Simplified switching strategy for four-pole four-wire voltage-source converters

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Abstract. Four-leg voltage-source shunt converters can effectively provide the neutral connection in three-phase four-wire systems. They can be used in an inverter, a rectifier, as an active filter and in various power quality conditioner applications to handle the neutral current caused by the unbalanced and/or nonlinear load. Three-dimensional space vector modulation schemes were proposed for controlling the four-leg voltage-source converters. The additional fourth neutral leg makes space vector modulation control a difficult task. Therefore, an alternative control strategy is proposed in this paper. A simple delta modulation with confined maximal switching frequency that provides a fast response and easy implementation for digital discrete time systems is chosen. For the driving of the fourth neutral leg traditional PWM modulation is employed. Proposed driving algorithm is verified by simulations in an advanced software package, namely PSCAD/EMTDC.

1 Introduction

The first configuration of a four-wire shunt AF is known as the capacitor midpoint type, used in smaller ratings. Here, the entire neutral current flows through dc-bus capacitors and also the DC bus voltage utilization is low.

The three single-phase bridge configuration is quite common and this version allows the proper voltage matching for solid-state devices and enhances the reliability of the system. However, 12 switches have to be used. A more detailed comparison of the features of these topologies is given in [1].

Therefore another configuration, known as the four-pole four-wire type, which provides a good DC-bus voltage utilization and prevents neutral current to flow trough DC-bus capacitor was chosen. The standard three-dimensional space vector modulation for four-poles voltage-source converters is proposed in [2].

Some atypical topologies handling neutral current were also proposed. One of them employing a transformer is described in [3].

Topology

The computation of required currents depends on the kind of conditioner. Algorithms used for active filter, dynamic voltage restorers etc. are universally known [4]. Therefore, the following text describes only driving of four-pole converter in order to handle required currents i_{aw}, i_{bw}, i_{cw}, where $i_{aw} + i_{bw} + i_{cw} \neq 0$.

Four-leg voltage-source converters can be obtained by replacing the three-leg switching network with a four-leg switching network, as shown in fig. 1. Let the switching function for each leg is defined as S_k = 1 when the top switch is closed and S_k= -1 when the bottom switch is closed k ={a,b,c,n}. If the DC bus voltage is sufficiently high, i_j independent from v_j is either deceased (when S_j= 1 and S_n= -1) or increased (when S_j= -1 and S_n= 1) j = {a,b,c}.

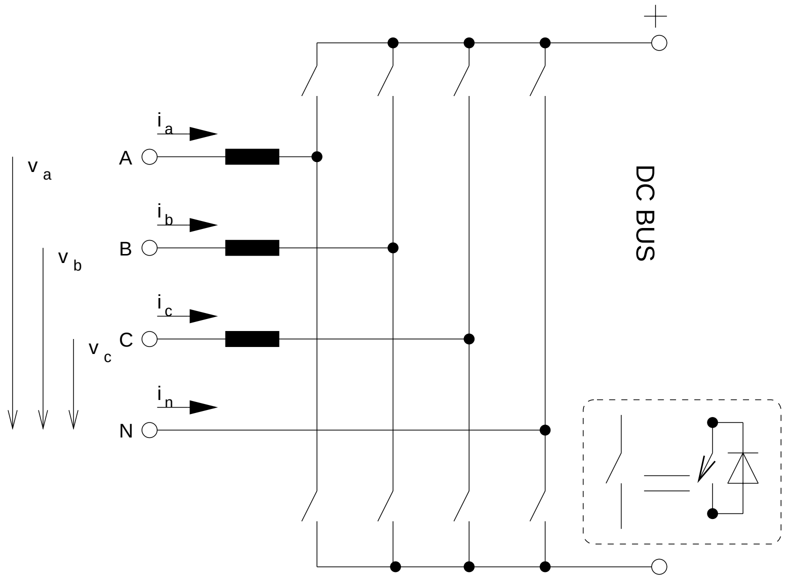


Fig. 1 four-leg switching network

Description of driving algorithm

Switching pattern for phase-legs is created as shown in fig. 2. In order to limit the maximum switching frequency, the decision about changing conduction between top and bottom switches can be mode only at certain instants ("CLOCK" signal).

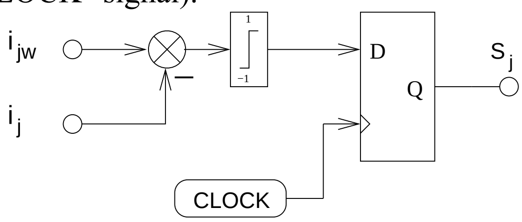


Fig. 2 delta modulation

The synchronistic decreasing or increasing of all phase currents cannot be permanently expected as desired. Therefore, instances when $S_j \,.\, S_n = 1$ are inevitable. During these instances the first derivation of phase currents depends only on their line voltages. Apparently, this first derivation can differ from the desired one. The error is linearly depended from $|v_j|$. Therefore, a cost function can be expressed in eq. 1 and signal "reference" computed according eq. 2 is used for standard PWM control of neutral-leg as shows fig. 3.

$$k_j = \frac{|v_j|}{|v_a| + |v_b| + |v_c|} \qquad j = \{a,b,c\} \qquad (1)$$

$$ref = \sum_j S_j . k_j \qquad j = \{a,b,c\} \qquad (2)$$

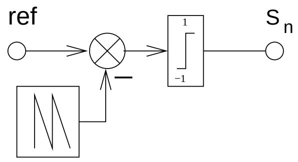


Fig. 3 PWM modulation

Results of simulations

The presented fig. 4 shows the basic functionality of the proposed driving algorithm. The injection currents of the four-leg voltage-source shunt converter, which is driven by the proposed algorithm, compensate an excessive neutral current caused by an unbalanced load.

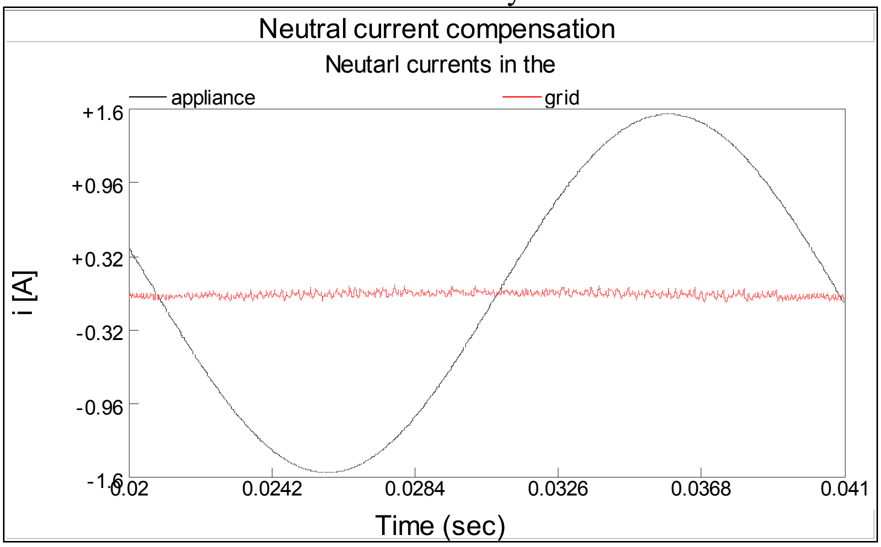


Fig. 4 basic functionality

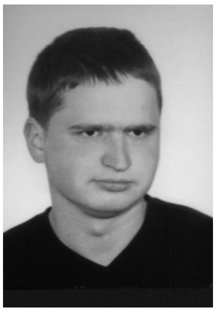
Conclusion

This paper proposes relatively simple control of four-pole for wire topology converters that can be employed for various applications e.g. a rectifier, as an active filter etc. However, the main weakness proposed strategy - namely uncertain switching pattern - has to be considered for using in large-scale industrial applications.

References

1. Bhim Singh, Kamal Al-Haddad, Ambrish Chandra ,"A Review of Active Filters for Power Quality Improvement," IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 46, NO. 5, OCTOBER 1999.
2. Richard Zhang, V. Himamshu Prasad, Dushan Boroyevich, Fred C. Lee, "Three-Dimensional Space Vector Modulation for Four-Leg Voltage-Source Converters," IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 17, NO. 3, MAY 2002.
3. Prasad N.,Enjeti, Wajiha Shireen, Paul Packebush, Ira J. Pitel, "Analysis and Design of a New Active Power Filter to Cancel Neutral Current Harmonics in Three-Phase Four-Wire Electric Distribution Systems," IEEE TRANSACTION ON INDUSTRY APPLICATIONS, VOL. 30,NO. 6, NOVEMBER/DECEMBER 1994.
4. O. Viktorin, J. Driesen, R. Belmans, "Comparison of dynamic restorer topologies," Bologna Powertech conference 2003.

Biographies



Ondrej Viktorin was born in Rychnov, Czechoslovakia, on May 12, 1978. In 2001 he obtained the Master degree in electrical engineering from University of west Bohemia in Pilzen, Czech. He is currently working as a research assistant in the Katholieke Universiteit Leuven (KULeuven), Belgium where he is preparing a Ph.D. His interests include power electronics, power quality issues, renewable energy and energy storage.