Cumhuriyet Üniversitesi Fen Fakültesi
Fen Bilimleri Dergisi (CFD), Cilt:36, No: 4 Özel Sayı (2015)
ISSN: 1300-1949

Cumhuriyet University Faculty of Science
Science Journal (CSJ), Vol. 36, No: 4 Special Issue (2015)
ISSN: 1300-1949

Evaluation of Using High Capacity Conductors in the Increase of the Capacity of Power Transmission of Lines

Shima RAHMANI[1], Mohsen NIASATI[2]

[1]*Master of Semnan University,Iran*

[2]*Assistant professor of Semnan University, Iran*

Received: 22.03.2015; Accepted: 29.05.2015

Abstract

one of the methods of increasing the capacity of power transmission of lines is the use of high capacity conductors. High capacity conductors remove the need to construction of new lines and it is installed on the exiting poles and towers without the need to change them. Therefore, in addition to the ability to supply high power, they are economical as well. In this paper, in terms of efficiency and economic issues, using high capacity conductors and construction of new lines were compared. The losses of transmission between the two methods are reviewed by considering the 400 KV line of Sirjan – Bandar Abbas and by running it in the environment of *MATLAB*.

Keywords: High Capacity Conductors, Establishment of a new line, Increase of the Capacity of Power Transmission

1. INTRODUCTION

Improvement of technology leads to the increase of the quality of life and therefore the growth of demand for electrical energy. The energy department of USA has predicted a 2.4% annual increase in the world electricity net generation over the next 20 years. In addition, statistics show that the growth rate of electricity generation changes from 1% to 3% in developed countries and 4% to 17% in developing countries in each year. Growth of transmission capacity has been limited due to several limitations which leads to some challenges in the electrical power transmission from the available transmission systems; whereas, there is an increase of the capacity of system generation [1].

A method for increasing the capacity of power transmission is construction of new lines. This method is not considered as a proper solution due to the barriers standing on its way. High land prices and presence of urban barriers and industries in the path of the line such as main roads, railways, gas and oil pipelines and their privacies are among these barriers [2]. As a result, other methods have been recommended as methods of increasing the capacity of power transmission of lines. One of these methods is using high capacity conductors. These conductors are installed on the exiting towers without the need to change them. Thus, it doesn't have problems associated with the construction of new lines and since it is able to work in high temperatures, thus it can transfer more power compared to conventional ACSR conductors.

Various papers have reviewed the usage of high capacity conductors for increasing the capacity of transmission from various aspects. In [2], using high capacity conductors for increasing the capacity of power transmission in Khorasan network has been economically reviewed in comparison with construction of new lines. In [3], losses of the West regional electricity network of Iran have been reviewed in two modes of using ACSR conductors and using high

* Corresponding author. *Email: shima1366_rahmani@yahoo.com, m-niasati@iust.ac.ir*

Special Issue: Technological Advances of Engineering Sciences

capacity conductors. In [4], available barriers in increasing the capacity of power transmission with the construction of new lines in Europe have been addressed and the impact of the application of high capacity conductors in the improvement of these barriers has been mentioned. In this work, it has been attempted to evaluate the efficiency and economic issues and losses of the method of using high capacity conductors compared to the construction of new lines from three aspects. In terms of efficiency, past works have only emphasized on the positive points of using high capacity conductors; therefore it has been attempted to review the advantages and disadvantages of this method all together. Since the implementation costs of both methods – construction of new lines and using high capacity conductors – vary in practice, unlike past works, here it has been attempted to introduce a range for costs instead of a value. Losses between the two methods of implementation of a practical model are reviewed as well. As it is described in the following section, this paper is as follows: in the second section high capacity conductors are introduced. In the third section the two methods of using high capacity conductors and construction of new lines are compared from three aspects: efficiency, economic issues and losses. In order to review the losses, the 400 KV line of Sirjan – Bandar Abbas and its implementation in the environment of MATLAB has been used. Ultimately, in the fourth section, we conclude.

1. High capacity conductors

1.1. ACSS conductor

It was presented to the market in America by Southwire Company for the first time in the year 1970. ACSS conductor is composed of fully annealed aluminum string (instead of partly annealed aluminum) around the steel core. Using this type of aluminum leads aluminum to be stretched with the rise of temperature and swiftly shift its load on the core. Since most of the cable's weight is tolerated by the steel core, thus most of the characteristics of the conductor, such as sag and strength, are specified by the steel core. Thus, in this condition, the cable can work in higher temperature with lower sag compared to ACSR conductors [2, 5 and 6].

1.2. ACCR conductor

ACCR conductor is a new type of improved conductors which has been designed and produced by 3M Company in America. ACCR has been composed of strings made of aluminum-zirconium alloy around the core composed of hybrid fibers of reinforced aluminum oxide (Al_2O_3). The core has similar strength characteristics to steel but its weight is like aluminum. On the other hand, due to the material of the core, a value of current goes through the core. Thus the conductor has lighter weight and more conductivity. The aluminum-zirconium alloy used in conductive strings tolerates higher work temperature without being annealed (being cold and warm) [2 and 7].

1.3. ACCC conductor

ACCC is a new improved conductor which has been created by Composite technology Company. ACCC has been composed of circular or trapezoidal aluminum strings around composite core with low density and high strength. This property of the core enables us to increase the cross-section associated with the aluminum strings in a similar weight and cross-section in length with conventional ACSR conductors. And also aluminum strings with high purity are used for reducing the resistivity [2 and 8].

2. EVALUATION

2.1. Evaluation of efficiency

Here, we intend to compare the construction of new lines and using high capacity conductors from 6 aspects.

The first thing is electromagnetic fields (EMF). Power transmission lines generate electromagnetic fields which can be harmful to health. Construction of a new line means generating more electromagnetic fields. Using high capacity conductors generates more electromagnetic fields, because it leads to the transfer of higher currents [4].

The second thing is the network issues. Network issues include problems associated with network stability and enhancement of the ring current. AC connections don't control power flow and power flow distribution depends on the impedance of lines which leads to ring currents. Network stability, in a simple language, is the ability of the system to return to a stable mode after the occurrence of a disturbance in the network in a way that all of the elements of power would be in a stable range. In both methods – construction of new lines and using high capacity conductors – some tools are not considered for controlling the power system for example for controlling power flow or voltage of buses. Thus, in both of them, increasing transmission power will lead to the increase of ring current and reduction of system stability [4 and 9].

The third thing is the increase of capacity. By using both methods we can increase the required transmission capacity.

The fourth thing is the length of lines. By using both methods we can transfer the high powers in hundreds of kilometers. Of course this article mostly focuses on air lines, but if establishment of new lines be done by using underground cables, there are some limitations about the length of the line.

The fifth thing is environmental issues. The impact on vegetation and land use and ugliness of the appearances of residential regions and environment are among issues associated with the construction of new lines; but since high capacity conductors are installed on the exiting lines and it delays the construction of new lines for a certain period of time, thus it is preferable compared to construction of new lines in terms of environmental issues.

The sixth thing is the time period of the implementation of the project. The time of construction of new lines is nearly five times more than using high capacity conductors, which only needs the conductors to be changed. Therefore, the required power is supplied in shorter time and the problem of black out and outage of the load will be resolved.

The mentioned issues have been shown in table 1.

Table 1: evaluation of methods

	Construction of new lines	Using high capacity conductors
Electromagnetic fields		
Network issues		
Increasing the capacity	+	+
Length of the line	+	+
Environmental issues		+
Time of implementation of the project		+

The symbol + means a positive impact and – means a negative impact of applying each of the methods – construction of new lines and using high capacity conductors – on the six aspects explained above. By considering the positive and negative points of each of the two methods, we can understand that the method of using high capacity conductors has more positive points compared to the construction of new lines. Thus, in terms of efficiency, we can say that this method is more efficient. Of course in this section, other items can also be included; but here we only referred to six of the most important items.

2.2. Economic evaluation

The cost of construction of new transmission lines depends on several issues including the capacity of a line. According to the data available in [10], establishing a new line for a particular capacity is reported to be in the following range:

- 250 to 1900 dollars per MW-km, including post and land costs for operating of transmission lines with voltages below 200 kilovolt
- 250 to 600 dollars per MW-km, including post and land costs for exploiting transmission lines with voltages above 200 kilovolt

Transmission capacity costs, to a large extent, depend on local issues including land ownership costs. Costs are higher for short lines, because the post cost does not dependant on the length of the line.

The international data available in [11-13] have a range which is compatible with the data of [10], of course except for Colombia and Brazil in which the costs are to some extent lower than the low limit of the ranges in [10].

Cost of high capacity cables is more expensive than conventional cables. About trapezoidal conductors, to some extent due to higher values of aluminum in the cable, the expenses are higher. Conductors with specific alloys and high purity are also more expensive than standard aluminum. Ceramic and composite cores are also more expensive than steel.

For two 138 KV and 345 KV lines, whose their characteristics have been provided in table 2, in [5] costs of capacity enhancement associated with these lines has been calculated with the ACCC cable. By using the same process of calculation, the costs of increasing capacity for ACSS and ACCR cables can be calculated as well.

Table 2: characteristics of lines

Voltage level (KV)	138	345
Capability to transfer thermal current of each conductor (A)	770	1010
Number of conductors in each bundle	1	2
Inductive reactance of each phase (Ohm per km)	0.490	0.370
Resistance of each phase (Ohm per km)	0.1021	0.0350
Capacitor reactance of each phase (Ohm per km)	0.116	0.088
Three-phase thermal capacity (MW)	184	1207

By assuming an approximate cost of 16 dollars per meter for ACCC cables and for one kilometer three-phase line, the cost of the conductor is approximately 48000 dollars. This cost is equal to 198000 dollars for ACCR cable with the approximate cost of 66 dollars per meter and it is 300000 dollars for ACSS cables with the approximate cost of 10 dollars per meter. Also the additional costs (engineering costs, costs associated with permit and construction costs) have been estimated to be 125000 dollars. Anyways, some of these costs might reduce in implementation.

For a 138 KV line and by assuming that this cable provides a double thermal capacity, costs of effective capacity increase on ACCC cable is nearly 940 dollars per MW-km. This value is nearly 1800 and 840 MW-km for ACCR and ACSS cables, respectively. If the costs of capacity enhancement was reduced to the conductor cost, so the cost of effective capacity enhancement will nearly be 260 dollars per MW-km for ACCC cable. This value is nearly 1100 dollars per MW-km for ACCR cable and nearly 160 dollars per MW-km for ACSS cable.

For the 345 KV line and by assuming that this cable provides a double thermal capacity, costs of conductor is respectively 96000, 396000 and 600000 dollars for ACCC, ACCR and ACSS conductors, because each phase has two bundled conductors and their total cost is two times more than the cost of 138 KV line. Thus the cost of effective capacity increase for the ACCC cable has been obtained to be nearly 180 dollars per MW-km. This cost for ACCR and ACSS cables is near 430 and 150 dollars per MW-km, respectively. If the cost of capacity increase was reduced to conductor cost, so the cost of effective capacity increase for the ACCC cable will be near 80 dollars per MW-km. This cost is nearly 330 dollars per MW-km for the ACCR conductor and nearly 50 dollars per MW-km for the ACSS conductor.

This information has been summarized in table 3.

Table 3: comparison of the costs of various methods

	Fixed cost	Assumption for calculating the total cost	Total cost in dollars per MW-km
Establishment of a new line [10]	250 – 1900 dollars per MW-km	operating below 200 KV	250-1900
Establishment of a new line [10]	250 – 600 dollars per MW-km	operating above 200 KV	250 – 600
Increase with ACCC cable [5]	16 dollars per meter	138 KV line	260 – 940
Increase with ACCC cable [5]	16 dollars per meter	345 KV line	80 – 180
Increase with ACCR cable	66 dollars per meter	138 KV line	1100 – 1800
Increase with ACCR cable	66 dollars per meter	345 KV line	330 – 430
Increase with ACSS cable	10 dollars per meter	138 KV line	160 – 840
Increase with ACSS cable	dollars per meter	345 KV line	50 - 150

By comparing these costs, it is observe that the cost of capacity increase with high capacity conductors for 138 kilovolt line for ACCC and ACSS cables overlaps the range of the cost of a new line construction in the lower end of the range. For the 345 kilovolt line, for ACCC and ACSS cables, this value is clearly less than the range of the cost of a new line construction, but for the ACCR cable it still overlaps with the range of the cost of a new line construction but this time, the overlap is in the lower end of the range.

2.3. Evaluation of losses

Loss is another one of the parameters which are effective in choosing the proper method. In order to evaluate this parameter, the 400 KV line of Sirjan – Bandar Abbas is used. Stimulation of this line is done in the environment of MATLAB. In the installation of the high capacity conductors, we assume that no change is created on the towers and the high capacity conductor and ACSR all work in the same temperature so that the losses will be evaluated in completely equal conditions.

Information of the 400 KV line of Sirjan – Bandar Abbas has been provided in table 4 together with the information of high capacity conductors.

By using this data, the stimulation for the considered line is done. In this stimulation, the losses of the considered line are obtained by power flow.

The available results in table 5 show that the high capacity conductors, in similar loading conditions, have less losses than ACSR conductors, but by construction of a new line, the current will be divided between two lines and since the loss is in proportion with the square of the current, thus the losses in this mode are less than high capacity conductors through which all of the current passes.

In this table the losses obtained from the stimulation of the 132 KV line of the Khorasan network has been brought from [2] and these results clearly show that the losses of transmission with construction of a new line are less than the method of using high capacity conductors.

Table 4: characteristics of 400 KV line of Sirjan – Bandar Abbas

	ACSR	ACCC	ACCR	ACSS
Voltage (KV)	400	400	400	400
Name of the conductor	cardinal	cardinal	cardinal	cardinal
Number of bundles	2	2	2	2
Maximum ability of current tolerance (A)	706	1887	1875	1865
Maximum of the conductor's temperature (ºC)	75	180	210	200
Power coefficient	0.9	0.9	0.9	0.9
Maximum transferrable power (MW)	880.44	2353.23	2338.27	2314.57
Loading coefficient	0.6	0.6	0.6	0.6
Ac resistance in 75 ºC temperature (ohm per km)	0.0748	0.0563	0.0701	0.07307
Inductive reactance (ohm per km)	0.2414	0.243	0.2415	0.24237
Capacitor reactance (mega ohm per km)	0.145	0.145	0.1428	0.145

Table 5: losses

	Losses (MW/km)	Losses (MW/km) [2]
ACSR (by considering the construction of a new line alongside the old line)	0.023	0.088
ACSR (by considering the whole loading on the old line)	0.102	-
ACCC	0.075	0.150
ACCR	0.095	0.190
ACSS	0.099	0.189

3. CONCLUSION

In this paper, the two methods – using high capacity conductors and construction of a new line – have been compared in terms of efficiency, economy and losses. In terms of efficiency, as it was mentioned, the high capacity conductors perform better. In terms of economy, the cost of using the method of high capacity conductors overlaps the cost of construction of a new line or it is less than that. In practical cases, the cost of both methods shall be calculated and then the proper method is selected by considering that. Nonetheless, in cases in which we face land limitation or the price of the land is high, the method of using the high capacity conductors are preferred. In terms of loss, the method of construction of a new line is considerably better than the method of using high capacity conductors. In practice, depending on the fact that which parameter (economic issues, losses and so on) are more important, the proper method is selected.

REFERENCES

[1] R. Bhattarai, A. Haddad, H. Griffiths, N. Harid, "Voltage Uprating of Overhead Transmission Lines," 2010 45th International Universities Power Engineering Conference (UPFC), pp.1-6, Aug/Sept 2010

[2] Seyed Saeed Mahdavi, Morteza Samadi, Ehsan Hosseini Manesh, Mohammad Hossein Javidi, Dariush Yazdan Panah, "optimal selection of using high capacity conductors in Khorasan network", 20th Iranian Conference on Electrical Engineering, May 17th and 18th, 2012, Tehran

[3] Majid Gandomkar, Saman Hosseini Hemmati, Ashkan Mohammadi, "Application of high capacity conductors in the reduction of West regional electrical losses of Iran", 25th International Conference on Electricity, November 18th and 20th, 2010, Tehran

[4] P.Buijs, D.Bekaert, S.Cole, D.Van Hertem, R.Belmans, "Transmission investment problems in Europe: Going beyond standard solutions," Energy Policy, vol.39, no.3, pp.1794-1801, March 2011.

[5] R.Baldick, R.P. O'Neill, "Estimates of Comparative Costs for Uprating Transmission Capacity," IEEE Transactions on Power Delivery, vol.24, no.2, pp.961-969, April 2009

[6] Alcan Corporation. www.cable.alcan.com

[7] 3M Corporation, www.3m.com
[8] Composite Technology Corporation, www.compositetech-corp.com
[9] P.Kundur, More Authors, "Definition and Classification of Power System Stability," IEEE transactions on Power Systems, vol.19, no.3, pp.1387-1401.Aug 2004
[10] K. Dixit and R. Baldick, "An empirical study of the economies of scale in AC transmission line construction costs," Dec. 2003
[11] "Valuation of electricity network assets: A policy guideline for New South Wales distribution network service," New South Wales Treasury, Australia, Technical Report, Feb. 2004
[12] "Investment costs spreadsheet," Transmission Service Development, ISA, Colombia, Technical Report, Aug. 2004
[13] L. A. Barroso, F. Porrua, L. M. Thomé, and M. V. Pereira, "Planning big things in Brazil," IEEE Power and Energy Magazine, vol. 5, no. 5, pp. 54–63,Sep/Oct 2007