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Microcontroller based Power Factor Correction using Synchronous Motor

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ABSTRACT

There are various types of loads available in the industry e.g. resistive, inductive and capacitive and the combination of all.Due to these loads the power factor of the system varies. The inductive load affectspower factor. This change in power factor leads to change in the reactive power of the system. There are many disadvantages of poor power factor like increased heating of equipment, large line losses, large KVA rating, poor voltage regulation, etc.Therefore there is need to maintain the power factor near to unity. The aim of this paper is to measure and correct the power factor of the system by using synchronous motor controlled by microcontroller and smooth control of power factor using the synchronous motor has been achieved.

Keywords—Arduino, Voltage generator circuit, Power Factor Correction, Synchronous Motor.

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I. INTRODUCTION

The power factor is the ratio of the active power (KW) to the apparent power (KVA).

$$Power Factor(\cos\emptyset) = \frac{Real\ Power\ in\ KW}{Apparent\ Power\ in\ KVA}$$

A lagging power factor results from inductive loads on the system and this can be improved by delivering the reactive power to the system. Similarly the leading power factor is a result of capacitive loads on the power system which can be improved by absorbing the excess reactive power from the system. In order to improve the power factor of the system there are many methods that has been implemented such as capacitor banks, static VAR compensator, STATCOM etc. But these techniques make use of capacitor which will cause the voltage and current distortion because, the capacitor banks has the tendency to offer a low resistance path to the harmonic current. Hence in order to improve the power factor of the system and to minimize the distortion caused by harmonics a synchronous motor can be used.

The synchronous motor has the capability to develop resistive, inductive and capacitive operating characteristics when its field current is varied. When synchronous motor is over excited or lightly loaded or unloaded i.e. $Back\ EMF(E_b) > V$,then it behaves as synchronous condenser. It delivers reactive power during over excited condition and absorbs reactive power during under excited condition. This can be achieved by driving the field current of the synchronous motor through the voltage generator circuit controlled by microcontroller. The output of the inverter corresponding to the required field current can be obtained by changing the firing angle of the thyristors used in the control circuit.

II. Block Diagram of Proposed system

Fig.1 shows block diagram of proposed system containing Power Factor Measurement Unit, Arduino Micro

Controller Unit (MCU), Voltage Generator Circuit and Synchronous Motor.

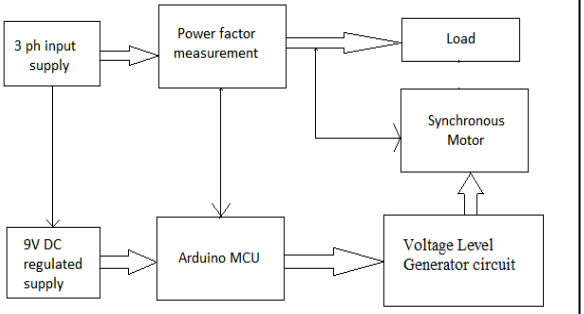

Fig.1 Block Diagram of Proposed System

The different components of Fig.1 are explained as follows:

1. Power Factor Measurement Unit:

This consists of components like current transformer (CT), voltage transformer or potential transformer (PT) and zero crossing detector (ZCD). They are as follows:

A. Current Transformer(CT):

The current transformer is a type of instrument transformer that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. It is a device for the transformation of current from a higher value to a lower value, or for the transformation of current at a low voltage with respect to earth potential[1]. The current transformer consists of only one or very few turns at its the primary winding. This primary winding can be either of a single flat

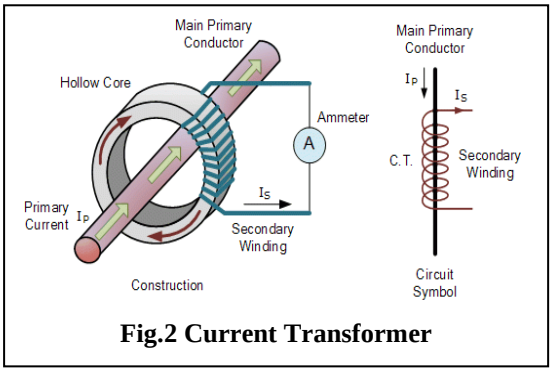

Fig.2 Current Transformer

turn coil of the heavy duty wire wrapped around the core or just as conductor or the bus bar placed through the central hole as shown in the Fig.2.Due to such type of arrangement, the current transformer is often referred to as the series transformer as the primary winding, which never has more than a very few turns, is in series with the curent carrying conductor supplying the load

B. Voltage Transformer/Potential Transformer(PT):

It may be defined as an instrument transformer for the transformation of voltage from higher value to a lower value [1]. Potential transformer is basically the step down transformer with extremely accurate turns ratio. These transformers have the large number of the primary turns and smaller number of secondary turns. PTs are made with high quality core operating at very low flux densities so that the magnetizing current is small[1]. A potential transformer is typically expressed in the primary to secondary voltage ratio.

Fig.3 shows the connection of PT in the system.

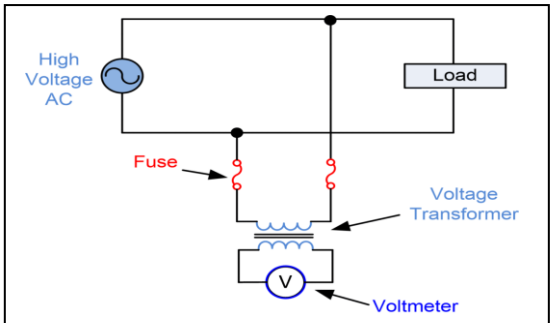

Fig.3 Voltage Transformer/Potential Transformer

C. Zero Crossing Detector(ZCD):

ZCD is a type of operational amplifier that is being used in open loop configuration which is one type of comparator commonly known as voltage comparator that changes output between +Vs and –Vs when input crosses Zero Reference voltage. ZCD is shown in Fig.4

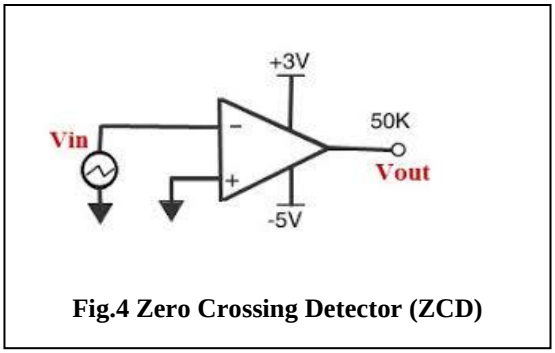

Fig.4 Zero Crossing Detector (ZCD)

2. Arduino Micro Controller Unit(MCU):

The ArduinoUNO is the heart of the system which is a type of development board having microcontroller chip ATmega328 on it. The code that is loaded in the controller will decide the operation of the voltage generator circuit. The Arduino operates at 5 volts and has the ability to withstand a voltage up to 20 volts, in case of the overvoltage it is protected by the voltage regulator IC which is present on the board. The output of the arduino is given to the voltage generator circuit in the form of the digital signals and similarly as it is the closed loop system the output of the overall system is being sensed by the CTs and the PTs which will send the information of the power factor of the system to the controller through the zero crossing detector (ZCD). The main aim of the controller is to take the information from ZCD, to store and to perform controlling operation using the algorithm written inside it thereby calculating the required KVAR or the amount of power factor to be improved for the system in the industry.

3. Voltage Level Generator Circuit:

This consists of a circuit with combination of MOSFET and diodes. This generates signal pulses for voltage generation unit as per requirement for power factor control. The signals given from Arduino unit helps in switching the MOSFETs. This circuit consists of four different MOSFETs provided with different voltage sources. The MOSFETs can generate 11 different voltage levels which can be used for field excitation control of synchronous motor.

4. Synchronous Motor:

A synchronous motor is a doubly excited machine, its armature winding is energized from an a.c. source and its field winding from a d.c. source[1]. It draws leading power factor in overexcited condition and also supplies reactive power in order to improve power factor. It runs at synchronous speed and its speed is independent of load. The main feature of this motor is, it can be operated under wide range of power factors both lagging and leading[1].
Fig.5 shows the Phasor diagram of synchronous motor for various conditions.

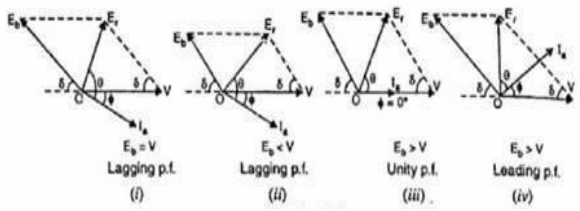

Fig.5 Phasor diagram for synchronous motor

An overexcited synchronous motor running on no-load is known as Synchronous Condenser. When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of load current. Thus the power factor is improved [2]. Fig.6 shows the power factor improvement by synchronous condenser method.

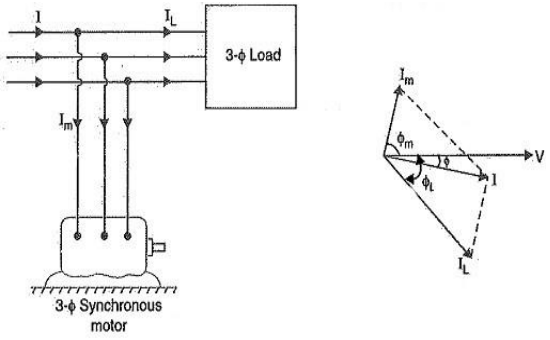

Fig.6 Power factor improvement by synchronous condenser method

III. CONCLUSION

This paper proposes a system to keep the power factor near to unity. The control unit used here is micro-controller. The excitation to the synchronous motor is controlled through the voltage generator unit. This system continuously monitors and controls the power factor of the system.

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