5.1 Introduction

This work presents a new method for power factor correction with low cost drives in SRM. Power factor control is a major role in the improvement of power system stability. Many of the existing systems are expensive and difficult to manufacture. Fixed capacitor systems are always leading power factor under any load conditions. This is unhealthy for installations of power system. The proposed embedded system drive is used to reduce the cost of the equipment and increase the efficiency of the Switched Reluctance Motor. Experimental results of the proposed systems are included. It is a better choice for effective cost process and energy savings.

Most of the consumers consume electricity for the purpose of inductive load. The inductive load acts as a lagging power factor. The result of lagging power factor increases the power losses in the power system. The reactive power is compensated by real power by using suitable value of capacitors. This improvement of power factor helps to avoid the heavy penalties and also offers incentives to the consumer. The existing work (Xue et al 2005) on power factor correction of SRM is having some disadvantages like switching operations and sensing stability of the system. Power factor is the cosine angle between the voltage and current. This current and voltages are sensed by using instrument transformers like current transformer and voltage transformer. In the proposed method, zero crossing detectors are used to convert the waveforms of voltage and current into TTL compatible square waves. The above square waves are fed into the microcontroller ATMEL 8951. The phase angle between the voltage and current is calculated by inbuilt computers in the microcontroller. The calculated values are compared with actual load present on the system. When the load on the system is increased, the capacitor bank is added in the system by using micro controller. These processes are continuously carried out and the power factor is maintained automatically.

This paper proposes the following solutions to correct the power factor of SRM.
- Reactive power is compensated by real power obtained from capacitors.

- Automatic power factor correction so as to achieve electrical energy conservation.

- Minimize the unwanted losses in energy and improve the efficiency of the power system.

- Eliminating the electromechanical relays by means of solid devices.

5.2 Theory

5.2.1 Power factor

Power factor indicates that the actual amount of power is delivered to the load.

\[
P.F (\cos \Phi) = \text{Active power/Apparent power.}
\]

The direction of the current and voltage vectors are not the same at all loads like inductive, resistive and capacitive loads. It is shown in Figure 5.1.

![Figure 5.1 Phasor diagram of Power](image)

5.2.2 Resistive load

For pure resistive load, there is no phase difference between voltage and current. It is shown in Figure 5.2. So the power factor of the resistive load is unity.

![Figure 5.2 Unity Power factor](image)
5.2.3 Inductive load

Current vector in the pure inductive load is lagging (behind the voltage vector) with angle 90°. i.e. Cos 90° = 0. It is shown in Figure 5.3. No power is consumed by inductive load. Practically, pure inductance is not possible. It has some small amount of resistance and reactance, so that angle of lagging is not exactly 90°.

\[
\begin{align*}
I & \quad \phi \\
v &
\end{align*}
\]

Figure 5.3 Lagging Power factor

5.2.4 Capacitive load

Current vector in the pure capacitive load is leading (in front of the voltage vector) with some angle pure capacitance is also not possible in the power system. It is shown in Figure 5.4. It also has resistance and reactance. Hence, angle of leading power factor is not exactly 90°.

In RLC circuit the capacitor is used to reduce the angle between voltage and current.

Hence, the quantity of the reactive power is reduced by phase angle.

\[
\begin{align*}
v & \quad \phi \\
I &
\end{align*}
\]

Figure 5.4 leading power factor

5.3 Existing system of Power factor correction Method in SRM

Power factor correction is very important for improving the efficiency of SRM. Xue et. al. 2005 and G.Venkatesan et al, 2006 pointed out the following power factor correction methods in SRM. They may be

- Buck-Boost converter method
- Diode Rectifier with Pulsating DC-Link voltage
> Diode Rectifier with Stable DC-Link voltage
> Diode Bridge Rectifier with Stable DC-link voltage
> Diode Bridge Rectifier Plus Step-up Converter

### 5.4 Performance of the Proposed System

The following functions are to be considered for the proposed system. Block diagram of proposed system is shown in Figure 5.5.

> Voltage and current signals are obtained from instrument transformer like potential and current transformers.

> Zero crossing detectors are used to convert the waveforms of voltage and current into corresponding square waveform.

> TTL is used to convert the square waveform to compatible waveform.

> Converted waveforms are fed into a counter positioned in the microcontroller.

> The counted pulses are converted into corresponding value of phase angle $\Phi$

![Block diagram of Power factor correction](image)

*Figure 5.5 Block diagram of Power factor correction*
5.5 Experimental Setup

Magnitude of the voltage and current are fed into the microcontroller 89C51. It is used to measure the phase shift between the voltage and current, i.e. the cosine value of the electrical quantities like voltage and current are measured by using microcontroller. It is shown in Figure 5.6. As per to the power factor, the number of relays are energized or deenergised. The signal from microcontroller (either 0 or 1) is used to operate the relay. When the relay contacts are closed, the capacitor is connected to the circuit through relay. Hence the power factor of the system is improved.

![Control circuit for Power factor correction](image)

**Figure 5.6 Control circuit for Power factor correction**

5.6 Embedded system

Embedded system is a combination of hardware and software that form the components of a larger system. It is a programmed system and it consists of dedicated functions with minimal operations. This also has a number of divisions at different conditions. It is very useful for more applications. It is generally prepared for speed of operation, accuracy and reliability. Embedded application software performs the predefined function of the embedded device. This software can support such applications as the internet-mail and MP3 decodes.
### Table 5.1 Power factor at various loads

<table>
<thead>
<tr>
<th>SI No</th>
<th>Inductive Load</th>
<th>Resistive Load</th>
<th>Relays</th>
<th>Actual P.F</th>
<th>Corrected P.F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L1</td>
<td>L2</td>
<td>L3</td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>1.</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>2.</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>3.</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
</tbody>
</table>

X-Toggling state

5.7 Microcontroller 89C51

This device is selected because it is an Intel 1X51 microcontroller. The Intel 1X51 is a standard reference architecture and easy to adapt to a variety of designs. In FLASH technology, the ATME 89C51 is program memory unit. FLASH ROM memory is a technology of starting programs in a controller and that can be erased without UV Eraser. So the erasing process is very fast. Hence it is called flash. The microcontroller actuates the necessary relay of the various power factors. It is tabulated in Table 5.1.
C

FIND PULSE

FIND

PULSE WIDTH/4

LOOK UP= COS

DISPLAY P,F

READ POWER P,F

<0.85

=1

<>B

CLOSE NTH RLY

INC RELAY NO

=1

DEC RELAY NO

OPEN NTH RLY

PAUSE

D
Figure 5.7 Flow chart for Power factor correction
> If the power factor is less (0.85) than the fixed value (0.98) then the corresponding relay is activated by microcontroller.

> If the power factor is greater than the fixed value then the corresponding relay is deactivated.

Thus this proposed system flow chart is used to check the power factor of each load and maintaining the power factor at various loads. The flow chart for power factor correction is shown in Figures 5.7.

5.8. Capacitor Value Calculation

![Capacitor Value Calculation Diagram]

**Figure 5.8 Calculation of Capacitor Value**

From the vector diagram, \( I \sin \Phi \) is calculated by using current and angle between the voltage and current.

\[
ISin\Phi = \frac{V}{X_c}
\]

\[
X_c = \frac{V}{ISin\Phi}
\]

In general

\[
X_c = \frac{1}{2\pi f C}
\]

\[
C = \frac{1}{2\pi f X_c}
\]

Hence suitable values of capacitances are calculated from the vector diagram. It is shown in Figure 5.9.
5.9 Zero crossing section

Zero crossing section is having two zero crossing detector circuits. The alternating sine wave of voltage and current signals are fed into each zero crossing detector. This circuit is used to convert the sine waveforms to the corresponding square waveforms. It helps to measure the power factor of the system.

5.10 Conclusion

The work has experimentally explained the power factor correction by using the embedded system. Electric energy is consumed in our day to day life. It is utilized by different types of consumers like domestic and industries. Unfortunately, electric power cannot be stored in any form. So, the power must be given to consumers. Experimental results confirm the theory and prove the concept of the power factor correction. In this experimental setup, static capacitors are used to maintain the power factor. These capacitors are switched on during peak load hours and switched off during light load hours. The power factor adjustment is used to maintain the stability of the power system.