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Facts by SVC, Flexible AC Transmission



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ABSTRACT

Static VAR Compensation under FACTS uses TSC (Thyristor switched capacitors) based on shunt compensation duly controlled from a programmed microcontroller.

Shunt capacitive compensation - ***This method is used improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor. The time lag between the zero voltage pulse and zero current pulse duly generated by suitable operational amplifier circuits in comparator mode are fed to two interrupt pins of the microcontroller where the program takes over to actuate appropriate number of opto-isolators duly interfaced to back to back SCR at its output for bringing shunt capacitors into the load circuit to get the power factor till it reaches 0.95.***

The microcontroller used in the project is of 8051 family which is of 8 bit.

The power supply consists of a step down transformer 230/12V, which steps down the voltage to 12V AC.

This is converted to DC using a Bridge rectifier. The ripples are removed using a capacitive filter and it is then regulated to +5V using a voltage regulator 7805 which is required for the operation of the microcontroller and other components.

Power factor improvement

Alternating current circuits

Unlike Director Current Circuits, where only resistance restricts the current flow, in Alternating Current Circuits, there are other circuits aspects which determines the current flow; though these are akin to resistance, they do not consume power, but loads the system with reactive currents; like D.C. circuits where the current multiplied by voltage gives watts, here the same gives only VA.

Like resistance, these are called “Reactance”. Reactance is caused by either inductance or by capacitance. The current drawn by inductance lags the voltage while the one by capacitance leads the voltage. Almost all industrial loads are inductive in nature and hence draw lagging wattles current, which unnecessarily load the system, performing no work.
Since the capacitive currents is leading in nature, loading the system with capacitors wipes out them.

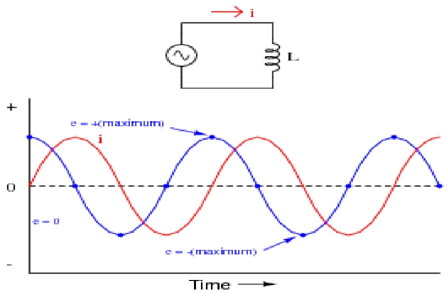

FIG: WAVEFORMS FOR INDUCTIVE LOAD

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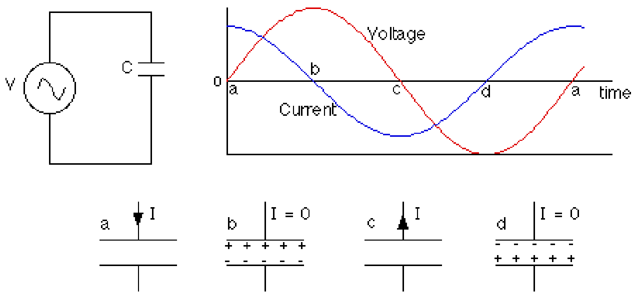

FIG: WAVEFORMS FOR CAPACITIVE LOAD

Capacitors for power-factor improvement

Whatever the power factor is, however, the generating authority must install machines capable of delivering a particular voltage and current even though, in a particular case, not all the voltage and current products is being put to good use. The generators must be able to withstand the rated voltage and current regardless of the power delivered. For example, if an alternator is rated to deliver 1000A at 11000 volts, the machine coils must be capable of carrying rated current. The apparent power of such a machine is 11 M V A and if the load power factor is unit this 11 MVA will be delivered and used as 11 MW of active power i.e. the alternator is being used to the best of its ability. If, however, the load power factor is say, 0.8 lagging, then only 8.8 MW are taken and provide revenue, even though the generator still has to be rated at 1000A at 11 kV. The lower the power factor, the worse the situation becomes from the supply authorities' viewpoint. Accordingly, consumers are encouraged to improve their load power factor and in many cases are penalized if they do not. Improving the power factor means reducing the angle of lag between supply voltage and supply current.

Location of power-factor improvement capacitor banks:

Any installation including the following types of machinery or equipment is likely to have low power factor which can be corrected, with a consequent saving in charges, by way of reduced demand charges, lesser low power factor penalties:

1. Induction motors of all types (which from by far the greatest industrial load on a. c. mains).
2. Power thyristor installation (for D.C. motor control and electro-chemical processes).
3. Power transformers and voltage regulators.
4. Welding machines
5. Electric-arc and induction furnaces.
6. Choke coils and magnetic system.
7. Neon signs and fluorescent lighting.

Apart from penalties like maximum demand charges, penalty for low power factor, the factory cabling and supply equipment can be relieved of a considerable wattles or reactive load, which will enable additional machinery to be connected to the supply without enlarging these services. Additionally, the voltage drop in the system is reduced.

The method employed to achieve the improvements outlined involves introducing reactive kVA (kvar) into the system in phase opposition to the wattles or reactive current mentioned above the effectively cancels its effect in the system. This is achieved either with rotary machines (synchronous condensers)

POWER FACTOR CORRECTION

The power factor of an AC electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1 (frequently expressed as a percentage, e.g. 0.5 pf = 50% pf). Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power.

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy

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lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

Power factor in linear circuits

In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. All the power entering the loads is consumed. Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads result in a time difference between the current and voltage waveforms. During each cycle of the AC voltage, extra energy, in addition to any energy consumed in the load, is temporarily stored in the load in electric or magnetic fields, and then returned to the power grid a fraction of a second later in the cycle. The "ebb and flow" of this non productive power increases the current in the line. Thus, a circuit with a low power factor will use higher currents to transfer a given quantity of real power than a circuit with a high power factor. A linear load does not change the shape of the waveform of the current, but may change the relative timing (phase) between voltage and current.

Circuits containing purely resistive heating elements (filament lamps, strip heaters, cooking stoves, etc.) have a power factor of 1.0. Circuits containing inductive or capacitive elements (electric motors, solenoid valves, lamp ballasts, and others) often have a power factor below 1.0.

Definition and calculation

AC power flow has the three components: real power (also known as active power) (P), measured in watts (W); apparent power (S), measured in volt-amperes (VA); and reactive power (Q), measured in reactive volt-amperes

The power factor is defined as:

In the case of a perfectly sinusoidal waveform, P, Q and S can be expressed as vectors that form a vector triangle such that:
If is the phase angle between the current and voltage, then the power factor is equal to the cosine of the angle, and:
Since the units are consistent, the power factor is by definition a dimensionless number between 0 and 1. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle.

If a purely resistive load is connected to a power supply, current and voltage will change polarity in step, the power factor will be unity (1), and the electrical energy flows in a single direction across the network in each cycle. Inductive loads such as transformers and motors (any type of wound coil) consume reactive power with current waveform lagging the voltage. Capacitive loads such as capacitor banks or buried cable generate reactive power with current phase leading the voltage. Both types of loads will absorb energy during part of the AC cycle, which is stored in the device's magnetic or electric field, only to return this energy back to the source during the rest of the cycle.

For example, to get 1 kW of real power, if the power factor is unity, 1 kVA of apparent power needs to be transferred (1 kW ÷ 1 = 1 kVA). At low values of

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power factor, more apparent power needs to be transferred to get the same real power. To get 1 kW of real power at 0.2 power factor, 5 kVA of apparent power needs to be transferred (1 kW ÷ 0.2 = 5 kVA). This apparent power must be produced and transmitted to the load in the conventional fashion, and is subject to the usual distributed losses in the production and transmission processes.

Electrical loads consuming alternating current power consume both real power and reactive power. The vector sum of real and reactive power is the apparent power. The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1.

Power factor correction of linear loads

It is often desirable to adjust the power factor of a system to near 1.0. This power factor correction (PFC) is achieved by switching in or out banks of inductors or capacitors. For example the inductive effect of motor loads may be offset by locally connected capacitors. When reactive elements supply or absorb reactive power near the load, the apparent power is reduced.

Power factor correction may be applied by an electrical power transmission utility to improve the stability and efficiency of the transmission network. Correction equipment may be installed by individual electrical customers to reduce the costs charged to them by their electricity supplier. A high power factor is generally desirable in a transmission system to reduce transmission losses and improve voltage regulation at the load.

Power factor correction brings the power factor of an AC power circuit closer to 1 by supplying reactive power of opposite sign, adding capacitors or inductors which act to cancel the inductive or capacitive effects of the load, respectively. For example, the inductive effect of motor loads may be offset by locally connected capacitors. If a load had a capacitive value, inductors (also known as reactors in this context) are connected to correct the power factor. In the electricity industry, inductors are said to consume reactive power and capacitors are said to supply it, even though the reactive power is actually just moving back and forth on each AC cycle.

The reactive elements can create voltage fluctuations and harmonic noise when switched on or off. They will supply or sink reactive power regardless of whether there is a corresponding load operating nearby, increasing the system's no-load losses. In a worst case, reactive elements can interact with the system and with each other to create resonant conditions, resulting in system instability and severe overvoltage fluctuations. As such, reactive elements cannot simply be applied at will, and power factor correction is normally subject to engineering analysis.

An **automatic power factor correction unit** is used to improve power factor. A power factor correction unit usually consists of a number of capacitors that are switched by means of contactors. These contactors are controlled by a regulator that measures power factor in an electrical network. To be able to measure power factor, the regulator uses a current transformer to measure the current in one phase.

Depending on the load and power factor of the network, the power factor controller will switch the necessary blocks of capacitors in steps to make sure the power factor stays above a selected value (usually demanded by the energy supplier), say 0.9.

Instead of using a set of switched capacitors, an unloaded synchronous motor can supply reactive power. The reactive power drawn by the synchronous motor is a function of its field excitation. This is referred to as a synchronous condenser. It is started and connected to the electrical network. It operates at a leading power factor and puts VARS onto the network as required to support a system’s voltage or to maintain the system power factor at a specified level.

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The condenser's installation and operation are identical to large electric motors. Its principal advantage is the ease with which the amount of correction can be adjusted; it behaves like an electrically variable capacitor. Unlike capacitors, the amount of reactive power supplied is proportional to voltage, not the square of voltage; this improves voltage stability on large networks. Synchronous condensers are often used in connection with high voltage direct current transmission projects or in large industrial plants such as steel mills.

Non-linear loads

A non-linear load on a power system is typically a rectifier (such as used in a power supply), or some kind of arc discharge device such as a fluorescent lamp, electric welding machine, or arc furnace. Because current in these systems is interrupted by a switching action, the current contains frequency components that are multiples of the power system frequency. Distortion power factor is a measure of how much the harmonic distortion of a load current decreases the average power transferred to the load.

Non-sinusoidal components

Non-linear loads change the shape of the current waveform from a sine wave to some other form. Non-linear loads create harmonic currents in addition to the original (fundamental frequency) AC current. Filters consisting of linear capacitors and inductors can prevent harmonic currents from entering the supplying system.

In linear circuits having only sinusoidal currents and voltages of one frequency, the power factor arises only from the difference in phase between the current and voltage. This is "displacement power factor". The concept can be generalized to a total, distortion, or true power factor where the apparent power includes all harmonic components.

This is of importance in practical power systems which contain non-linear loads such as rectifiers, some forms of electric lighting, electric arc furnaces, welding equipment, switched-mode power supplies and other devices.

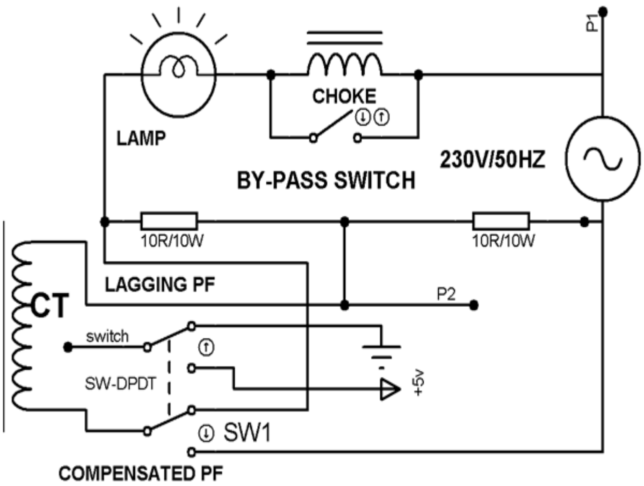
A typical multimeter will give incorrect results when attempting to measure the AC current drawn by a non-sinusoidal load; the instruments sense the average value of a rectified waveform. The average response is then calibrated to the effective, RMS value. An RMS sensing multimeter must be used to measure the actual RMS currents and voltages (and therefore apparent power). To measure the real power or reactive power, a wattmeter designed to work properly with non-sinusoidal currents must be used.

Distortion power factor

The distortion power factor' describes how the harmonic distortion of a load current decreases the average power transferred to the load.

$$\text{distortion power factor} = \frac{1}{\sqrt{1+\mathrm{THD}_i^2}} = \frac{I_{1,\mathrm{rms}}}{I_{\mathrm{rms}}}$$

THD_i is the total harmonic distortion of the load current. This definition assumes that the voltage stays undistorted (sinusoidal, without harmonics). This simplification is often a good approximation in practice. $I_{1,rms}$ is the fundamental component of the current and I_{rms} is the total current - both are root mean square-values.



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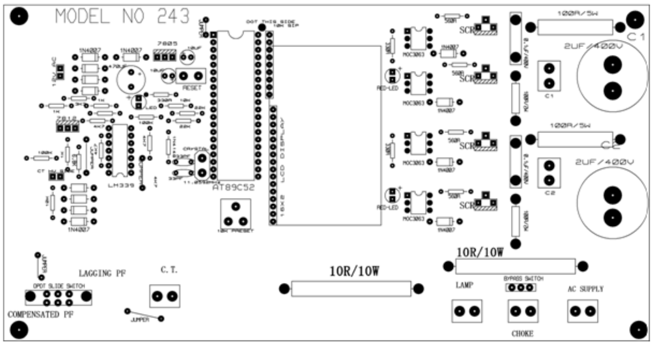
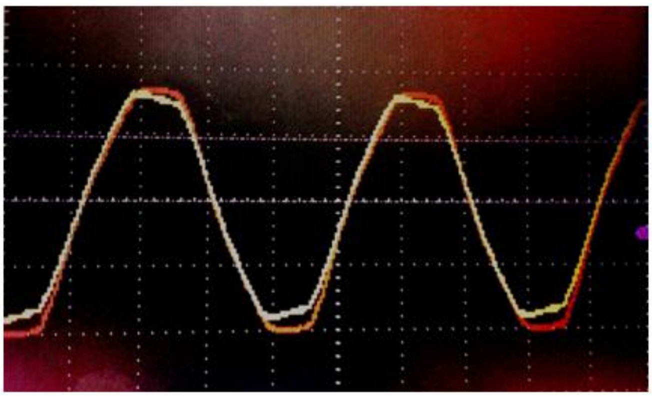


COMPONENT NAME	QUANTITY
Resistors	
330R	3
10K	2
3.3K	1
4.7K	4
6.8K	1
22K	2
100K	4
1K	2
560R	4
100R/2W	2
100R/5W	2
10R/10W	2
10K PRESET	1
10K SIP RESISTOR	1
Capacitors	
470uF /1000uF (PREFERABLE)	1
10uF	2
33pF	2
2uF/400V (FAN CAPACITOR)	2
0.1uF/400V	2
Integrated Circuits	
7805	1
7812	1
AT89S52	1
LM339	1
MOC3063	4
IC Bases	
40-PIN BASE	1
16-PIN BASE	1
08-PIN BASE	4
DIODE	
1N4007	13

Miscellaneous

CRYSTAL	11.0592MHz	1
LED-RED		3
2-PIN PUSH BUTTON		1
BULB	100W	1
BULB HOLDER		1
CHOKE		1
CURRENT TRANSFORMER (0-12V 500mA Transformer)		1
SCR		4
LCD	16X2	1
PCB CONNECTOR	2-PIN	6
SLIDE SWITCHES	SPDT	1
SLIDE SWITCHES	DPDT	1
POWER CORD		1
AC CONNECTOR	2-PIN	1
TRANSFORMER	12V, 1 AMPERE MUST	1
MALE BURGE	2-PIN	2
FEMALE BURGE	2-PIN	2
FEMALE BURGE	16-PIN	1
MALE BURGE	16-PIN	1(INCLUDED WITH LCD)

HEAT SINK		1
SCREW NUT FOR HEAT SINK		1
COPPER WIRE	FOR LOAD	
ASSEMBLED PCB (WORKING)		1
PLAIN PCB		1
ZERO BOARD		1
SOLDERING IRON		1
CUTTER		1
MULTIMETER		1
SCREW DRIVER		1
SOLDERING LED (50 gm)		
CONNECTING WIRE		
RIBBON WIRE FOR ZEROBOARD		
CD		1
DVD		1



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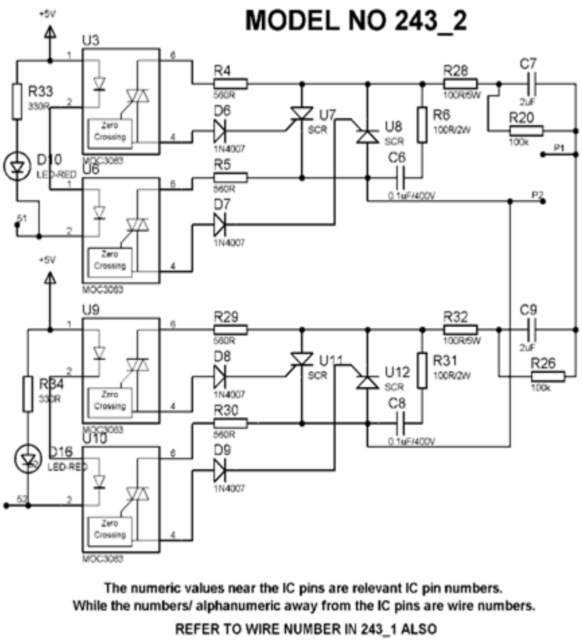
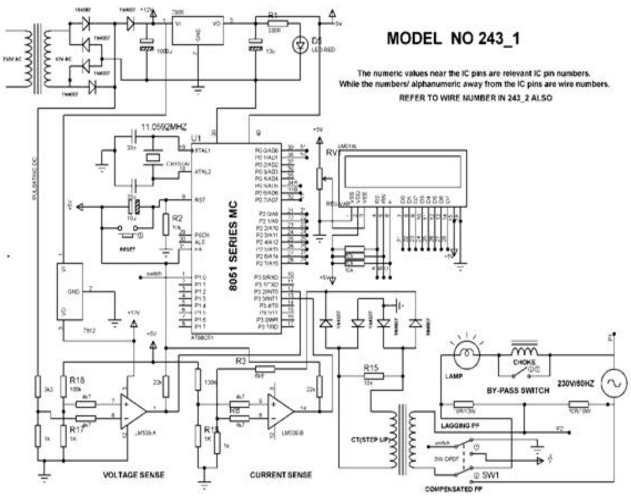
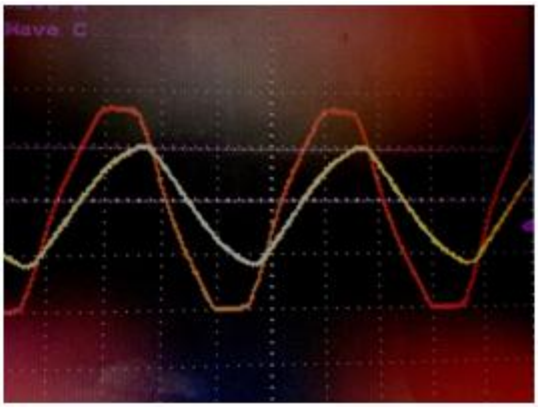
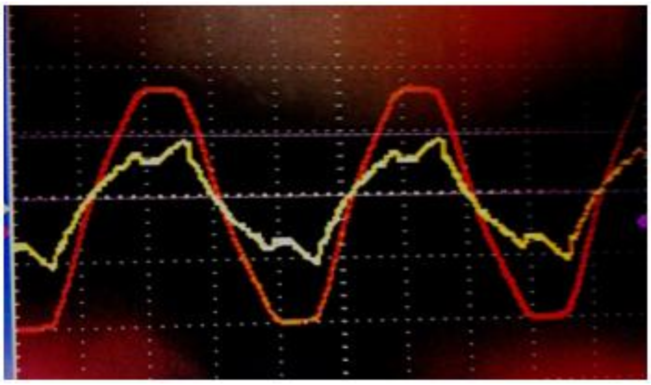
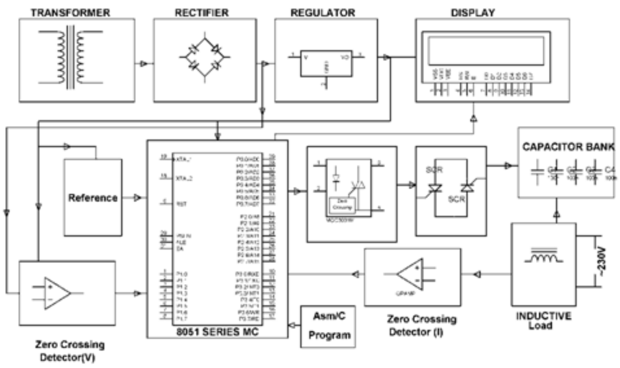








BLOCK DIAGRAM



Conclusion

The designed circuit shows the overall effect of the whole system due to use of FACTS devices installed locally.

Control Strategies can be developed by designing the pattern and timing of the control input signal of the dynamic FACTS model, as well as where the FACTS device should be located in the transmission system.

The Static VAR Compensator (SVC) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids

The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system.

When system voltage is low, the SVC generates reactive power (SVC capacitive).

When system voltage is high, it absorbs reactive power (SVC inductive).

The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer.
Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC).

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