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Investigation of Three-Phase Thyristor Converters under Generalized Impedance Unbalance

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Abstract

Line-commutated current converters operated in electrical power systems will work asymmetrically, if the system is not balanced. This asymmetrical operation causes non-characteristic harmonics in the currents and therefore a higher distortion level. As a high distortion level is always disadvantageous, it is worthwhile to find appropriate methods to lower the distortion level by reducing the amplitudes of these non-characteristic harmonics.

In this paper, three-phase thyristor converters operated in systems with unbalanced AC-line short-circuit impedances are investigated. To achieve a competent and well-grounded understanding of the problem a suitable method of calculation has been developed. This method firstly offers the opportunity to calculate the operation of line-commutated current converters in an unbalanced three-phase system. Furthermore it offers the opportunity to optimize the operation of the unbalanced system. This optimization is done by balancing the systems operation and reducing the amplitudes of the non-characteristic harmonics using asymmetrical firing angles.

Key words

Power converter, unbalance, converter control, distortion, optimization

1. Introduction

Electrical three-phase power systems are never perfectly balanced. These unbalances can be results of an unbalanced mains voltage, unbalanced loads or unbalanced AC-line short-circuit impedances. The latter case with unbalanced short-circuit impedances is investigated in this paper. An unbalance of this kind can be caused by faulty transmission lines or overhead transmission lines without transposition for example.

Current converters operated in unbalanced electrical systems will generally work asymmetrically. This is also valid for similar electrical power equipment, like FACTS, HVDC converters and current limiters based on power converters, when this equipment is operated in an unbalanced electrical system. In all of these cases this asymmetrical operation firstly introduces the appearance of non-characteristic harmonics. These non-characteristic harmonics lead to a distortion level, higher than the distortion occurring in case of a balanced operation of the system [1, 2]. As a high distortion level is always disadvantageous, both for the converter and the power system, a method to keep the distortion as low as possible is desirable.

For a given system the impedance unbalance is fixed and not changeable. So the reduction of the distortion level can only be done by reducing the amplitudes of the non-characteristic harmonics. With controllable current converters, such as thyristor converters, this reduction of the distortion level can be realized by balancing the current converter's operation using a control strategy with unsymmetrical firing angles [3, 4]. This makes the operation of a current converter in an unbalanced electrical power system more balanced and reduces the THD.

The aim is now to calculate optimal firing angles for a given system with a given impedance unbalance. Due to the unbalance, these optimal firing angels will be asymmetrical. This means for example for a six-pulse thyristor bridge in asymmetrical operation the spacing between two optimal firing impulses is not 60° like in normal symmetrical operation.

This possibility with unsymmetrical firing angels has already been shown for forced-commutated converters both with an unbalanced mains voltage and with unbalanced AC-line impedances [5, 6] and for line-commutated power converters with an unbalanced mains voltage [7, 8]. A first approach has been shown for line-commutated converters with a simplified unbalance of the AC-lines short-circuit impedance [9]. In this work, a generalized approach is presented, wherein the simplifications of [9] do not have to be complied with. Hence the unbalance of the AC-lines short-circuit impedance can be of any kind and practical problems can be investigated more realistically.

In calculating the operation of current converters it is common to assume all impedances to be lossless and the