Power Factor Improvement Using Thyristor Switched Capacitor Using Microcontroller

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ABSTRACT

Due to electrical distribution systems are consists of large losses in industries were loads are wide spread, less effective reactive power compensation facilities and their improper control which results in ineffective utilization of electrical energy and hence result in power losses which cost great in terms of money for industries. The comprehensive static VAR compensator consisting of capacitor bank in four binary and eight binary binary sequential steps in conjunction with a Thyristor (SCR) or Traic controlled reactor of smallest step size is employed in the investigative work. The performance evaluation through analytical studies and the practical implementation on the existing system consisting of a distribution transformer of 1 PH phase 50 Hz, 1KV/230V capacity. This paper describes advancement of single phase SCR based Static VAR Compensate and SVC for reactive power compensation and power factor correction using ARM microcontroller and isolation circuit. The ARM microcontroller determines the firing pulse in square wave for the SCR or Traic to compensate excessive reactive components, thus making the PF near to unity. Due to small percentages of harmonics of TCR size is minimum, practically there is no need to provide inrush current limiting reactors, and The switching operations obtained are transients free facilitates step less variation of reactive power depending on load requirement so as maintain power factor near unity.

Keyword: - *ARM Microcontroller, Reactive power, Power Factor Correction, Static VAR Compensator Control, Dynamic Control of Reactive Power.*

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1. INTRODUCTION

It is well documented that power loss is taking place in low voltage distribution system at various level on account of poor power factor, due to inadequate reactive power compensation facilities and their improper control [1].

Due to the expansion of rural power distribution systems with new connections and catering to agricultural sector and industrial sector in wide spread remote areas Thus creating great necessity to closely match reactive power with the load so as to improve power factor and boost the voltage and reduce the losses [7] in the load.

In this system binary sequential steps with Thyristor switched capacitor unit is arranged and they are a more reliable technically sound, fast acting and low cost scheme is presented Due to this the reactive power variation is enable with the least possible resolution.

In addition a lowest step size is operated by controlled Thyristor reactor of the conjunction with capacitor bank, so as to achieve continuously variable reactive power. shunt capacitor also improves the feeder performance enhancing transformer loading capability reduces voltage drop in the feeder & transformer improves the feeder performance improves power factor , improves system giving scope for additional loading security with enhanced utilization of transformer capacity, and mainly improves power factor and gives scope for additional loading, increases over all efficiency, saves energy as the system losses are reduced and also avoids low power factor penalty, and reduces maximum demand charges.

1.1 Power Quality Problems Definition

Due to use of nonlinear load the purity of the wave form is lost as the power distribution system should provide uninterrupted flow of energy to their customer this effect the load quality significantly the purity of the wave form is lost due to this quality problem are increased and effects the sensitivity of the system which lead in power loss, the power quality problem has wide range of disturbances such as follow:-

• Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.

• Voltage sag: Voltage sags can occur at any instant of time, with amplitudes ranging from ten to ninety percent and a duration lasting for half a cycle to one minute.

• Voltage swell: Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from half cycles to one min.

• Voltage 'spikes', 'impulses' or 'surges': These are terms used to describe abrupt, very brief increases in Voltage value.

• Voltage transients: They are temporary, objectionable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.

• Harmonics: The fundamental frequency of the AC electric power distribution system is fifty Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal frequency.

• Flickers: Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects.

1.2 SVC with Binary Sequential Switched Capacitors:

In the proposed paper to make the resolution small capacitor bank step values are chosen in binary sequence weights. An analysis of switching transients indicates that if the following two conditions are met transient free switching can occur.
a) The Thyristor is fired at the negative/positive peak of voltage,
b) Capacitor is pre-charged to the negative/positive peak voltage.

The first condition is easy to get by timing the control circuitry and the second condition is only met immediately after switching off Thyristor. The construction for five capacitor bank steps in binary sequence weight with Thyristor switch is shown in Fig.1.

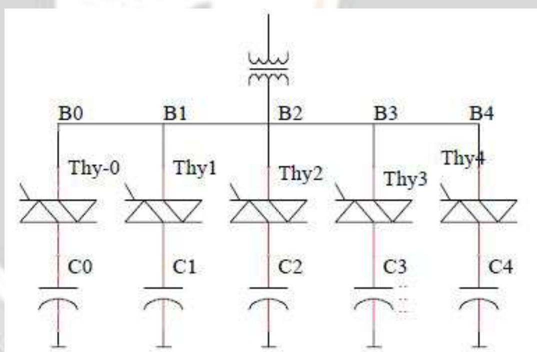


Fig. 1:-Thyristor Binary Compensation (TBC)

At the distribution transformer requiring total reactive power Q required for improving the power factor from some initial value Pf1 to the desired value Pf2 at the load.

This Q can be arranged in binary sequential 'n' steps, satisfying the following equation.

$Q = 2^n C + 2^{n-1} C + \cdots + 2^1 C + 2^0 C.$ (1)

2 System Hardware :-

A. System model

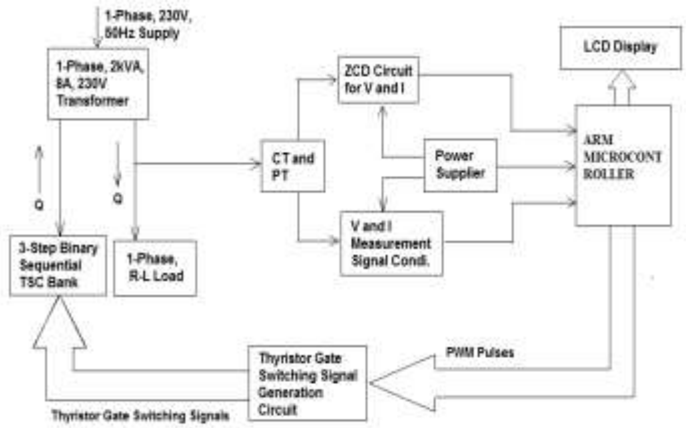
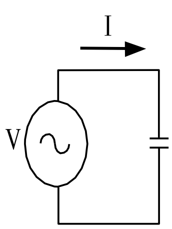


Fig 2:- Block Diagram

Basics Components of system:
-Thyristor Switched Capacitor (TSC)
- Isolation and firing circuit of SCR.
-Current Transformer (CT) and potential Transformer (PT)
-Voltage ZCD and Current ZCD for phase shift measurement
-ARM controller
-Signal Conditioning Block For voltage & current measurement

B. Power Factor:-

Power factor is the ratio of watts (true power) to VA (volt-amperes, also called apparent power). When the load is resistive only, the power factor is one, or unity, because the voltage waveform and the current waveform are in phase. Thus, for resistive loads only, true power and VA are the same.
When the load is reactive, the storing of energy is done in the load, due to which while the releasing it during a different part of the cycle. This shifts the current waveform so that it is offset, or out of phase with the voltage waveform.
Reactive loads can be inductive (electric motors), capacitive, or non-linear (rectifier power supplies). Where the load is inductive, the inductance tends to oppose the flow of current, releasing energy after storing then it later in the cycle. The current waveform lags behind the voltage waveform. Where the load is capacitive, the opposite occurs, and the current waveform leads the voltage waveform lags.



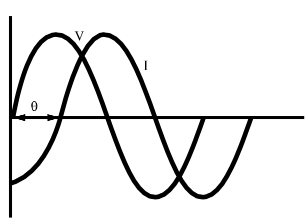


Fig.2a Fig.2b
Power Factor for a linear load as shown in Fig. 2a is defined as:
Power factor = VA cos Θ
Where, pf = power factor
V = RMS of AC line voltage
A = RMS of AC line current I
Θ = phase angle

C. Phase Shift Measurement:-

1. Potential Transformer (PT) & Current Transformer (CT):

The magnitude of voltage and current have high level of signals and it can be sensed by the input stage of the system by consuming power at the load So these signals are transformed into equivalent small level signals 0-230 V range is dropped to 0-5 A current is dropped to 0-50 mA current and 0-6V by potential transformer.

2. Signal Conditioning Block:

Precision rectifier is the second block consisting of system. AC signals of 50 Hz is carried by line provided by electricity board. Actual processing can be accomplished by dropping these signals to low levels, the transforming this ac signal to an equivalent dc signals. General Purpose Op-amp is used along with the diodes, resistors and capacitors. A precision rectifier & active filter is very accurate in this respect. The dc signal is then applied to the inbuilt ADC of ARM controller. AN0 is used for PT and AN1 is used for CT.

3. Zero Crossing Detectors (ZCD):

Using comparator ZCD block will convert sine wave signal into square wave signal. Diode will act as clamper which converting the bipolar signal to unipolar signal. Both the square wave signals will be given to INT0 & INT1 of ARM controller of voltage & current. When INT0 interrupt will occur then internal timer will start and it will stop at INT1 interrupt. Time measured by timer will give the respective phase shift in terms of Θ which will help to identify the phase shift.

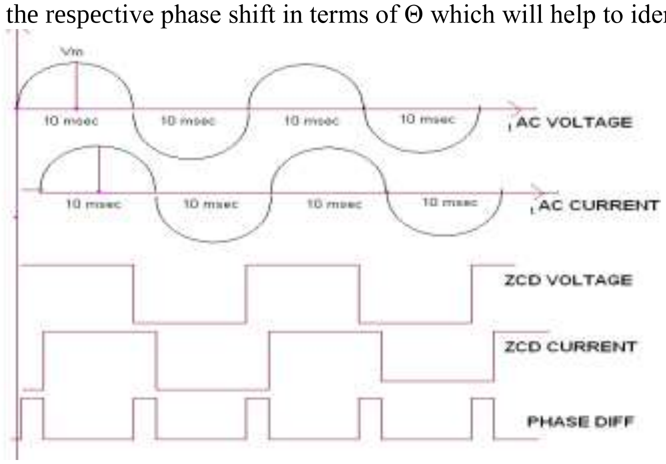


Fig 3.Waveform for phase shift

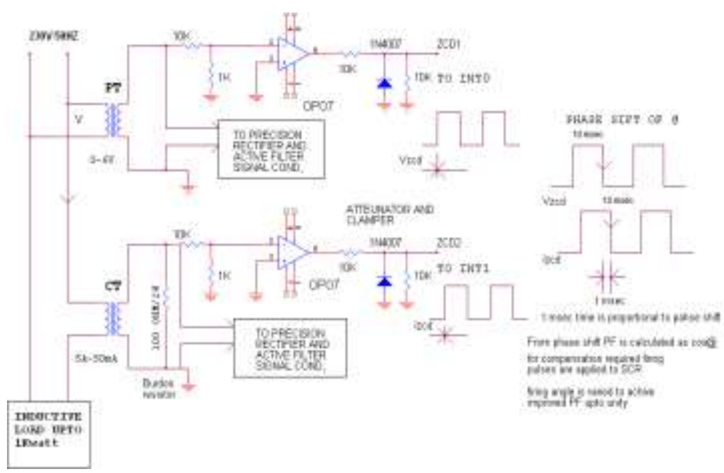


Fig 4.ZCD block for phase shift measurement

D. Arm Controller Interfacing:-

LPC2148 is ARM controller used for the system. The basic feature of ARM controller is it has in build ADC (10-bit, 8channel) which can be used for current & voltage signals which reduces the hardware requirement of system. ARM has three external interrupt which can be used for ZCD output for measurement of phase shift. It has Capture/Compare/PWM (CCP) modules which can be used to generate trigger pulses for SCR.

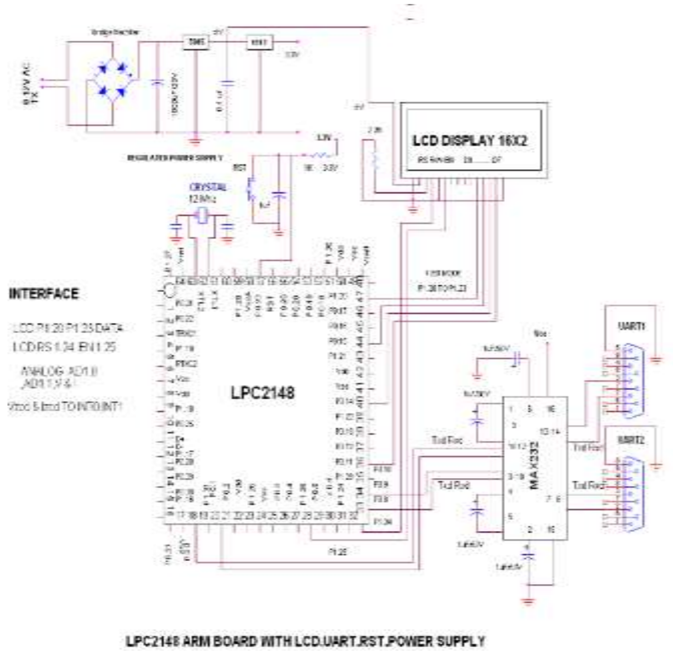


Fig5.ARM Controller interfacing

E. **Isolation And Firing Circuit:-**

The firing circuit it is assumed that it can may handle an anti-parallel SCR of higher current rating (up to 25A) whose gate drive requirement may be up to 0.5 mA to 1 A. Just we have to replace anti-parallel SCR of higher rating only to handle a load of higher wattages. Isolation is provided between power circuit and controller circuit using opto-coupler MCT2E. Trigger pulse generated from ARM controller are applied to opto-coupler. 555 timer is astable -multivibrator which is driven by a PWM pulse from the part of micro controller through reset of timer. Timer converts single pulse into multi pulse. Gate driving capability is improved using Push-Pull pair of transistor.

Capacitor bank will be selected according to the required demand for pf improvement. For respective bank firing angle is varied to achieve pf close to unity. This provides the VAR compensation for improving the pf.

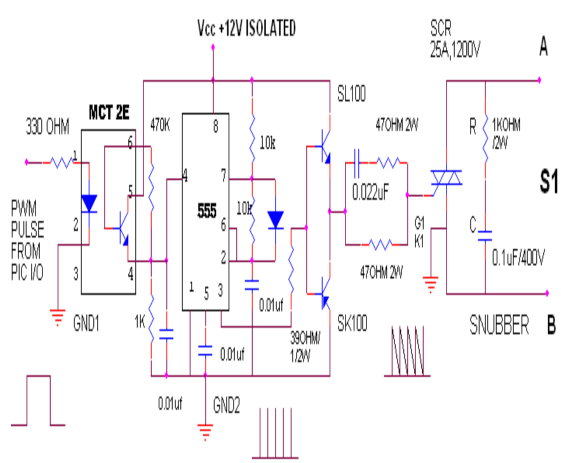


Fig6. Firing circuit

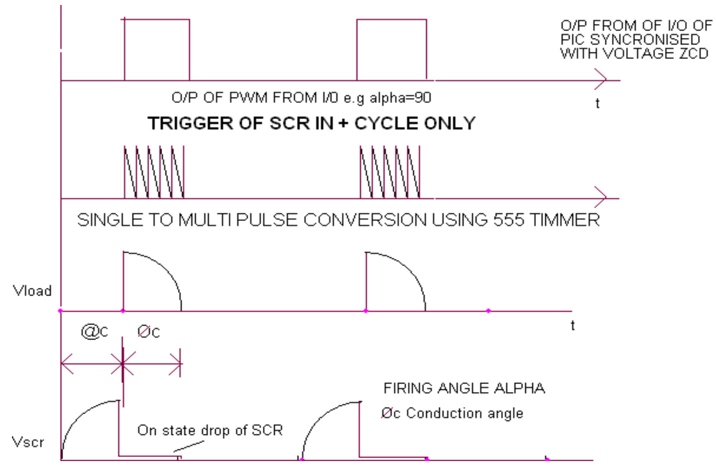


Fig7.Trigger for SCR

3. ALGORITHM:-

1) Measure voltage current and frequency for connected load resistive or reactive.
2) Measure phase shift of I and V from ZCD nature using timer and interrupt of ARM from phase shift calculate PF.
3) We may display active and reactive power on LCD using PF without compensation.
4) For compensation we have to add equal and opposite reactance in parallel with load.
5) By controlling firing angle of capacitor (Anti parallel SCR) we can compensate pf up to unity.
6) Capacitor may be 2,3,4,5... As per requirement.
7) After compensation we may observe PF which will be improved.
8) From required pf & actual measured pf error calculation is done in software. Firing angle is calculated to compensate pf up to unity. Control action implemented will be proportional or PI.

4. SOFTWARE DESIGN:-

The programming can be done in C language. C Programming makes the program development cycle short, enables use of the modular programming approach. Readily available modules in C compilers for embedded system & library codes that can directly port into the system programmer codes. MPLAB software is used for compiling program.

5. CONCLUSION:-

When observed on DSO, CT, PT with signal conditioning blocks and ZCD gives very accurate result. Voltage, current, frequency, phase shift, active power and reactive power, On LCD display all with compensation and without compensation are calibrated and displayed on LCD. System gives better performance for power factor improvement using this circuit.

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