrying capacity due to future increasing of electrical energy demand
Fig. 2 shows a piece of first three-layer CC that is made in Iran. This CC has semiconductor, LDPE and HDPE layers. The width of semiconductor layer is more than Hendrix type. The conductor has past desired test procedures.

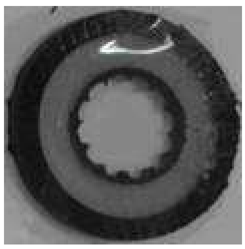


Figure 2 – Three layer of first produced CC

Mechanical design

A software prepared for mechanical design purpose. The software calculates sag-span characteristic of messenger wire before and after installation of spacers and CCs. It calculates the sag-span characteristic of CC, too. These calculations are based on six loading conditions as follows:
(a) Heavy Ice
(b) High Wind
(c) Ice & Wind
(d) Every Day Stress (E.D.S.)

(e) Minimum Temperature
(f) Maximum Temperature

These calculations determine the worst condition from sag and tension points of view. According to obtained results, the sag of messenger wire is set in installation stage to such a value that, its sag be in acceptable value after installation of CCs and spacers in worst loading condition. Fig. 3 shows a typical window of prepared software. Fig. 4 shows a part of typical output characteristic of software. This characteristic shows the sag versus span of messenger wire. The upper and lower groups of curves show the sag of messenger after and before installation of CCs and spacers for worst loading case, respectively. The parameter of these curves is ambient installation temperature. The horizontal axis is from 40 to 100 (m) by 10 (m) intervals. The vertical axis is from zero to 1 (m) by 0.5 (m) intervals. The temperature is from 10 to 40 ^{0}C by 10 ^{0}C intervals from top to down. (it was not possible to present better quality for these figures because of pages limitation). The tensions on poles are not calculated by mentioned software in this stage.

Fitting and tools design

There are some fittings, accessories and tools which have to be designed and fabricated before installation of SC.

One of the main parts of SC configuration is the brackets. As mentioned before, it is possible to make brackets by galvanized steel or aluminum alloy. Aluminum alloy brackets are lighter and have more beautiful shape. Also, they are easier to mass product. After mechanical analysis by ABAQUS software, the research group find the compound and production procedure of this kind of brackets to withstand the necessary loading. Figures 5 and 6 show a sample mechanical analysis result and a failed tension test, respectively.

It was necessary to design and product other accessories such as some attached parts to brackets, installation tools, spacers (not produced in this stage) and dead-end heli-forms. Fig. 7 shows some selected designed and fabricated parts.

ECONOMICAL ANALYSIS

The installation cost was about 65% of equivalent MV ABC system. It was more economical compared with the announce prices from some foreign companies. It seems, it is possible to decrease the prices in near future by modifying some design and production procedures [11].

FUTURE ACTIVITIES

The second 20 kV SC project is finished and is in operation since Nov. 2010 in Marand (another city in east Azerbaijan provience). It is one circuit per pole 20 kV SC system. It is installed on top of poles of a LV bare existence feeder. The project length is 2200 (m). The height of 9 (m) existence poles is increased by galvanised steel extension parts. These extensions are 2 (m) in high. The new SC system is installed on these extension parts. The project route had a narrow right of way corridor and installation of SC solved the problem.

The first and second authors of paper who have introduced CC systems in Iran and are also the manager and co-manager of "National standards for covered and insulated overhead distribution lines and their right of way rules" project respectively, are finishing the mentioned national standard and after that, it is possible to forecast a big market for SC in near future in Iran. Now, another SC project is going to start in Gorgan (a city in north-east of Iran) that will be 800 (m) four circuits per pole.

Figure 3 - Sample window of mechanical design software

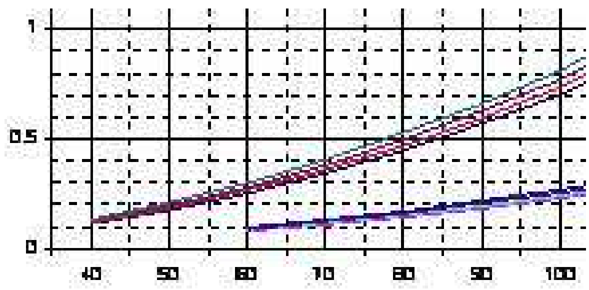


Figure 4- A part of sag-span characteristic for messenger wire before and after installation of CCs and spacers

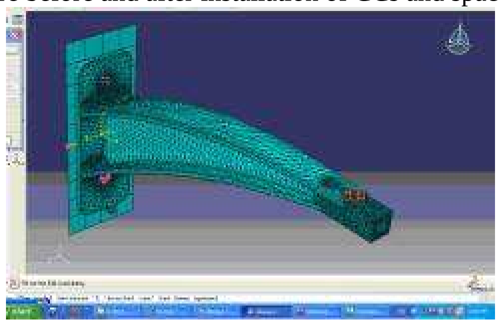
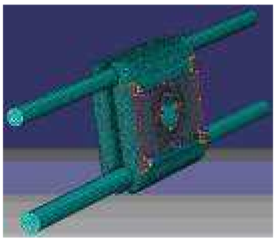


Figure 5- Sample mechanical analysis by ABAQUS

(a) a broken bracket

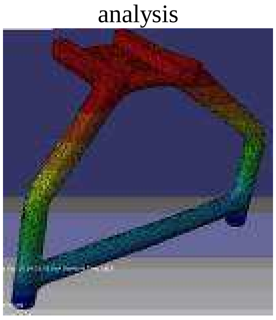
(b) magnified picture of figure 6(a)

Figure 6- One of failed tension tests results on brackets



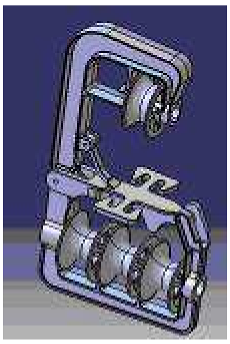
(a) a sample ABAQUS analysis

(b) an attached part to bracket, fabricated after fig 7(a) analysis and passing necessary tests -

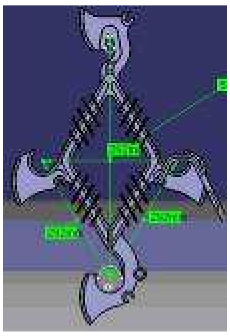


(c) a sample ABAQUS analysis

(d) produced part after fig. 7(c) analysis-an attached part to bracket



(e) CATIA designed installation tool



(f) CATIA designed spacer (not produced yet)

(g) produced dead-end helical form

Figure 7 – Some of designed and fabricated parts and tools

ACKNOWLEDGEMENT

The authors appreciate East Azarbaijan Distribution Co for financial supporting of this research. Also, the authors appreciate Hendrix Co. for presenting and developing basic idea of spacer cable systems.

REFERENCES

[1] M. Tarafdar Hagh, S. Ghiasi, K. Roshan Milani, "Overhead Covered Conductors, the Future Generation of Distribution Lines in Iran", 10'th Conf. On Distribution Network of Elect. Energy, 4-5 May, Tabriz, Iran, Faculty of Elect. and Computer Eng., pp. 64-72, (in Persian).

[2] M. Tarafdar Hagh, S. M. Seyed Giasi, K. R. Milani, M. Mostofi, "State of The Art of Application of Covered Conductors in IRAN", TPE-06 3rd International Conference on Technical and Physical Problems in Power Engineering May 29-31, 2006, Ankara, Turkey, pp. 872-876, (in Persian).

[3] M. Tarafdar Hagh, S. Ghasi, M. Mostoofi, F. Farnam, "Overhead Covered Conductors and Experimental Results of its Semi-Mass Production", 20'th Intl. Power Sys. Conf. PSC 2005, Tehran, Iran, paper ID 98-F-PDS-468, (in Persian)

[4] M. Hadizadeh, M. Tarafdar Hagh, K. R. Milani, "Problems of Low Voltage Aerial Bundled cables Due to Non Standard IPCs", 15'th Electric Power Distribution Conf. (EPDC), 4-5 May 2010, Tehran, Paper on CD.

[5] Ricardo C. C., et. al., "New Technologies, Standards, and Maintenance Methods in Spacer Cable Systems", IEEE Trans. on Power Delivery, Vol. 17, No. 2, APRIL 2002, pp. 562-568.

[6] J. D. Bouford, "Spacer Cable Reduces Tree Caused Customer Interruptions", Transmission and Distribution Conference and Exposition, 2008. Chicago, IL., pp. 1-3.

[7] Neal A. Smith, "Design Considerations of Spacers for Aerial Spacer Cable", IEEE Trans. on Electrical Insulation, Vol. EI-4, No. 1, March 1969, pp. 12-17.

[8] Western power, 2009, "Hendrix Covered Conductor Manual", Marcel Oosthuizen, February 2009.

[9] M. R. Soares, F. R. Britto, F. Nishimura, L. D. Cicarelli, "Spacer Cable and ABC Distribution Lines a Long - Term Analysis", Transmission and Distribution Conference, 1996. Proceedings., 1996 IEEE, Los Angeles, CA., pp. 219 – 224.

[10] M. Tarafdar Hagh, K. Roshan Milani, "20 kV Spacer Cables Systems, Future Generation of Overhead Distribution Lines", 24'th International Power System Conference (IPSC)'2009, lecture on Conf.

[11] K. R. Milani, M. Tarafdar Hagh, "Economic Analysis of Medium Voltage Over-head Non-bare Distribution Conductors", 15'th Electric Power Distribution Conf. (EPDC), 4-5 May 2010, Tehran, Paper on CD.