Power Factor Improvement in Switched Reluctance Motor Drive

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This paper presents Switched Reluctance Motor (SRM) has inherent mechanical strength without rotor winding and permanent magnet. The high speed drive systems are much interested in the field of industrial applications due to the compact size, reliability and high efficiency. A new single-phase power factor corrected converter is proposed to improve the input power factor for an efficient Switched Reluctance (SR) motor drive. The power factor correction has been done on the basis of phase current waveform, fourier analysis and Total Harmonic Distortion (THD). In order to improve the power quality in terms of Power Factor Correction (PFC), reduce the THD at the input AC side. The need for PFC in SRM systems supplied from single-phase mains. It is shown that for certain applications, a PFC circuit has to be implemented. The developed PFC circuit is connected with input side of SRM. The power factor increases and almost negligible input current THD of 2.62% is achieved. The simulation of switched reluctance motor drive has been done using MATLAB.

Keywords: SRM, Power Factor Correction, Total Harmonic Distortion, Converter, PWM

Introduction

Power Factor correction (PFC) is applied to electric circuits as a means of minimising the inductive component of the current and thereby reducing the losses in the supply. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. Low power factor can be corrected with a passive network of capacitors or inductors. The reliability of a power transistor in a power converter is the source of most problems in several industrial applications. It is critical to correctly diagnosis the faults occurring in a drive system to avoid harmful accidents and to ensure continuity of operation1. The SRM has become an attractive candidate for variable speed drives applications and is rapidly advancing due to the advent of inexpensive, high power switching devices and since possesses many distinguished merits, such as simple construction while the rotors have no windings or magnets, negligible mutual coupling, higher or comparable reliability due to fault tolerant robust structure and low cost2. A new controller design for SRM drive system. The converter consists of one switch for each phase is the least number of switches among the converters used in the SRM drive and also this converter performs phase current commutation faster3. The performance analysis of a new converter for switched reluctance motor drive with component sharing. SRM has become an important alternative in variable speed drive applications. The possibility of high motor speeds, high torque-to-inertia ratio.SRM requires a converter circuit to control the unipolar phase current in its phase windings4. The performance and efficiency5 of a drive system incorporating a SRM with input PFC. The SRM system consists of a PFC, bi-directional converter, an inverter, anda SRM operating as based Voltage Source Drives (VSD). The inherent mechanical strength without rotor winding and permanent magnet. To improve the PFC and to perform the commutation faster, several topologies are analyzed such as buck, boost and buckboost, dc-dc converter. The boost converter with PFC to improve the performance of the converter with high rectified output6. The effect of decreased decay time for form of wave current by adding resistance in the return path, so that give us a flexibility to tuning the overlap angle (on and off angles) without developing negative torque, finally lead to reduce the torque ripple. Torque ripple are intolerable for many high performance applications, especially at low speeds. The advantage of this method is very simple, inexpensive and effective to improvement torque ripple control scheme are emphasized7. The single-
stage PFC converter\textsuperscript{8} is proposed to improve input power factor for an efficient SR motordrive. The proposed converter uses the winding of SR motor as an input inductor for PFC. Converter switches play two important roles; one is to improve the input power factor and the other is to excite the motor phase. Consequently, ac-to-dc power converter and SR motordriver are incorporated into one power stage, so called a single-stage approach is realized; thus, it shows a simple structure.

The single-phase 6/4 pole SR motor is manufactured to evaluate the performance of the proposed drive system. An algorithm\textsuperscript{9} to calculate the switching angles of a cascaded multilevel inverter minimizing the THD. The implementation uses a cascaded multilevel inverter with only one battery feeding one bridge and one transformer for each switching angle and connected in cascade with the other transformers. The boost type front end DC/DC converter is externally equipped, the on-board charger is formed by the embedded components of SRM windings and converter. In the driving mode, the DC/DC boost converter is controlled to establish boostable well regulated DC-link voltage for the SRM drive from the battery. During demagnetization of each stroke, the winding stored energy is automatically recovered back to the battery.

**Power factor improvement**

Power factor is defined as the cosine of the angle between voltage and current in an AC circuit. There is generally a phase difference $\theta$ between voltage and current in an AC circuit. $\cos \theta$ is called the power factor of the circuit. If the circuit is inductive, the current lags behind the voltage and power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading. In a circuit, for an input voltage $V$ and a line current $I$,

- $VI \cos \theta$ - the active or real power in watts or kW
- $VI \sin \theta$ - the reactive power
- $VI$ - the apparent power

Power Factor gives a measure of how effective the real power utilization of the system is. It is a measure of distortion of the line voltage and the line current and the phase shift between them.  

$$\text{Power Factor} = \frac{V}{I}$$

where, the apparent power is defined as the product of RMS value of voltage and current. Improvements in power factor and THD can be achieved by modifying the input stage of the diode rectifier filter capacitor circuit. Passive solutions can be used to achieve this objective for low power applications. With a filter inductor connected in series with the input circuit, the current conduction full wave rectifier is increased leading to a higher power factor and lower input current distortion. With smaller values of inductance, these achievements are degraded. However, the large size and weight of these elements, in addition to their inability to achieve unity power factor or lower current distortion significantly, make passive more suitable at lower power levels. The PFC technique has been gaining increased attention in power electronics field in recent years. For the conventional single-phase diode rectifier, a large electrolytic capacitor filter is used to reduce dc voltage ripple. This capacitor draws pulsating current only when the input ac voltage is greater than the capacitor voltage, thus the THD is high and the power factor is poor. To reduce THD and improve power factor, passive filtering methods and active wave-shaping techniques have been explored. Reducing the input current harmonics to meet the agency standards implies improvement of power factor as well. Several techniques for power factor correction and harmonic reduction have been reported and a few of them have gained greater acceptance over the others. Commercial IC manufacturers have introduced control ICs in the market for the more popular techniques.

**Results and Discussions**

An ideal PFC should emulate a resistor on the supply side while maintaining a fairly regulated output voltage. In the case of sinusoidal line voltage, this means that the converter must draw a sinusoidal current from the utility; in order to do that, a suitable sinusoidal reference is generally needed and the control objective is to force the input current to follow, as close as possible, this current reference. The main aim of the PFC technique is to bring the power factor closer to unity by reducing the effects of reactive power. In most of the cases, poor power factor is due to inductive loads which can be corrected by adding electrical devices such as capacitors into the circuit. In the market there are many PFC devices available to accommodate the each type of situation. Among them PFC involving capacitor fitting is the simplest. It is worth shopping around specialist companies and taking expert advice on the system.
that suits better. If a single machine has a poor power factor, capacitors can be connected in parallel with the device, that is, connected to the live and the neutral terminals of the reactive device, so that they compensate for the poor power factor whenever the machine is switched on. This is a form of ‘fixed’ PFC. If the power factor at a site is permanently poor and no single item of equipment is solely responsible, fixed PFC can be employed also. In this case, the PFC capacitors will be connected across the main power supply to the premises, that is, the capacitor banks terminals are connected to each of the three phase cables as they enter the site. In this case, PFC can be linked with the switch gear. However, there are other circumstances where PFC is not so straightforward. Where many machines are switching on/off at various times, the power factor may be subject to frequent change. In these cases the amount of PFC needs to be controlled automatically – that is, the banks of capacitors need to be selectively switched in and out of the power circuit appropriately. In order to determine which type of static power converter is most recommended for a given application several issues must be taken in to account, such as robustness, power density, efficiency, cost, and complexity.

Within this context, numerous boost-type topologies have been proposed in the last few years with the aim of improving the characteristics of the traditional converter used for PFC purposes, such as the reverse recovery problem of the boost diode and increase of the output voltage. To combine the capabilities of power factor correction, active power filter and AC/DC converter, an advanced power factor correction technique using PFC Boost converter is proposed to work simultaneously as an active power filter to supply compensated currents that are equal to the harmonic currents produced from the nonlinear loads, and a AC/DC converter supplies the DC power to its load and takes a nearly sinusoidal current from the supply. This approach reduces the cost of the filter and also no special dedicated power devices are needed for the harmonics elimination. Here the full bridge diode rectifier is considered as the non-linear load which is the source of harmonics and output of this is given to the boost converter for PFC. The simulation results of the single-phase Switched Reluctance Motor is carried out which uses the asymmetric bridge rectifier and the power factor correction. Figure 1 shows the PF waveform, source voltage and current response of SRM. In contrast to the asymmetric drive circuit, the capacitor appears at the back end of the proposed PFC circuit. The positive pulse output voltage of a full-wave bridge is applied to the SRM phase winding directly. On the other hand, the capacitor can supply to the SRM phase winding during magnetization, and store recovered energy during demagnetization. The magnitude of the AC current has been reduced, so this drive improves the crest factor and the PF at the same time. The most widely used power factor correction technique is adding a resistor to a supply side. A sinusoidal reference is needed when converter takes the sinusoidal current from the source. There is some control strategies which force the input current to follow the current reference. The main objective of the power factor improvement is to bring the power factor closer to unity. The inductive loads are the main cause for the poor power factor, and the poor power factor is corrected by means of adding the capacitors to the circuit. Adding capacitor to the circuit is the simplest technique for correcting the poor power factor. Figure 2 shows the single-phase PFC circuit for SRM drive circuit. The drive circuit has a simple diode rectifier, a filter capacitor and an asymmetric bridge converter. The rectifier and the filter capacitor supply the dc source. The filter capacitor reduces dc voltage ripple and stores the recovered energy from the motor during

![Fig 1—AC Voltage and Current waveform](image-url)
demagnetization. This drive structure is very simple, but the capacitor charges and discharges, which illustrates a pulsating ac line current and results in a low PF. The low PF of the motor increases the reactive power of the power line. Figure 3 shows the output side voltage and current waveforms of rectified topology with filter. Due to filter source current goes to distorts and get non-unity power factor, for improvement of these conditions we prefer two stage conversion techniques i.e., full bridge rectifier circuit followed by the boost converter circuit. Rectifier circuit converts the AC to unregulated DC and then the boost converter converts unregulated DC to regulated DC with the output voltage greater than the input voltage. Figure 4 shows that the FFT analysis of SRM drive circuit. It has shown that decrease in
current THD. It has mentioned one cycle for revolution and 50 Hz for fundamental frequency. It shows that the power factor improves while the THD decreases. The THD in input current was analyzed through the Fourier transform analysis tool. The input current waveform and the THD in Simulink are found.

Conclusion

In this paper the PFC is achieved by means of the asymmetric bridge converter and also a new SRM drive is introduced. From the discussion, it follows that asymmetric bridge converter is the most common topology used for operating a SRM drive. These circuits are however suitable for low and medium power application. Due to the inclusion of one asymmetric bridge converter in the circuit to eliminate the harmonic current that would otherwise generated by the non-linear load, doesn’t require the use of any dedicated circuit. With the help of simulation study, it can be concluded that, this configuration removes almost all lower order harmonics, hence with this configuration it was achieved power factor nearer to unity and hence THD got reduced. Simulation results for SRM Drive with PFC circuit are presented.

References