TWO-STAGE INDIRECT MATRIX CONVERTER TOPOLOGIES AND THEIR APLICATION IN THE DOUBLY-FED INDUCTION GENERATOR

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Introduction. During the last years, the most used configuration in wind power projects has been the doubly-fed induction generator (DFIG) [6]. The main advantage of this configuration is that it allows to produce constant-frequency electric power with a variable mechanical speed, reduce copper losses and wide operational range. Therefore, the power extraction from the wind can be optimized. The converter feed the low-frequency rotor circuits from the grid [3]. The converters are partially scaled requiring a rated power of about 30% of the generator rating. Usually, the slip varies between 40% at sub-synchronous speed and 30% at super-synchronous speed.

In recent years (approximately the beginning of the century) a new directions in research and development of matrix converters (MC) have been proved [1]. Saving all the known advantages of MC, such as 4-quadrant operation, close to a sine of the input and output currents, a single input power factor, new circuit topologies and control algorithms that are directed to simplifying overall system control have been introduced.

Now indirect MCs (IMC) are known, structure of which can be divided into the rectification stage and the output voltage inverting stage, which is directly connected to the DC link [4], [5]. This converter referred to conventional matrix type because each phase of network is connected directly to the each load phase through semiconductor power devices without intermediate storage elements (LC).

The aim of the paper is to study different types of IMC and their possibility to supply DFIG.

Materials of study. The circuit of two-stage indirect MC (TSMC) (Fig. 1) consists of PWM rectifier section, PWM-inverter section (VSI) and the AC source filter [3]. These types of converters are essentially bi-directional and therefore can regenerate energy back into the mains from the load side. However, the DC voltage in a TSMC has only positive polarity. In order to allow bi-directional current flow (four-quadrant operation), bi-directional active switches are needed in the input bridge of the IMC as shown in fig.1. On the output side, the classical voltage source inverter is used to form output voltages. The IMC employs 18 IGBTs and 18 diodes similar to those in the classical direct MC.

Due to the presence of the DC link in the conventional two-stage MC, it has new properties:

- ability to change the voltage range;
- use different frequency switching rectifiers and inverters to reduce losses;
- well known inverter control algorithm.

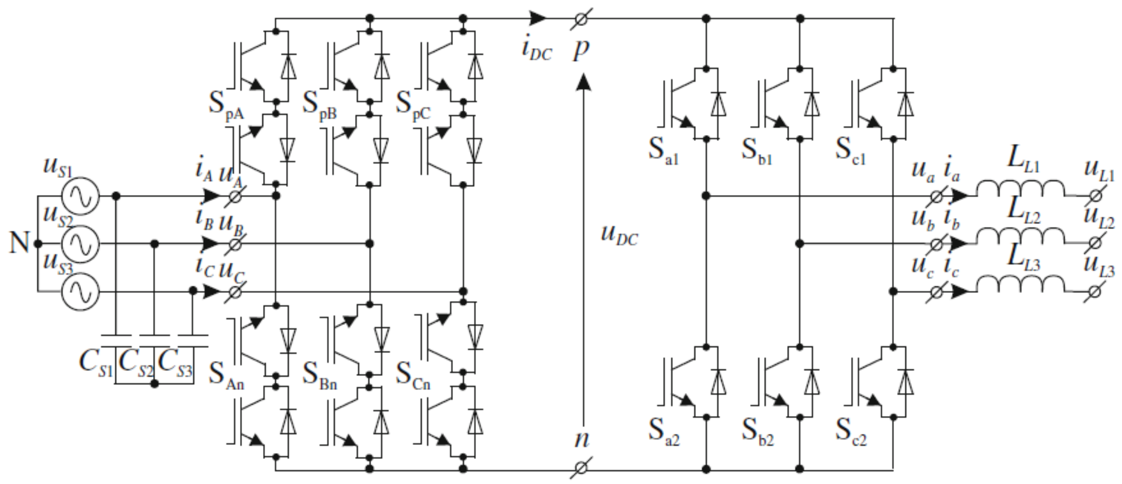

Figure 1 – AC/AC Two Stage Indirect Matrix Converter

Similarly as in conventional MC, special commutation methods are needed to avoid shorting of input phases without cutting load current path. The four-step commutation is commonly used in the IMC. The modulation strategies are based on an indirect concept.

Modification of the basic topology TSMC allows to get other circuit solutions [2]. This preserves the bi-directional communication between the current phase of the power line and each output line of the rectifier. Thus, the total number of transistors in the base scheme can be reduced in the rectifier from 18 to 15 (Fig. 2). Converters built on such topology are called in the literature as sparse matrix converter (SMC). In this circuit configuration, the bi-directional power flow could in principle be obtained with positive and negative DC link voltage. If assumed that the DC link voltage is positive polarity, a reduction in the number of active switch devices is possible.

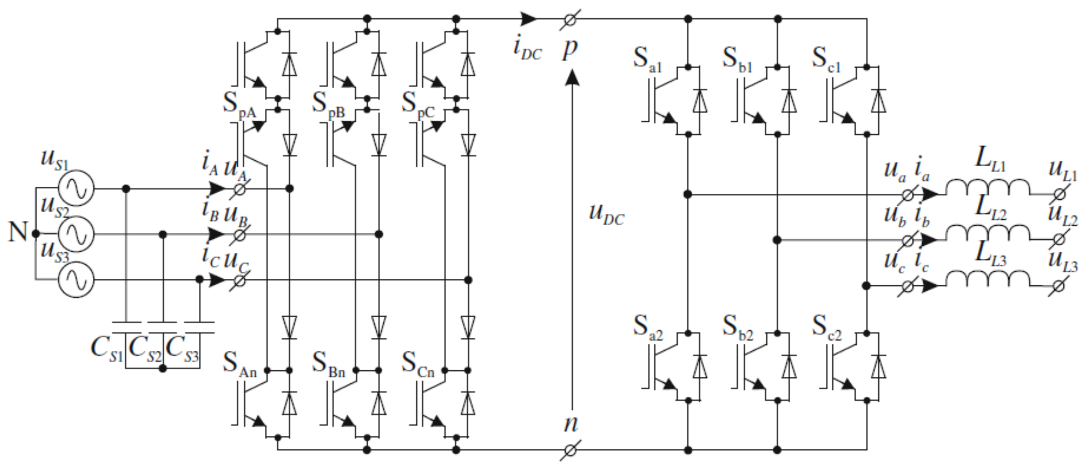

Figure 2 – Sparse matrix converter (SMC)

More simplified version of the converter is possible, but only if a unidirectional power flow is required. This is an ultra sparse matrix converter (USMC). The source bridge consists of three IGBTS and 12 diodes.

In another topology a simplified commutation is possible. This converter is named a very sparse matrix converter (VSMC). This topology is functionally similar to TSMC but also allows conduct power only in one direction. In the VSMC structure, the 12 IGBTs and 30 diodes are employed.

Zero DC link current commutation and bidirectional power flow allow the employment of the circuit topology of the inverting link matrix converter (ILMC), which is shown in Fig. 3. Here, the bidirectional current carrying capability of the input stage is achieved by connecting an input rectifier and a voltage inverter through two power transistors and two diodes. Unfortunately, the inversion of the voltages has to be performed with high frequency. Then the switching losses are increased. Furthermore the control algorithm becomes complicated.

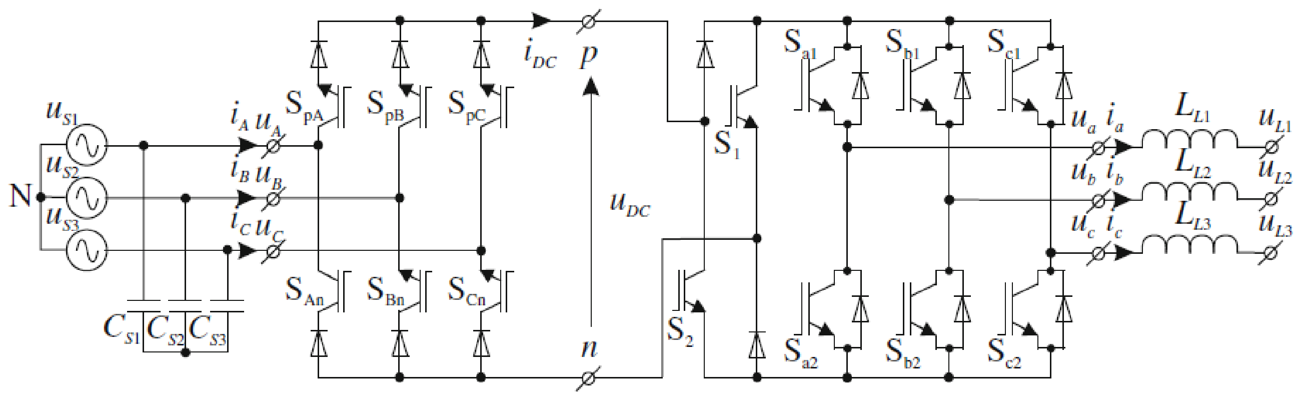

Figure 3 – Inverting link matrix converter (ILMC)

The topologies of the two-stage, sparse, very sparse, ultra sparse and inverting link matrix converter are characterized by a voltage transfer ratio also less than one, with its maximal level equal to 0.866 [6].

Conclusion. Bidirectional power flow in MC is needed for application in DFIG. Therefore only standard IMC topologies such as (TSMC), sparse IMC and ILMC are suitable. Although ILMTS and SMC have fewer transistors, but their application much more complicated.

References

1. Чехет Э. М., Соболев В. Н., Михальський В. М., Шаповал И. А., Поліщук С. И. "Тенденции развития матричных преобразователей для асинхронного электропривода" // Вестник НТУ «ХПИ». Проблемы автоматизированного электропривода. Теория и практика. – Харьков: НТУ «ХПИ». – 2005. – Выпуск 45. – С.32-37.

2. Szcześniak P. "Three-Phase AC-AC Power Converters Based on Matrix Converter Topology. Matrix-reactance frequency converters concept" // London: Springer. – 2013. – 174 p.

3. Wenlang Deng, Zhiyong Chen, Liming Zhou, Yu Yang "Research on the Performance of low voltage ride-through for doubly fed induction generator excited by two-stage matrix converter" // Proceedings of IEEE 6th International Power Electronics and Motion Control Conference IPEMC `09, Wuhan, China. – 2009. P. 638-643.

4. Friedli T., Kolar J. W., Tani A. "Milestones in Matrix Converter Research" // IEEJ Journal of Industry Applications, – July 2012 – Vol.1. – No. 1. – P. 2-14.

5. Klumpner C., Blaabjerg F. "A New Cost-Effective Multi-Drive Solution based on a Two-Stage Direct Power Electronic Conversion Topology" // Proceedings of the 2002 IEEE Industry Applications Conference IAS`2002. – 2002. – Vol. 1. – P. 444-452.

6. Cardenas R., Pena R., Alepuz S., Asher G. "Overview of Control Systems for the Operation of DFIGs in Wind Energy Applications" // IEEE Trans. on Industrial Electronics. – July 2013. – Vol. 60. – No. 7. – P. 2776–2798.