ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Review: Reduction of Harmonic Losses in HVDC Converter Transformer

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ABSTRACT:A high-voltage direct current (HVDC) electric power transmission system uses direct current for the bulk transmission of electrical power over a long distance and our basic requirement of transmitting large amount of power over a long distance with minimum losses. The converter transformer is an integral part of an HVDC system. The major loss in the converter transformer is a harmonic loss. This paper presents review in literature of converter transformer based on HVDC system. Traditional converter transformer produces more harmonic current. So to overcome the existing problem of the traditional converter transformer, new converter transformer and an inductive filtering method are presented in this paper.

KEYWORDS: Converter transformer, High-voltage direct current (HVDC), Inductive filtering, Harmonics, Traditional Converter transformer, New Converter transformer.

I. INTRODUCTION

In the recent day the power demand is continuously increasing with small increase in power generation. So we require meeting the growing demand with low losses power transmission system. A high-voltage direct current (HVDC) electric power transmission system uses direct current for the bulk transmission of electrical power, in contrast with the more common alternating current (AC) systems. For long-distance transmission, HVDC systems may be less expensive and suffer lower electrical losses. For underwater power cables, HVDC avoids the heavy currents required to charge and discharge the cable capacitance each cycle. For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be justified, due to other benefits of direct current links.

HVDC allows power transmission between unsynchronized AC transmission systems. Since the power flow through an HVDC link can be controlled independently of the phase angle between source and load, it can stabilize a network against disturbances due to rapid changes in power. HVDC also allows transfer of power between grid systems running at different frequencies, such as 50 Hz and 60 Hz. This improves the stability and economy of each grid, by allowing exchange of power between incompatible networks. The HVDC system mainly contains generating station, converter transformer, converters, dc line and inverter station. Converter transformers react as coupling elements between the connected AC grids and high power rectifiers, also these transformers are necessary for adapting the voltage.

HVDC transmission system is mainly used for transmitting power over a long distance with low losses. Generally most of the losses occur due to the harmonics which are produced in the converter transformer. Due to these harmonic losses may cause malfunction and overheating of the electrical equipments such as the transformers, generators and electrical machines [1]. The objective of this paper is to provide an overview of converter transformer and reduce the harmonic losses which are produced in the transformer.

II.CONVERTER TRANSFORMER

Converter transformer is an integral part of the HVDC system. It acts as a coupling element between the connected AC grids and high power rectifiers. They insulate the rectifier itself from the AC grid and generate a phase shift. New HVDC applications are seen between existing, well-established networks.

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Converter Transformer used in HVDC system for:

- Supply of AC voltages into two separate circuits feeding the rectifier bridges with a phase shift of 30 electrical degrees for reduction of low order harmonics esp. 5th & 7th harmonics.
- As a galvanic barrier between AC and DC systems to prevent DC potential entering into the AC system
- Reactive Impedance in the AC supply to reduce short circuit currents and to control the rate of rise in valve current during commutation.
- Voltage transformation between the AC supply and the HVDC system.
- A fairly large tap range with small steps to give necessary adjustments in supply voltage.

Fig 1 shows the location of the converter transformer. In which primary winding of converter transformer is connected to the source i.e generating station and secondary winding connected to the converter.

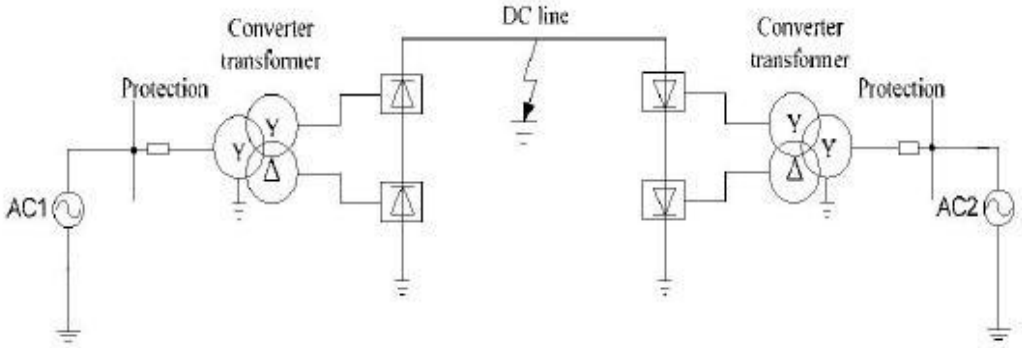

Fig1:Schematic Diagram of HVDC System

Main Components of the Converter Transformer:

1) Core: HVDC transformers are normally single phase transformers, whereby the valve windings for the star and delta connection are configured either for one core with at least two main limbs or separately for two cores with at least one main limb, depending on the rated power and the system voltage.
2) Windings: Generally converter transformer is a three winding transformer in which primary winding is star winding and secondary winding i.e. valve winding is star and delta connected. Valve winding contains high insulation level.

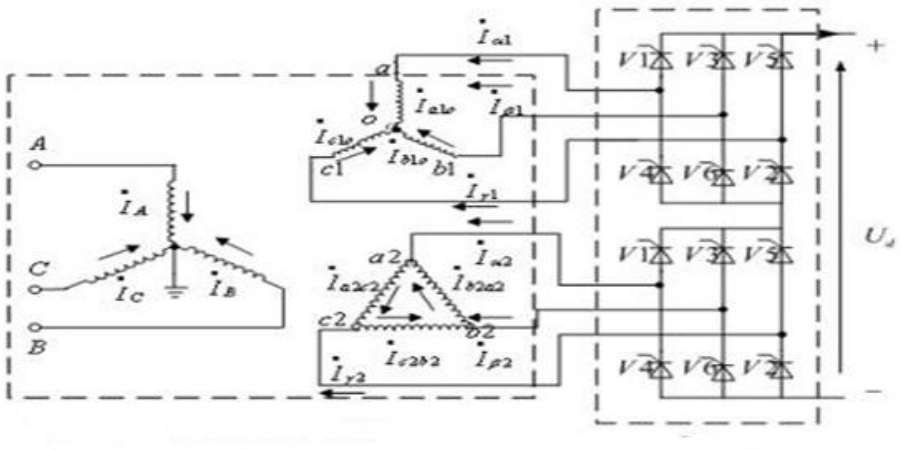

Fig 2: Converter Transformer

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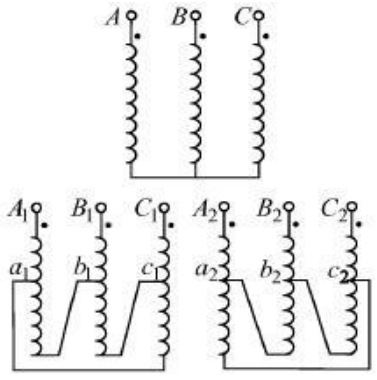
Ake Carlson et. al.[2] gives the information various functions of converter transformer, transformer connection also gives the information of the losses. The losses are present in the converter transformer are of two types RI^2 loss and stray loss. Stray loss contains harmonic losses which are harmful for the transformer and this loss is very dominant loss. Xuan Wang et. al. [3] analyses the various test performed on the converter transformer for the ordinate insulation level and gives information about the working principle of converter transformer. Bendapudi S. Ram et. al.[4] gives the information of the effect of harmonic losses on the converter transformer. In this method IEC 146 method is used for the calculation of harmonic losses. This paper analyses various parameter variation with the load loss i.e the parameters are harmonic number, firing angle and transformer reactance. As the harmonic value increases the load loss decreases i.e. 23^{rd} to 49^{th} harmonics contributing less than 1% to the load loss. It also analyses, with the increase in firing angle load loss also increases so normal firing angle being 18^{o}. J. Alan C. Forrest et. al.[5] in the previous paper transformer reactance are not taken into the consideration for the calculation of the load losses. With the consideration of transformer reactance it has been possible to obtain a more accurate harmonic loss factor. Longfu Luo et. al. [6] uses new converter transformer and an inductive filtering method to solve the existing problem of the traditional transformer.

The traditional HVDC ac passive power filters (PPF) for the harmonic suppression purpose. Due to this harmonics causes series of problems, such as additional harmonic loss, heat, vibration and noise. But the active power filter (APF) has better filtering effect than passive power filter (PPF). APF needs a complex regulation and control system, especially a large power harmonic-generating source, which is inapplicable in current HVDC transmission system [7]-[9]. Traditional converter transformer adopts star/star/ delta wiring and ac filter are placed at a transformer's primary side.

Disadvantages of traditional converter transformer,

1) A three-phase bridge converter usually generates $6k \pm 1$ (k=1,2,3…..) characteristic harmonic currents at the ac side because of the turning of the thyristor. The non-characteristics of the harmonic current also generated due to the various unbalances in the ac voltages, system impedance and transformer parameters. This harmonic current passes through the primary and secondary winding of the traditional converter transformer, which increases transformer additional heat, vibration and noise. Due to this added loss causes difficulty of the insulating design which increases the cost of traditional converter.
2) Passive filtering method is mainly used for the harmonic suppression but still have some disadvantages. The most dangerous one is that series/ parallel resonance may occur between system impedance and the passive power filters. This series/parallel resonance will result in the amplification of the harmonic current and harmonic voltage and it may damage the passive power filters and neighboring power equipment [10], [11].

So, to overcome this disadvantages new converter transformer and the corresponding inductive filtering is used. Fig 3 shows the new converter transformer and the corresponding inductive filtering system in which (a) shows the wiring mode of the transformer and its secondary winding adopts prolonged delta wiring.



(a)

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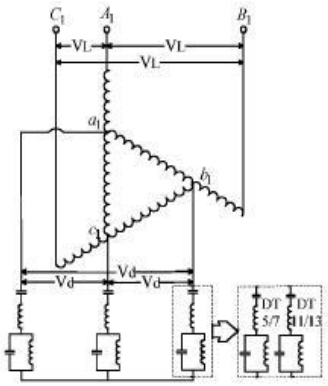

(b)

Fig 3:New converter transformer and the corresponding inductive filtering system

The winding of $A_i - a_i$, $B_i - b_i$, $C_i - c_i$ (i = 1,2) is called prolonged winding and the winding of $a_1 - b_1$, $b_1 - c_1$, $c_1 - a_1$, $a_2 - b_2$, $b_2 - c_2$, $c_2 - a_2$ is called common winding. Fig 3(b) shows the arrangement of the filters. New converter transformer contains phase-shifting principle due to which produces phase-shift of 30^o, self coupling action due to which material required for the new converter transformer is reduced, inductive filtering mechanism causes harmonic current into the branch of the secondary common winding and there is no harmonic current in the primary winding. This transformer also used for the reactive power compensation [12]-[18].

III. CONCLUSION

Converter transformer is an integral part of the HVDC system which acts as a galvanic barrier between AC and DC system. The main loss in the converter transformer is a harmonic loss. The traditional converter transformer has produces harmonic current which produces additional heat, vibration and noise also there is a problem of series/ parallel resonance which damage the passive power filters and neighbouring power equipment. To overcome this new converter transformer is used. The secondary windings of the new converter transformer adopt prolonged delta wiring, which brings about symmetrical characteristics to its structure. Also the inductive filtering method can optimize the structure of the HVDC transmission system, greatly reducing the negative effect of harmonic on the operation of the transformer and improving the filtering effect at the ac side of the HVDC system.

REFERENCES

1. Longfu LUO, Jiazhu XU, Ji LI, Yong LI, Fusheng LIU, "A Novel Method of Harmonic Suppression in the AC/DC Transmission System Based on Novel Converter Transformer", 2006 International Conference Power System Technology.
2. Ake Carlson, "Specific requirements on HVDC transformers", ABB Transformers AB.
3. Xuan Wang, Juanjuan Yang, Xiaolong Cao, Man Xu, Jingshun Lv, "The Electric Testes of Ordinate Insulation in Converter Transformer by the Method of Applying Voltage on Single-phase", 7th International Conference on Properties and Applications of Dielectric Materials June 1-5 2003 Nagoya.
4. Bendapudi S. Ram, J. Alan C. Forrest, Glenn W. Swift, "Effect of harmonics on converter transformer load losses", IEEE Transactions on Power Systems, Vol.3, No.3, July 1988.
5. J. Alan C. Forrest, "Harmonic load losses in HVDC converter transformers", IEEE Transactions *on* Power Delivery, Vol. 6, No. 1, January 1991
6. Longfu LUO, Yong LI, Jiazhu XU, Ji LI, Bo Hu and Fusheng LIU, " A new converter transformer and a corresponding inductive filtering method for HVDC transmission system", IEEE Transaction on Power Delivery, Vol. 23, No.3, July 2008.
7. W. Zhamg, A. Aberg, U. Jonsson and O. Loof, " Active DC filter for HVDC system- A test installation in the konti-skan DC link at Lindom converter station", IEEE Trans. Delivery, Vol.8, No.3, pp.1599-1606, Jul.1993.
8. T. Westerweller, M. Pereira, H. Huang and G. Wild, "Performance calculation and operating results of AC harmonic filters for HVDC transmission systems", in Proc. IEEE Power Eng. Soc. Summer Meeting, Jul. 15-19, 2001, vol. 1, pp.337-342.
9. D. Basic, V. S. Ramsden and P. K. Muttik, "Harmonic filtering of high power 12-pulse rectifier loads with selective hybrid filter system", IEEE Trans. Ind. Electron, Vol.48, No.6, pp. 1118-1127, Dec. 2001.
10. H. L. Jou, J. C. Wu, and K. D. Wu, Parallel operation of passive power filter and hybrid power filter for harmonic suppression", Proc. Inst. Elect. Eng. Generation, Transmission, Distribution, vol.148, no.1, pp. 8-14, Jan. 2001

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11. B. Singh, G. Bhuvneswari and V. Grag, " T- connected auto transformer based 24 pulse ac-dc converter for variable frequency induction motor drives", IEEE Trans. Energy Conv., Vol. 21, No. 3, pp. 663-672, Sep. 2006
12. Yong Li, Dajiang He, "Study on the Effects of the DC Bias on the Harmonic Characteristics of the New Converter Transformer", IEEE Trans. 2010
13. Yong LI, Longfu LUO, Kazuo Nakamura, C. Rehtanz, Jie ZHANG, Jiazhu XU, and Fusheng LIU, "Transient Response Characteristics of New HVDC Transmission System Based on New Converter Transformer", Nanjing China DRPT2008 6-9 April 2008
14. Longfu LUO, Yong LI, Kazuo Nakamura, Gerhard Krost, Ji LI, Jiazhu XU, and Fusheng LIU, "Harmonic Characteristics of New HVDC Transmission System Based on New Converter Transformer", Nanjing China DRPT2008 6-9 April 2008
15. Dechang Yang, Yong Li, Christian Rehtanz, Longfu Luo, Jiazhu Xu, "Study on Harmonic Losses of Inductive Filtering Converter Transformer (IFCT) in HVDC System", IEEE conference 2010
16. Yong Li, Longfu LUO, Christian Rehtanz, Kazuo Nakamura, Jiazhu Xu, " Study on characteristics parameters of a new converter transformer for HVDC systems", IEEE Transaction on Power Delivery, Vol. 24, No.4, October 2009.
17. Li Peng, Wang Ye, Wang Yuting, Huang Haosheng, Yuan Yubo, " Characteristic and Influence analysis on the Inrush Current of HVDC Converter Transformer", 2014 International Conference on Power System Technology (POWERCON 2014), Chengdu, 20-22 Oct. 2014
18. Chonggan Liang, Longfu Luo, Yong Li, Wendi Liao and Qi Qi, "A New Method Highly Integrated with Converter Transformer for Harmonic Suppression and Reactive Power Compensation", 2014 International Conference on Power System Technology (POWERCON 2014), Chengdu, 20-22 Oct. 2014