International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 06 | Jun 2022 www.irjet.net p-ISSN: 2395-0072

Power Converter Configurations for Switched Reluctance Motors: A Review

Shambhavi K N[1], Dr. V Chayapathy[2]

[1]PG Student, Dept. of Electrical and Electronics Engineering, R V College of Engineering, Karnataka, India
[2]Associate Professor, Dept. of Electrical and Electronics Engineering, R V College of Engineering, Karnataka, India

---***---

Abstract - *The Power Converters are an essential part of the Switched Reluctance Motor drives. With extensive research being conducted in the field, various configurations have emerged which make the control of the motor easier and adaptable. It is necessary to take into account multiple parameters like the type of application, Power Electronics devices available and cost constraints before determining the type of Power Converter to be used. Keeping one of these configurations as reference, novel converters can be designed specific to the application. This paper presents a comprehensive review of the different types of configurations available based on various parameters.*

***Key Words*: Power Converters, Bridge Converters, Switched Reluctance Motor.**

1. INTRODUCTION

The demand for Electric Vehicles (EVs) is drastically increasing in response to the increasing threats to the environment because of the use of fossil fuels in conventional vehicles. This, in turn has paved way for extensive research in the field for optimising the power trains. Induction Motors (IM) and Permanent Magnet Synchronous Motors (PMSMs) are widely in use because of their desirable properties. Even so their disadvantages like temperature constraints on IM and high cost of permanent magnets in PMSM promote research to find a better alternative. Owing to their many advantages like rugged nature, ability to withstand high temperatures, controllability, nominal cost, capability of extremely high-speed operation, fault tolerance and high efficiency, Switched Reluctance Motors (SRMs) are preferred to their contemporaries. However, research is underway to overcome the challenges in this like high acoustic noise and torque pulsations.

SRM is by far the simplest in construction amongst electrical machines. The stator consists of windings whereas the rotor consists of just laminations stacked onto a shaft. There are no windings or permanent magnets on the rotor which contribute to its cost effectiveness. In contrast to other motors, SRM does not work on a mere AC or DC supply. For every step, the magnetic flux is established from zero in proper sequence. There are four essential parts in SRM drive as shown in Fig. 1.1.

- The motor that converts electrical energy into mechanical energy.
- The sensor to detect the position of the rotor so as to excite the appropriate stator phase.
- The power electronic converter acts as a supply and excites the appropriate phase in accordance with the controller's commands.
- The controller takes input from the sensor and sends signal to the converter to excite the appropriate phase.

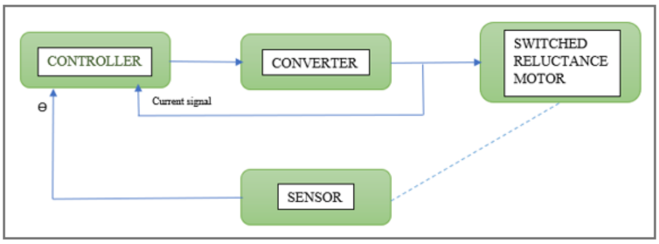

Fig - 1.1: Typical SRM drive system

Power converters are one of the most important parts in a SRM drive as they considerably affect the performance parameters like efficiency, torque, etc. With developments in Power Electronics, the converters have evolved with time and presently various types are available to choose from depending on application, available components, cost effectiveness and ease of developing. The two most basic requirements of a SRM converter include:

- Each phase of the SRM must be able to conduct independent of other phases so that loss of or abnormal working of one of the phases does not affect the working of the drive.
- The converter of the drive must be able to demagnetize a particular phase completely before it goes into generating region.

Along with these, the below mentioned additional requirements must be met for improved efficiency, reliable operation, and power density:

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 06 | Jun 2022 www.irjet.net p-ISSN: 2395-0072

- Phase overlap control must be permitted.
- The energy from demagnetization must be utilized by sending it back to source and/or using it in next phase.
- Sufficient high negative voltage must be generated to demagnetize the off going phase quickly thereby reducing demagnetization time.
- Switching frequency and its losses must be mitigated by operating in freewheeling mode.
- High positive voltage excitation must be given to increase the phase current so that output power is improved.

2. CLASSIFICATION OF POWER CONVERTER TOPOLOGIES

Power converters for SRM drives are classified mostly depending on the type of switching employed. There are two categories based on the type of switching: Hard switched converters and Soft switched converters. The sub types in each of these categories is illustrated in Fig. 2.1.

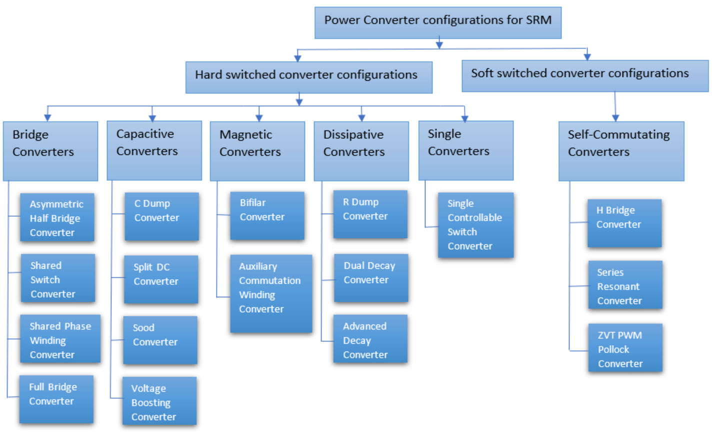

Fig – 2.1: Classification of power converter topologies

3. BRIDGE CONVERTERS

These converter topologies consist of diodes and switches. They are basically derived from H-Bridge converter topology and stand out owing to their simple structure and controllability. The different types of Bridge Converters are explained below with their circuit diagrams, benefits, and drawbacks.

3.1 Asymmetric Half Bridge Converter

In this type of converter configuration, if there are q motor phases, the converter consists of 2q active switches. The circuit of the same is as shown in Fig. 3.1. When soft switched, the converter provides for operation in 3 different modes: Magnetization, Demagnetization and Free-wheeling mode. When hard switched, it operates in only two, i.e., Magnetization and Demagnetization modes.

Advantages:

- Maximum flexibility as the upper and lower switches can be controlled independently.
- The converter has the same efficiency in Magnetisation mode as in case of Demagnetisation mode.
- The winding is in series between the two switches. Thus, in case of a short circuit fault, the inductance of the windings limits the current rise thereby providing sufficient time to the protective devices to locate and isolate the fault.

Disadvantages:

- The number of power electronic devices per phase is high.
- In case of low voltage operations, the total forward voltage drop of the two switches may be significant when compared to the available DC voltage.
- Voltage ripple is very significant due to the magnetisation and demagnetisation of the phase winding which necessitates the use of a large capacitor to filter it out.

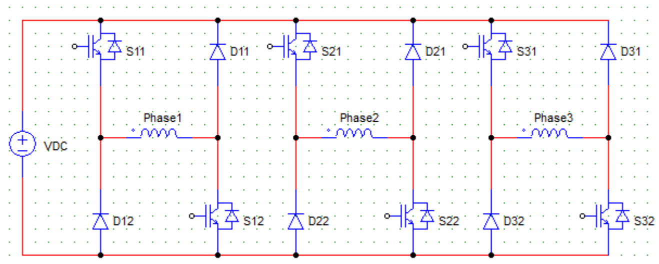

Fig – 3.1: Asymmetric half bridge converter

3.2 Shared Switch Converter

This converter configuration is similar to Asymmetric Half Bridge Converter but differs in the fact that the power electronic devices like the switch and the diode are shared between different phases in Shared Switch Converter unlike Asymmetric Half Bridge Converter. It is also called Miller Converter. The general version makes use of q+1 switches where q is the number of phases. Analogous to Asymmetric Half Bridge Converter, Shared Switch Converter operates in

3 modes, Magnetization, Demagnetization and Freewheeling mode, when soft switched and in Magnetization and Demagnetization mode when hard switched. Fig. 3.2 represents a general Shared Switch Converter.

Advantages:

- The necessary number of power electronic devices is reduced.
- The number of power supplies required for driver circuits is less.

Disadvantages:

- Very limited freedom of operation and lesser fault tolerance as the operation of all phases depends considerably on the shared switch.
- When reversing the direction of the machine, the reference speed must be maintained at zero until all phase currents are zero and only then negative motion can be achieved.
- Significantly high switching stress on the shared switch.

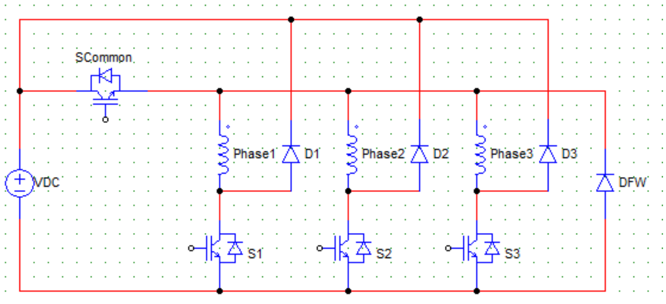

Fig – 3.2: Shared Switch Converter

3.3 Shared Phase Winding Converter

In this converter configuration, a single asymmetric half bridge converter is shared between 2 phases. It uses the same number of switches as the number of phases (q). Thyristors are used to steer current into the desired phase but not for control. This configuration is particularly useful for SRMs with even number of phases. Freewheeling mode can be achieved by making use of diodes. This converter can be operated with both soft switched and hard switched approaches. The circuit representation of the same is shown in Fig. 3.3.

Advantages:

- Independent control of phase current is possible because of freewheeling diode.
- Lesser number of power electronic device and better utilization of each of them.
- Positive, negative and zero output can be obtained from the converter which allows greater current control flexibility.

Disadvantages:

- Very less fault tolerance.
- Even within the same half bridge, current overlap between phase windings is not possible.
- Inclusion of thyristors increases the cost as well as complexity of the circuit.

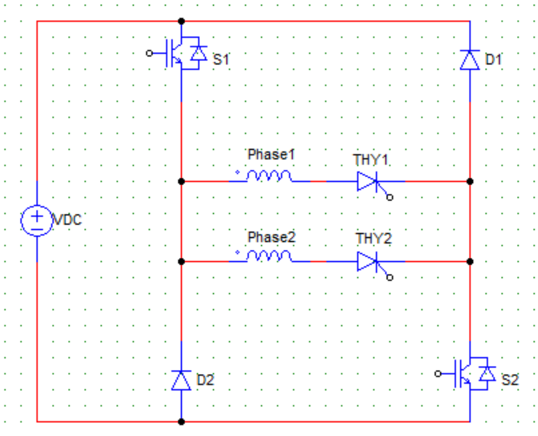

Fig – 3.3: Shared Phase Winding Converter

3.4 Full Bridge Converter

In this converter configuration, 4q switches are used where q is the number of phases, as shown in Fig. 3.4. This converter configuration is similar to half bridge converter except the usage of switches instead of diodes. Not unlike Asymmetric Half Bridge Converter, even this converter operates in 3 modes, Magnetization, Demagnetization and Freewheeling mode, when soft switched and Magnetization and Demagnetization mode when hard switched. The usage of switches reduces conduction and switching losses during Demagnetization and Freewheeling mode.

Advantages:

- This converter configuration provides improved control flexibility when working as motor and generator.
- During Demagnetisation mode and Freewheeling mode, the operational efficiency is sufficiently enhanced.

Disadvantages:

- As the number of power electronics devices used is more, it suffers from underutilisation of devices.
- The cost of the converter is comparatively high because of the inclusion of more devices and the driving circuits corresponding to them.

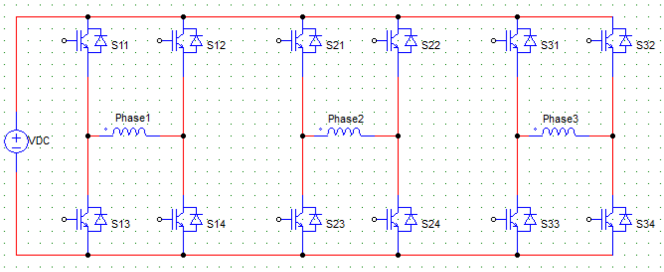

Fig – 3.4: Full Bridge Converter

3. CONCLUSIONS

A comprehensive review of different types of Bridge Converter circuits for SRMs has been discussed. Each of the topologies have their own merits and limitations. The choice of the converter mainly depends on the type of application and requirements. For automotive application, the Asymmetric Bridge Converter is advantageous because of its inherent scope for short circuit protection and greater fault tolerance. The performance in all three modes, namely, magnetization, Demagnetization and Freewheeling, is satisfactory. These benefits make up for the drawbacks associated. These are the reasons owing to which this configuration is widely accepted.

REFERENCES

[1] Bostanci, E.; Moallem, M.; Parsapour, A.; Fahimi, B. Opportunities and challenges of switched reluctance motor drives for electric propulsion: A comparative study. IEEE Trans. Transp. Electrif. 2017, 3, 58–75.

[2] Pires, Vitor & Pires, A. J. & Cordeiro, Armando & Foito, Daniel. (2020). A Review of the Power Converter Interfaces for Switched Reluctance Machines. Energies. 13. 3490. 10.3390/en13133490.

[3] S. J. Watkins, J. Corda and L. Zhang, "Multilevel asymmetric power converters for switched reluctance machines," 2002 International Conference on Power Electronics, Machines and Drives (Conf. Publ. No. 487), 2002, pp. 195-200, doi: 10.1049/cp:20020113.

[4] O. Ellabban and H. Abu-Rub, "Switched reluctance motor converter topologies: A review," 2014 IEEE International Conference on Industrial Technology (ICIT), 2014, pp. 840-846, doi: 10.1109/ICIT.2014.6895009.

[5] A. Ajan, J. Babu, M. Mohan, V. S. Nair and T. Babu, "Performance comparison of a bridge converter and a modified miller converter: Torque ripple minimization in switched reluctance motor," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), 2016, pp. 3581-3584, doi: 10.1109/ICEEOT.2016.7755373.

[6] S. Rajendra Thakare and S. V. Patil, "Speed Control Strategy of Switched Reluctance Motor Drive Using Asymmetric Bridge Converter Topology," 2019 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), 2019, pp. 313-317, doi: 10.1109/RTEICT46194.2019.9016716.

[7] M. Thakre, J. Mane and V. Hadke, "Performance Analysis of SRM Based on Asymmetrical Bridge Converter For Plug-in Hybrid Electric Vehicle," 2020 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), 2020, pp. 1-6, doi: 10.1109/ICPECTS49113.2020.9337059.

[8] Inderka, R.B.; Menne, M.; De Doncker, R.W. Control of switched reluctance drives for electric vehicle applications. IEEE Trans. Ind. Electron. 2002,49, 48–53.

[9] Kamalakannan, C.; Kamaraj, V.; Paramasivam, S.; Paranjothi, S.R. Switched reluctance machine in automotive applications—A technology status review. In Proceedings of the 2011 1st International Conference on Electrical Energy Systems (ICEES), Newport Beach, CA, USA, 3–5 January 2011; pp. 187–197.

[10] Ahn, J.W.; Liang, J.; Lee, D.H. Classification and analysis of switched reluctance converters. J. Electr. Eng. Technol. 2010, 5, 571–579.

[11] Mahmoud, S.M.; El-Sherif, M.Z.; Abdel-Aliem, E.S.; Nashed, M.N. Studying different types of power converters fed switched reluctance motor. Int. J. Electron. Electr. Eng. 2013, 1, 281–290.

[12] Krishnan, R.; Materu, P.N. Analysis and design of a low-cost converter for switched reluctance motor drives. IEEE Trans. Ind. Appl. 1993, 29, 320–327.