Automatic Power Factor Correction of Synchronous Motor

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ABSTRACT *Induction motors are widely used in industrial production processes. Use of an induction motor will result in increased lagging power factor. This power factor must be corrected. If not, the result is the penalty of larger kVA burdens to the interconnected system. The synchronous machine, with the aid of an intelligent excitation controller, can control power factor to reduce the plant reactive loading to the connected system. This paper provide informations of power factor correction of synchronous motor. The power factor measured at the input terminals of a synchronous motor is adjusted to a reference value. If the measured power factor is different than the required reference value, error signal is generated. This error signal is evaluated by PI controller to obtain a control signal for the synchronous motor excitation circuit since the power factor of a synchronous motor can be controlled and held at a desired value by adjusting the excitation current.*

I. INTRODUCTION

Synchronous Motors are widely used in power plant and industrial area to maintain the overall system power factor towards the unity. One of the important problems with recent trends of energy utilization is to use the generated electrical energy efficiently. If the energy is not utilized properly resulting in low utilization efficiency for users. This is due to Utilized of energy at the Low Power factor. Therefore, power factor of systems must be corrected [1]. Since the reason of low power factor operation of systems is the reactive power requirements of loads, this problem should be eliminated at load terminals. Thus, the required reactive power is supplied from another source, so generally compensating capacitors used to supply a require reactive power at load terminals and the reactive power loading of systems is reduced [1]. The control of reactive power flow and voltage magnitude in high voltage alternating current (HVAC) systems has become an important task. Regarding the voltage and power variations in industry and systems the design of new and special compensation systems have emerged [2].

In this paper, the reactive power control of an industrial plant having synchronous motors is studied. In the Synchronous motor power factor is mainly dependent on the excitation current. If the load changes suddenly or due to voltage dip in supply the excitation requirement is changed, hence power factor. Therefore, the operating power factor of synchronous motor is controlled separately to reduce the reactive power extracted from the supply system. This characteristic of the motors can be understood with the help of v-curves[5].

II. AN OVERVIEW OF SYNCHRONOUS MOTOR

The geometry of a synchronous motor is quite similar to that of the induction motor. The stator core and windings of a three-phase synchronous motor are practically identical to that of a three-phase induction motor. The function of the synchronous motor stator is similar to that of stator of induction motor. The synchronous motor rotor, on the other hand, is different than that of the induction motor. The rotor of the synchronous machine is a rotating electromagnet with the same number of poles as the stator. The poles of the synchronous motor rotor are created by the rotor windings which carry DC currents. Thus, the synchronous motor requires simultaneous AC and DC excitation of the stator windings and the rotor windings, respectively. Thus, the fundamental difference between a synchro-nous motor and an induction motor is that the rotor currents of the induction motor are induced while those of the synchronous machine are not.[6]

The power factor of a synchronous motor is controllable by controlling the rotor current. It may operate at unity, leading, lagging power factor. Once the synchronous motor is synchronized, the field poles on the rotor are in line with the rotating magnetic poles of the stator. If dc is applied to the rotor pole windings, the rotor can supply the necessary ampere turns to generate the flux that produces the internal motor voltage. Thus, the field current can replace part or all of the magnetizing current. In fact, if more dc field current is supplied, the increased flux will try to increase the line voltage. To increase the line voltage, the motor will supply AC magnetizing current to all "magnets" on the system to increase their magnetic flux. This is leading power factor.

Conversely, as the load increases beyond rated, the power factor becomes lagging. [6]

III. TYPES OF EXCITATION SYSTEM

All synchronous machines require a DC supply to excite their field winding. As synchronous motor is a constant speed machine for a constant frequency supply. This excitation current is supplied from the exciter. Exciter should be capable of supplying necessary excitation in a reasonable period during normal and abnormal conditions. The source of power can be a shaft-mounted exciter, a motor-generator set, or a static rectifier.

DC exciter: This excitation systems utilize dc generators as sources of excitation power and provide current to the rotor of the synchronous machine through slip rings. The exciter may be driven by a motor or the shaft of the generator. It may be either self-excited or separately excited. When separately excited, the exciter field is supplied by a pilot exciter comprising a permanent magnet generator.

AC exciter: This system was developed to avoid commutator and Brush Gear assembly. In this system, a shaft driven AC pilot exciter, which has a rotating permanent magnetic field and a stationary armature, feeds the DC field current of the main high frequency AC exciter through controlled rectifiers The high frequency output of the stationary armature is rectified by station-

ary diodes and fed via slip-rings to the field of the motor.

Static excitation: Here, DC excitation can be obtained by means of a rectifier and a suitable AC supply. This method eliminates the commutation limits inherent in DC exciters. The rectifier unit has no moving parts, requires very little maintenance, and is immune to hazardous or dusty atmospheres.

Brushless Excitation System: In brushless excitation system diode rectifiers are mounted on the main shaft and their output is directly connected to the field of the motor thus eliminating brushes and slip rings. This arrangement necessitates the use of a rotating armature and stationary field system for the main AC exciter. Synchronous motors with brush less excitation require low maintenance cost once they are not fitted with bushes. Since they are not built with slip electric contacts, avoiding sparking, synchronous brush less excitation motors are recommended for explosive atmosphere applications.

IV. SYSTEM DESCRIPTION
Block diagram of the proposed excitation system is shown in Fig. 2.
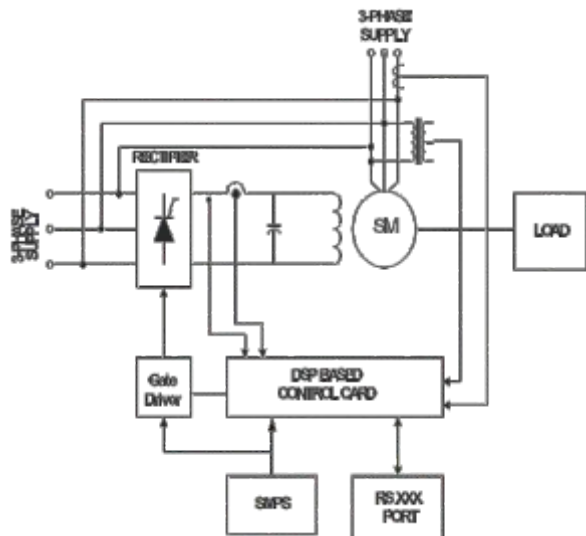

Fig. 2 Block diagram of Excitation System

As shown in block diagram, 3-phase controlled rectifier is used to get the DC current, which is given to the field winding of synchronous motor. By changing the firing angle of thyristor, the excitation current can be changed. Power Factor is sensed by monitoring the voltage across motor and current from motor terminal. Then this signal is given to DLL to measured the actual power factor. The output of DLL is compare with the reference set point power factor value. Output of Comparator is given to the PI controller and controller will change the excitation to set the actual power factor at the reference set point value. Power factor is related to the phase angle between voltage and current. Synchronous motors seldom, if ever, operate continuously at lagging power factor. Synchronous motors run at either unity or some value of leading power factor. Lagging power factor appears when the motor load angle increases beyond rated, becoming almost fully lagging (90°) as the motor slips out-of-step. Motor Power factor during induction motor operation (that is with field removed) is always lagging. Therefore, lagging power factor can be utilized to initiate action to prevent slipping. Lagging power factor can again be utilized as an indicator of "slip" during induction motor operation. For synchronous motors, power-factor monitoring can be employed to guard against pull-out or loss of field conditions.
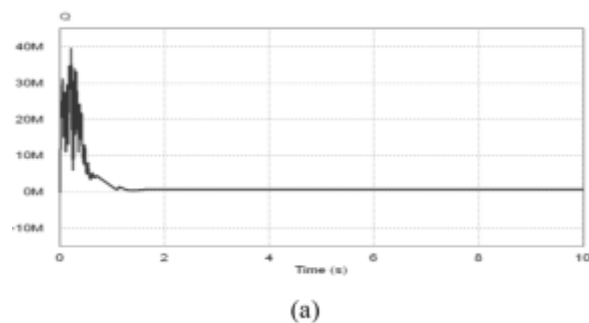
V. POWER FACTOR CORRECTION OPERATION
For the constant loads, power factor mode is the preferred. If the rotor excitation is varied when the motor is running on load, the load angle and stator current change, but the speed and load (and hence input power) remains the same. The power factor of the motor can therefore be adjusted by means of the excitation. Unity power factor operation is possible over wide range of the loads and by using a high rotor excitation the motor can operate at leading power factor. This is particularly valuable with a large synchronous motor, which can be used to compensate for the lagging power factor of the other induction motor on the same size. At other extreme, there is a limit to how low the excitation can be set, because if the rotor field is too weak it will not be capable of developing the required load torque, even at the optimum load angle. Sometimes loads are not constant, means pulsating load, so in this case if the motor operates in power factor mode, the power surges will be sensed and so that excitation system will produce cyclic surges of field power in response to the load, so in this condition var control provides the best solution. In this mode the pulsating power component is not sensed by the controller, so the motor provides smooth, stable operation for the motor.

VI. SIMULATION AND RESULTS

A. FOR LOW EXCITATION LAGGING POWER FACTOR

Reference power factor = 0.8(lagging)

(a)

A. FOR HIGH EXCITATION LEADING POWER FACTOR

Reference power factor = 0.8(leading)
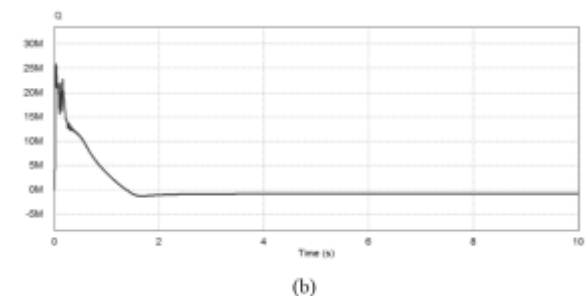

(b)

Fig. 5 (a) for 0.8 PF Lagging, (b) for 0.8 PF Leading

IX. CONCLUSION
In this paper an application of automatic power factor correction of synchronous motor has been studied. This system very useful for power factor improvement and system voltage stability. So in the large transmission and distribution (T&D) systems and industrial area this system can be used in the different modes as per requirement to improvement of power factor. Finally from the simulation results the power factor of the motor can be change within certain range and motor is operated at unity , leading or lagging power factor as per the requirement.

Close loop simulation of the proposed topology is run successfully.

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