# Digital Static VAR Compensator for three phase Induction Motor

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## ABSTRACT

*Three phase Induction Motor is inherently inductive in nature and used in most of the industrial applications. Because of these, the power factor affects very badly due to reactive power present in system. To nullify the effect of reactive power on system, power factor improvement techniques are used. Static VAR compensation (SVC) is one of the FACTS device used to these purposes, but smart, efficient, precise, and accurate control over changing load can be achieved by Digital Static VAR compensator (D-SVC). This paper proposes better methodology for measurement of power factor, accurate capacitor value selection and proper switching of it by D-SVC.*

**Keyword**: - *Digital SVC, Smart VAR compensation, three phase induction motor power factor correction, etc….*

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## 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 [1]; 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 [2].
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 undercompensation 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].

### 1.1 Block diagram of D-SVC

The schematic block diagram of D-SVC has no. of elements and devices, which work according to each other's output. The different mechanisms and processes which combine and work as Digital SVC are listed as follow. It has three main mechanisms [3],

- Power factor measurement mechanism
- Decision making mechanism
- Capacitor switching mechanism

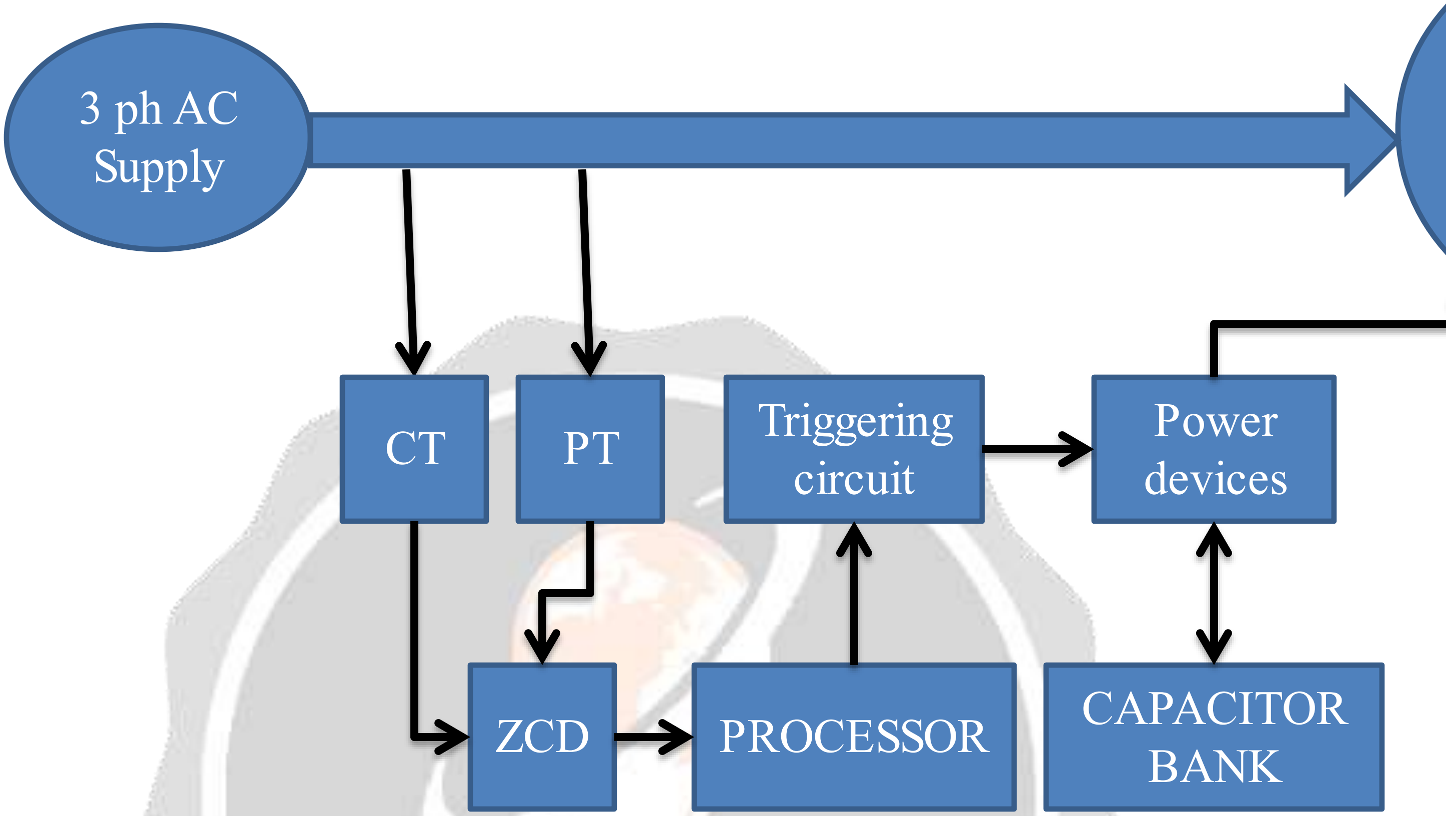



**Fig-1**: Block diagram of Digital Static VAR Compensator.

This paper proposes proper techniques for accurate power factor measurement, exact capacitor selection and switching on proper timing so as to get correct compensation without overcompensation or undercompensation. For this no of methodologies are used and explained as under.

## 2. Power factor measurement mechanism

Particularly speaking about three phase induction motor, as the load increases on motor; power factor of motor improves i.e. from no load to full load power factor of system enhances. Clearly compensation for no load requires more capacitor value than full load compensation. But still full load power factor is as low as that should not be neglected, there must be any small capacitor value to achieve good healthy power factor. That's why there must be all time perfect power factor measurement mechanism, which can give accurate power factor with change of loading on motor [3].

From the block diagram shown above the Current transformer (CT), Potential transformer (PT) and ZCD block give continuous measurement to changing load power factor. Together that is called as Zero crossing Detector (ZCD). For ZCD; CT and PT are the current and voltage sensors, which give proper value of current and voltage to ZCD in measurable form. After CT and PT there is an opto-isolator, which helps to form square wave from sine wave of I and V, i.e. the main aim of ZCD, that to produce square waves of I and V of system and give it to microcontroller. Controller gets the square waves and analyzes which wave cuts the zero line first; at the same time counter started by controller and when second wave cuts the zero line exactly on that moment counter stops. The period which is counted is denoted by "Δt" and measured in microsecond. From that Δt controller can found phase difference between I and V; that's in degree. The relation between Δt and phase angle is ($1^{o}$ = 55.555556μs). After taking its cosine controller shows the power factor of system. The total mechanism is so sensitive that small change in load shows very accurate change in power factor and that can be displayed on LCD board by controller [4],[5].

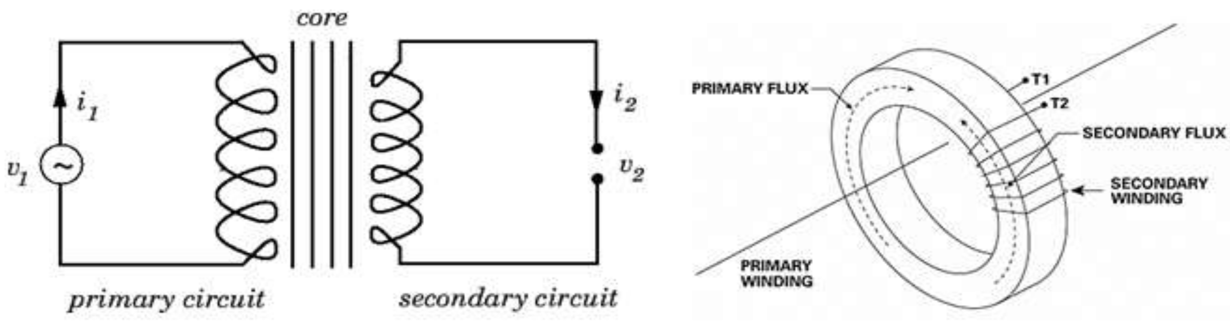



**Fig-2**: Potential Transformer (PT) and Current Transformer (CT)

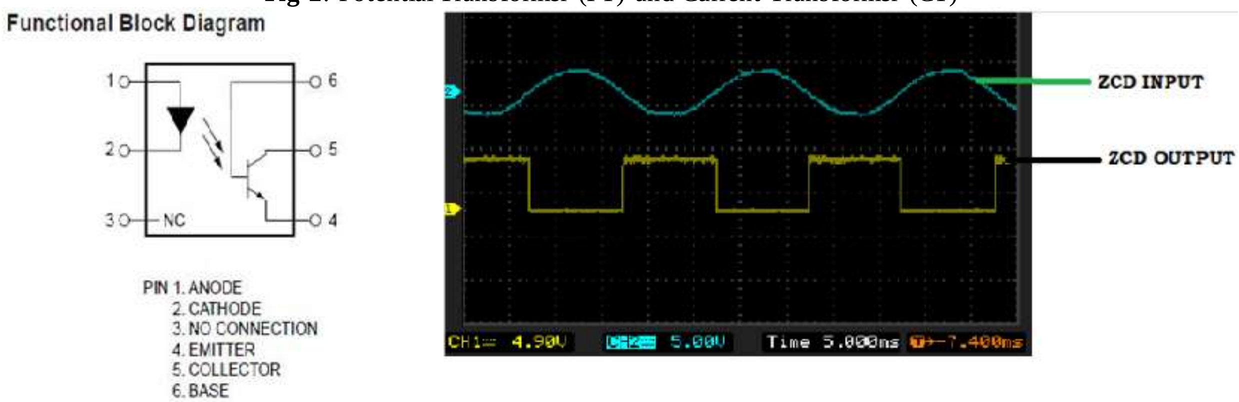



**Fig-3**: OptoIsolater and CRO readings of ZCD

## 3. Decision making mechanism

As accurate power factor is measured with above mechanism, now proper selection of capacitor for compensation is the role of this mechanism. Here all the work is done by controller (PIC16F877); controller got the power factor, from that calculation of reactive power (Q) taken place. Formula is used to calculate capacitor to compensate Q. The whole process is as follows [4][5],

$$C = \frac{1}{\omega X} = \frac{1}{2\pi f X} = \frac{V}{2\pi \sin(\emptyset)}$$

Controller not only calculates accurate capacitor value but also observes the change in load and accordingly change capacitor bank. For no load, capacitor bank value is larger, so controller triggers arrangement of capacitors. Then as load increases accordingly some capacitor are switched off, to avoid overcompensation. Finally on full load very small capacitor banks are in circuit so there must not be undercompensation. For no load to full load capacitor banks are removed from circuit; similarly for full load to no load capacitor banks come in picture; that total sequences properly followed under observation of controller [5][6].

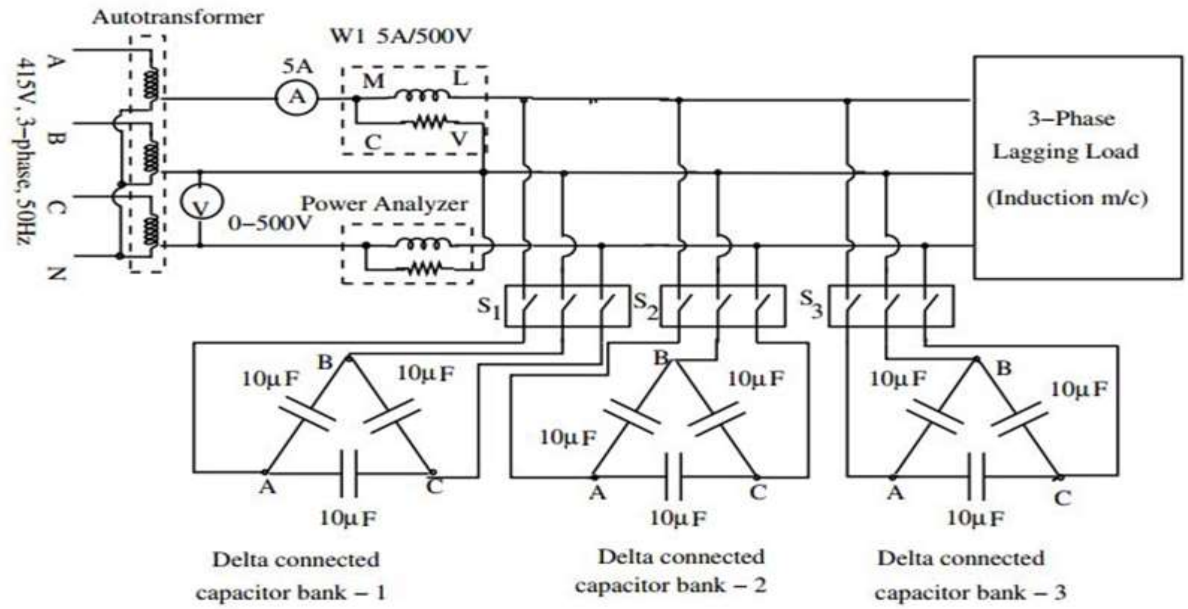



**Fig-4**: Capacitor selection and decision making.

## 4. Capacitor switching mechanism

Capacitor gets in circuit with the help of switching devices; here triac (BTA16) is used also for interfacing and controlling triac to microcontroller driver ICs (MOC3041) are used. Different load on motor gives different power factor so different capacitor comes in circuit, that trigger given by controller switches on triac trough driver IC, and capacitor switches on. As overcompensation condition seems the controller gives command to switch off the some capacitors, for that commutation of triac is done again through driver IC [3][4][6].

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. So after switching of capacitor the job of controller is not finalized. 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 [6].

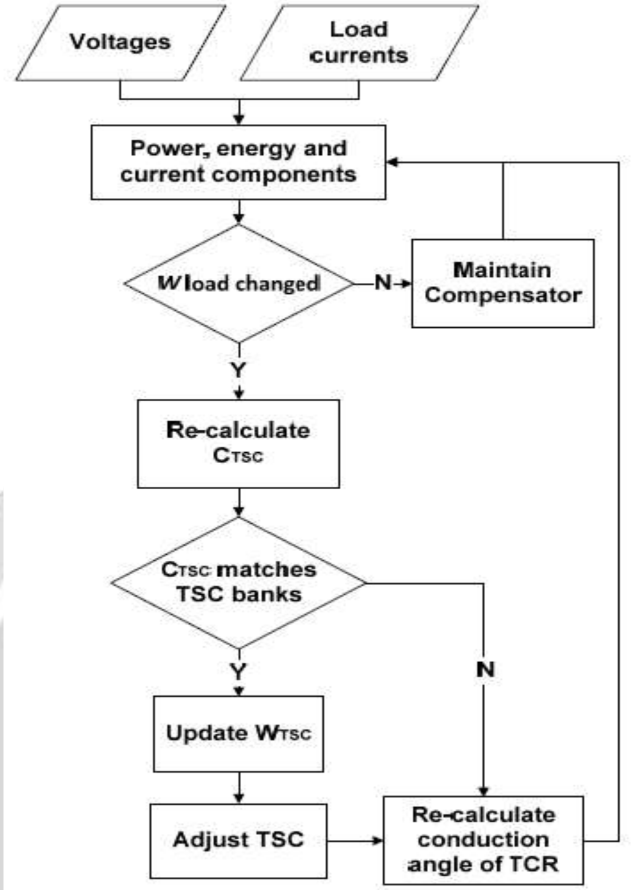



**Fig-5**: Flow chart of algorithm used in controller.

## 5. Simulation and observations.

For particular three phase induction motor; the table below shows power factor values, phase difference in degree, reactive power values, and compensating capacitor values all from no load to full load variation of motor. These readings give perfect idea about capacitor values and power factors at different load conditions, so that controller can compensate the reactive power of system. Also after compensation, power factor becomes varying in between 0.93 to 0.98, which is acceptable for all consumers and distribution systems.

Also simulation gives the information about how the real compensation of reactive power by induction motor takes place. Here Proteus8 professional software is used for that and results in waveforms with compensation and without compensation. The chart, waveforms and simulation gave perfect idea about the sensitivity, approach and range of D-SVC. As induction motor is inductive in nature, so there is no need of inductive compensation; but there can be change if the load has changed from inductive to capacitive. To compensate that there will be arrangement of inductive compensation [5][6].

**Table-1:** Readings of all parameters of 3 phase induction motor

| Load Current (A) | P.F. (Cos Ø) | Ø (Radian) | Ø (Degree) | Sin Ø | VAR's | Capacitance (F) | Corrected P.F. |
|---|---|---|---|---|---|---|---|
| 3 | 0.209 | 1.36024406 | 77.92614 | 0.977916 | 2108.71861 | 3.8994E-05 | 0.93 |
| 3.1 | 0.209 | 1.36024406 | 77.92614 | 0.977916 | 2179.00923 | 4.0293E-05 | 0.96 |
| 3.2 | 0.212 | 1.3571753 | 77.750336 | 0.97727 | 2247.81405 | 4.1566E-05 | 0.956 |
| 3.3 | 0.53 | 1.01219576 | 57.987026 | 0.847998 | 2011.42836 | 3.7195E-05 | 0.966 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3.4 | 0.58 | 0.95206764 | 54.542385 | 0.814616 | 1990.8021 | 3.6813E-05 | 0.965 |
| 3.5 | 0.614 | 0.90967792 | 52.113948 | 0.789306 | 1985.68084 | 3.6718E-05 | 0.959 |
| 3.6 | 0.642 | 0.87369233 | 50.052393 | 0.766705 | 1983.93105 | 3.6686E-05 | 0.957 |
| 3.7 | 0.671 | 0.83523967 | 47.849503 | 0.741457 | 1971.89544 | 3.6463E-05 | 0.96 |
| 3.8 | 0.692 | 0.80654046 | 46.205373 | 0.721897 | 1971.76484 | 3.6461E-05 | 0.97 |
| 3.9 | 0.715 | 0.77417222 | 44.35105 | 0.699124 | 1959.81503 | 3.624E-05 | 0.97 |
| 4 | 0.725 | 0.75976193 | 43.525509 | 0.688749 | 1980.23564 | 3.6618E-05 | 0.959 |
| 4.1 | 0.732 | 0.74954344 | 42.940108 | 0.681305 | 2007.80338 | 3.7127E-05 | 0.967 |
| 4.2 | 0.747 | 0.72725823 | 41.663425 | 0.664824 | 2007.02133 | 3.7113E-05 | 0.97 |
| 4.3 | 0.757 | 0.71208677 | 40.794277 | 0.653415 | 2019.54464 | 3.7345E-05 | 0.975 |
| 4.4 | 0.775 | 0.68408123 | 39.189886 | 0.631961 | 1998.66082 | 3.6958E-05 | 0.954 |
| 4.5 | 0.79 | 0.65998733 | 37.809586 | 0.613107 | 1983.10021 | 3.6671E-05 | 0.975 |

The power factor enhances from the no load condition to full load condition is the property of induction motor. So the compensation capacitor value also changes from large value to low value. After adding capacitor to circuit the power factor increases to acceptable level. The all above phenomenon are shown in tabular form above. These are experimental readings of D-SVC for three phase induction motor power factor compensation.

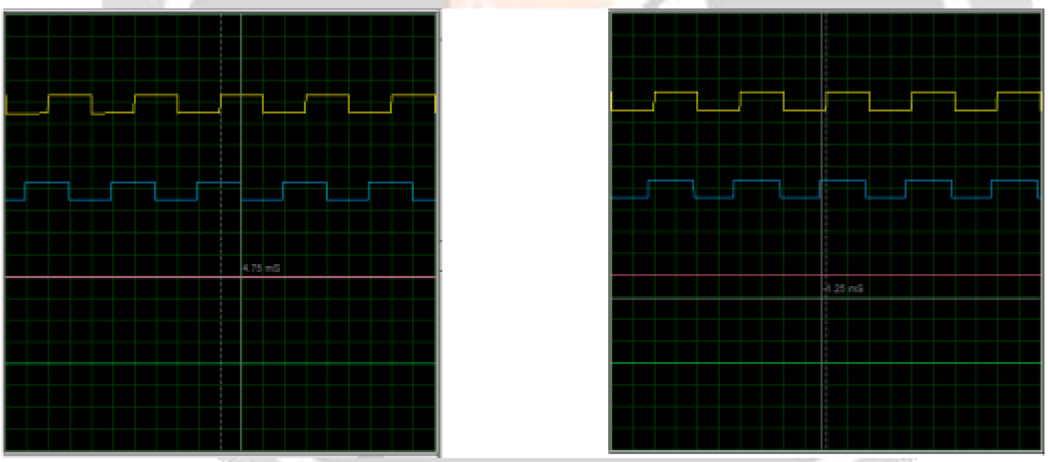
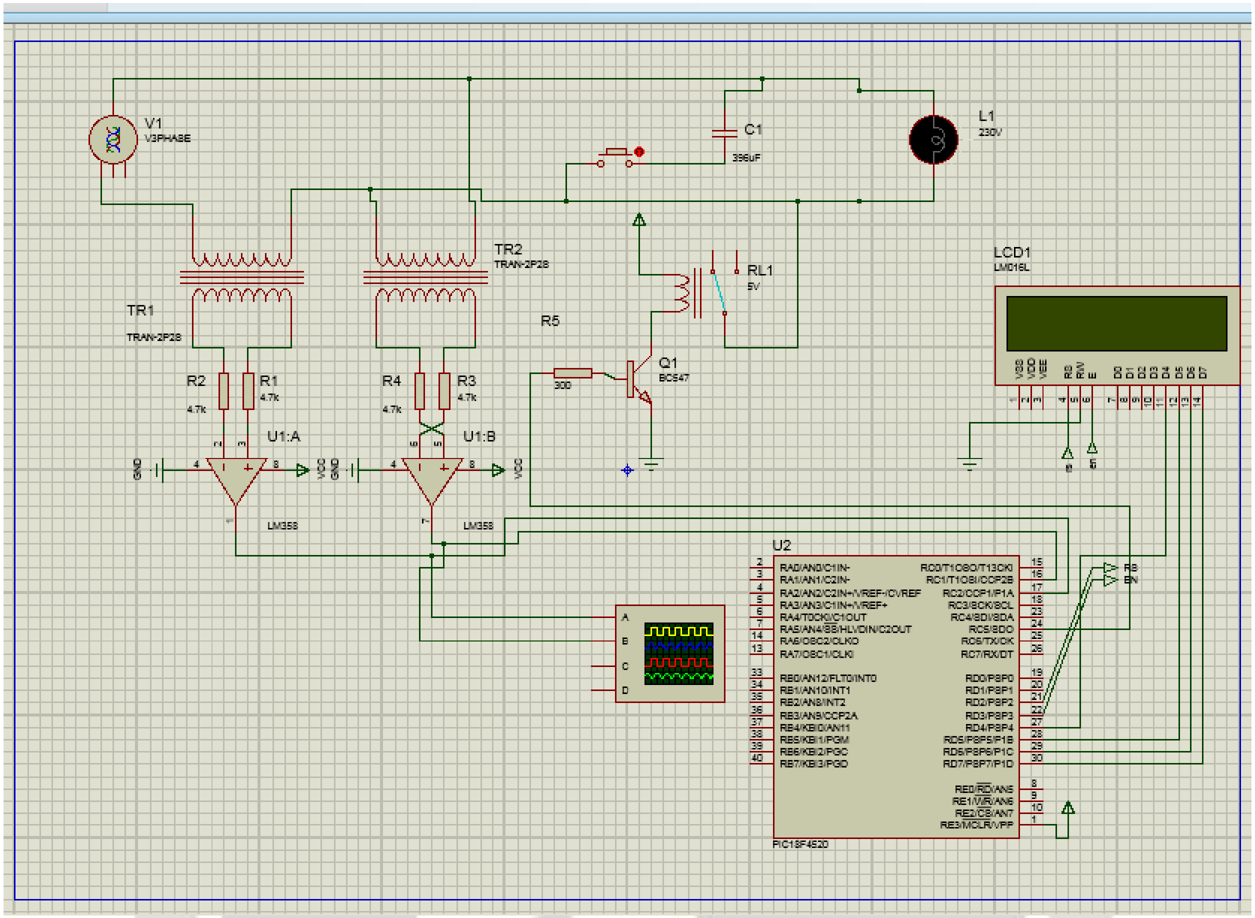


**Fig-6:** simulation waveform

The above figure represents difference between current and voltage wave in both before compensation and after compensation. At the time of no compensation the difference is very good, but after compensation it becomes negligibly small. That means current and voltage becomes in phase and there is no phase difference between them. The simulation circuit is shown below .




## 6. Conclusion

This paper estimates new methodology, to measure power factor and new accurate compensation technique to mitigate reactive power, at varying load, for three phase induction motor. This all tasks are fulfilled by Digital Static VAR Compensator, one circuit; so that consumer can get power factor within range 0.93to 0.98. Also simulation of total for total concept is added above, which represents working of D-SVC.

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