Design of Digital-Static VAR Compensator for Induction Motor

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Abstract: Due to industrialization, the use of inductive load has increasing day by day, as we already know most of the industries are using the induction motors. It is inherently inductive in nature and hence have low lagging power factor, due to reactive power which gives heavy penalties to consumers by electricity board. To nullify the effect of reactive power on system, power factor should be improved. There are many methods for improvement of power factor such as Static Capacitors, synchronous condenser and phase advance. But in our project we used recent FACTS device that is static VAR compensator (SVC) for upgrading of power factor as well as to make the motor in secured level. In addition to this, digitalized version of SVC that is Digital- SVC is designed. This compensation technique facilitates automatic control on the reactive power which is depending on load requirement. Accurate compensation technique is used to mitigate the lagging reactive power, at varying load, for single phase induction motor. So as to maintain power factor near unity always this results in efficient electrical power system.

1. Introduction

The efficiency of electrical energy got more and more importance as the demand of it increases day by day. So the VAR compensation is one of the major issues now a day. Nearly in all industries, induction motor is famous equipment so reactive power comes in picture of supply system; due to that, the power factor of system affect badly. Low power factor means useful power utilization by load is very low and increased reactive power consumption. That is why losses of system increases by increased load current. Also system stability gets disturbed, so there is rule to maintain power factor of system within 0.95 and above. Otherwise consumer may have to pay penalty for low power factor.

In early days fixed capacitor banks were used for mitigation of reactive power, but recently Static VAR Compensator (SVC) is popular for the same purpose. SVC can give transient and dynamic stabilities, oscillations damping and voltage stability to system. Modified version of SVC is Digital Static VAR Compensator (D-SVC) which has fast processing for different conditions of load than simple SVC. For the changing loads, compensation of reactive power is limitation for fixed capacitor banks; but with D-SVC, this can achieved very precisely. D-SVC has controller to observe, analyze and decide the perfect value of capacitor for compensation of appropriate reactive power. If capacitor value selection is not proper; then there will be under compensation or overcompensation of system. Both the situations are hazardous to load and system parameters. That’s why perfect capacitor selection for appropriate load is vital important.

2. Literature Survey

1. “Aparna Sarkar , Umesh Hiwase” International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue ISSN: 2277-3754 ISO 9001:2008 Certified 10, April 2015. This paper gives idea about PF measurement and correction by continuous observing the parameters of system such as current and voltage. Also it gives control strategy with the use of PIC microcontroller (µC). This is the base paper for the project; proposes a perfect aspect about VAR compensation for varying load.

2. “Pranjali Sonje, Anagha Soman” International Journal of Engineering and Innovative Technology (IJEIT) ISSN: 2277-3754 ISO 9001:2008 Certified Volume 3, Issue 4, October 2013.[5] From this paper PIC µC logic and programming is achieved, so the fast and precise work can be featured in project. The program gives idea for measurement PF, precise amount of compensating element selection and switching. The logic behind it is to monitor behavior of parameters of system, record it, analyze it and finally process according to the records.

3. “Sabir RUSTEMLI, Muhammet” ATEŚ Przegląd Elektrotechniczny (Electrical Review), ISSN 0033-2097, R. 88 NR 6/2012. This paper makes the perspective for measurement of PF with variable load on three phase IM, clear for this project. Also new technique for PF measurement is introduced here by continuous monitoring the
parameters of system. PIC μC is data processing and analysing unit, which plays role of decision making element

4. “Sapna Khanchi, Vijay Kumar Garg”
The capacitor selection for particular loading condition is one of the crucial things. It tells the adverse effects of selecting wrong one to motor and system. The effect on PF and magnetizing current by addition of capacitor also studied in this paper. This paper gives vital role of accurate capacitor selection in circuit of D-SVC.

An IEEE paper deals with the performance evaluation through analytical studies and implementation of hardware circuit model of SVC at single phase, 50Hz, 2kVA transformer. The SVC consisting of thyristor switched capacitor bank in binary sequential steps. This compensation technique facilitates control on the reactive power depending on load requirement so as maintain power factor near unity always.

3. Existing System

In present situation, the reactive power compensation is carried out by static VAR compensator. But designing the Digital Static VAR Compensator for smart, efficient, precise, accurate control over changing loads is possible.

4. Methodology

The block diagram is divided into three main mechanism:

1. Power factor measurement mechanism:
From the block diagram shown above, the current transformer (CT), potential transformer (PT) and ZCD block give continuous measurement of power factor according to load. CT and PT are current sensor and voltage sensor for ZCD block. The main aim of these devices is to convert current and voltage into measurable level or workable range of PIC μC so as to recording and analysing will be accurate. ZCD is particular arrangement of devices such as CT, PT, Opto-coupler which senses the parameters, analyses them, process them and display the PF of system on LCD. As the name implies, ZCD records the current and voltage square wave cutting to zero line and measures difference between these two waves so as to measure the PF. For that first there should be current and voltage wave sensed in appropriate range and then it should be converted in square form. Controller gets square wave and analyzes which wave cuts the zero line first; at the same time counter started and when second wave cuts the zero line, on that moment counter stops. The counted time is denoted by ‘Δt’ in microsecond. From that controller can found the phase difference between I and V; in degree. The relation between Δt and phase angle is \(1° = 55.5556\mu\text{s}\). After taking its cosine, controller shows the power factor of the system.

2. Decision making mechanism:
As the proper power factor is measured with above mechanism, now accurate selection of capacitor for compensation is the role of this mechanism. In this mechanism whole the work is done by the controller (PIC18F4520). Controller got the power factor, from that reactive power is calculated as:

\[Q = X * I^2 = V^2 / X = V * I * \sin(\phi)\]

Then from this, capacitor value is calculated as:

\[C = \frac{1}{\omega X} = \frac{1}{2\pi f X} = \frac{I\sin\phi}{2\pi f V}\]

Controller calculates accurate capacitor value as well as observes the change in load and according to that, change the capacitor bank. For no load, capacitor bank value is larger, so controller triggers arrangement of capacitors. As load increases, some capacitors are switched off, to avoid overcompensation and for full load, small capacitor bank is in the circuit so there should not be the under-compensation. Total sequences of capacitor bank switching is properly followed under the observation of controller.

3. Capacitor switching mechanism:
Capacitor gets in circuit with the help of switching device; relay. Different load on motor gives different power factor, so different capacitor comes in circuit, that trigger given by the controller. Continuous monitoring is done, as in any case of load; power factor measured must be precise and according to
that capacitor bank is triggered or/and switched off. The logic behind the monitoring is shown in flowchart below. Continuous observing the load and comparing the switched capacitor to required compensated value, is the motive behind algorithm.

![Flowchart of algorithm used in controller](image)

**5. Implementation**

From the three mechanisms discussed above, in this project firstly power factor is measured and then according to the capacitor value the capacitor bank is selected by provided relay signal.

![Hardware](image)

**6. Result**

The aim of project is to maintain PF above 0.9, at any load conditions. The average PF at different loading conditions is maintained at 0.9. the PF and capacitor values are shown below.

<table>
<thead>
<tr>
<th>Current (A)</th>
<th>PF before compensation</th>
<th>Calculated capacitor value (μF)</th>
<th>Selected capacitor value (μF)</th>
<th>Compensated PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>0.30</td>
<td>15.18</td>
<td>20</td>
<td>0.91</td>
</tr>
<tr>
<td>1.2</td>
<td>0.575</td>
<td>14.20</td>
<td>15</td>
<td>0.93</td>
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<td>1.3</td>
<td>0.676</td>
<td>13.86</td>
<td>15</td>
<td>0.956</td>
</tr>
<tr>
<td>1.4</td>
<td>0.75</td>
<td>13.39</td>
<td>15</td>
<td>0.94</td>
</tr>
<tr>
<td>1.5</td>
<td>0.805</td>
<td>12.87</td>
<td>15</td>
<td>0.916</td>
</tr>
</tbody>
</table>

Table: PF before and after compensation

**7. Conclusion**

This paper gives the design of Digital Static VAR Compensator for Induction Motor. Hence, Consumer can get the power factor within range 0.95 or above.

**8. Acknowledgement**

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**9. References**


