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Minimizing Penalty In Industrial Power Consumption By Engaging Apfc Unit

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ABSTRACT-

In the present technological revolution power is very precious. It is more important to find out the causes of power loss and improve the stability of the power system[1].Due to industrialization the use of inductive load has increased and power systems lost its efficiency. So we need to improve the power factor with a suitable method. Now a days, the embedded is very much popular and most are the product are developed with microcontroller based embedded technology.

The project is designed to minimize penalty for industrial units by using automatic power factor correction unit(APFC UNIT)[1]. The automatic power factor correction is a very useful device for improving the power factor and sufficient transmission of active power[2]. If the consumer connects an inductive load, then the power factor is lagging in nature, if the power factor goes below 0.95(lag) hence the Electric supply company charge penalty to the consumer. So it is essential to maintain the power factor within the limit. Automatic Power Factor Correction device reads the power factor from line voltage and line current, calculates the compensation required and according to that switches on different capacitor banks[3].

I. INTRODUCTION

The electrical energy is almost exclusively generated, transmitted and distributed in the form of alternating current. Therefore, the question of power factor immediately comesinto picture. Most of the loads (e.g. induction motors, arc lamps are inductive in nature and hence have low lagging power factor. The low power factor is highly undesirable as it causes an increase in current, resulting in additional losses of active power in all

the elements of power system from power station generators down to the utilisation devices.In order to ensure most favourable conditions for a supply system from engineering and economic standpoint, it is important to have power factor as close to unity as possible[4].

POWER FACTOR

The cosine of angle between voltage and current in an ac. circuit is known as power factor. In an ac. circuit, there is generally a phase difference φ between voltage and current.The term cos φ is called the power factor of the circuit. If the circuit is inductive, the current lags behind the voltage and the power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and power factor is said to be leading[4].

The power factor of a circuit may also be defined as the ratio of active power to the apparent power.

i.e. $COS\emptyset = \frac{KW}{KVA}$

Disadvantages of low power factor-

(i) Large kVA rating of equipment-

The electrical machinery (e.g., alternators, transformers, and switchgear) is always rated in kVA.

Now, $KVA = \frac{KW}{cos\emptyset}$

It is clear that kVA rating of the equipment is inversely proportional to power factor. The smaller the power factor, the larger is the kVA rating. Therefore, at low power factor, the kVA rating of the equipment has to be made more, making the equipment larger and expensive.[4]

(ii)Higher current drawn by the equipment-

At lower power factor higher current is required by the equipment due to which the economic cost of the equipment is increased.[4]

(iii) Large copper losses-

The large current at low power factor causes more I^2R losses (copper loss) in all the elements of the supply system. This results in poor efficiency.[4]

(iv) Poor voltage regulation-

Higher currents produce a large voltage drop in the apparatus. This results in poor voltage regulation of the system.[4]

(v) Reduced handling capacity of system-

The lagging power factor reduces the handling capacity of all the elements of the system. It is because the reactive component of current prevents the full utilization of installed capacity.[4]

(vi) Penalty on keeping low power factor-

Electrical supply companies impose penalty on a industry or a sector for low power factor.[4]

II. POWERFACTOR IMPROVEMENT

Improving power factor means reducing phase difference between voltage and current. Since majority of loads are of inductive nature they require some amount of reactive power for them to function. This reactive power is provided by the capacitors or bank of capacitors installed in parallel to the loads.

Some methods of power factor improvement are as follows –

- Static Capacitor
- Synchronous Condenser
- Phase Advancer

(1) Static capacitor-

The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load. Static capacitors are invariably used for power factor improvement in factories.[4]

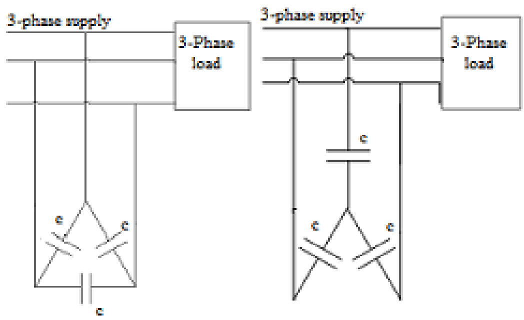

Fig.1. Static Capacitor

Advantages-

(i) They have low losses.
(ii)They require little maintenance as there are no rotating parts.
(iii)They can be easily installed as they are Xlight and require no foundation.
(iv)They can work under ordinary atmospheric conditions.[4]

Disadvantages-

(i) They have short service life ranging from 8 to 10 years.
(ii) They are easily damaged if the voltage exceeds the rated value.

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(iii) Once the capacitors are damaged, their repair is uneconomical.[4]

(2) Synchronous Condenser-

A synchronousmotor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited 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 the load. Thus the power factor is improved.[4]

Advantages

(i) By varying the field excitation, the magnitude of current drawn by the motor can be changed by any amount. This helps in achieving step-less control of power factor.

(ii) The motor windings have high thermal stability to short circuit currents.

(iii) The faults can be removed easily.[4]

Disadvantages-

(i)There are considerable losses in the motor.

(ii)The maintenance cost is high.

(iii)It produces noise.

(iv)Except in sizes above 500 kVA, the cost is greater than that of static capacitors of the same rating.

(v)As a synchronous motor has no self-starting torque, therefore, an auxiliary equipment has to be provided for this purpose.[4]

(3)Phase advancers-

Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90̊. If the exciting ampere turns can be provided fromsome other a.c. source, thenthe stator winding will be relieved of exciting current and the power factor of the motor can be improved. This job is accomplished by the phase advancer which is simply an a.c. exciter.[4]

III. ADVANTAGES OF IMPROVED POWER FACTOR

- Reactive power decreases
- Avoid poor voltage regulation
- Over loading is avoided
- Copper losses decrease
- Transmission loss decrease
- Improved voltage regulation
- Efficiency of supply system and apparatus increases.

IV. MODULES OF THE AUTOMATIC POWER FACTOR CORRECTION PANEL (APFC)-

The various modules in the APFC panel are-

- Power supply
- Transformer
- Rectifier
- Voltage regulator
- Microcontroller (89S52)
- LCD display
- Shunt Capacitor
- Current transformer
- Potential transformer
- Zero crossing detector(LM339)
- Relays and relay driver

V. BLOCK DIAGRAM

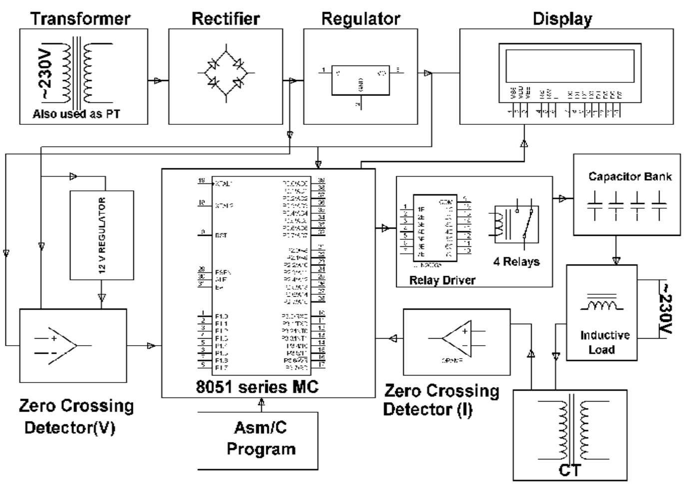

Fig.2. Block Diagram

VI. DESCRIPTION

Power supply-

The circuit uses standard power supply comprising of a step down transformer from 230v to 12v and 4 diodes forming a bridge rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor of about 470μF to 1000μF. The filtered dc being unregulated, IC LM7805 is used to get 5V DC constant at its pin no.3 irrespective of input DC varying from 7V to 15V . The input DC shall be varying in the event of input ac at 230V Section varies from 160V to 270V in the ratio of the transformer primary voltage V1 to secondary voltage V2 governed by the formula,

$$\frac{V1}{V2} = \frac{N1}{N2}$$

Thus if the transformer delivers 12V at 220V input it will give 8.72V at 160V. Similarly at 270V it will give14.72V. Thus the dc voltage at the input of the regulator changes from about 8V to 15V because of AC voltage variation from 160V to 270V the regulator output will remain constant at 5V.[1]

The regulated 5V DC is further filtered by small electrolytic capacitor of 10 μF for any noise so generated by circuit. One LED is connected of these 5V point in series with current limiting resister of 330Ω to the ground i.e. negative voltage to indicate 5V power supply availability. The unregulated 12v point is used for other application as and when required.[1]

TRANSFORMER

Transformer are used to transfer AC electricity from one circuit to another with constant frequency with a minimum loss of power. Step up transformer are used to increase voltage whereas step down transformer are used to reduced voltage.[1]

The input coil is called primary coil and the output is called the secondary coil. There is no electrical connection between the two coil, instead there linked by an alternating magnetic field created in the soft-iron core of the transformer. The two lines in the middle of the circuit symbol represent the core. Transformers waste very little power so the power out is (almost) equal to the power in. Note that as voltage is stepped down and current is stepped up. The ratio of the number turns on each coil, called the turn's ratio, and determines the ratio of the voltages. A step-down transformer has a large number of turns on its primary (input) coil which is connected to the high voltage mains supply, and small number of turns on its secondary (output) coil to give a low output voltage.[1]

TURNS RATIO = $\frac{Vp}{Vs} = \frac{Np}{Ns}$

Where,

Vp = Primary (input) voltage.

Vs = Secondary (output) Voltage

Np = No. of turns on primary coil

Ns = No. of turns on secondary coil

Ip = Primary (input) currents

Is = Secondary (output) current

RECTIFIER

A rectifier is an electrical device that converts alternating current (AC) , which periodically reverses direction, to direct current(DC), current that flows in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. The output from the transformer is fed to the rectifier. It converts ac into pulsating dc. The rectifier may be half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification. In positive half cycleonly two diodes (1set of parallel diodes) will conduct, in negative half cycle remaining two diodes will conduct and they will conduct only in forward bias only.[1]

VOLTAGE REGULATOR

The LM78XX/LM78XXA series of three-terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a Wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.[1]

MICROCONTROLLER AT89S52

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufacture using Atmel's high-density non-volatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.[1]

Pin Configuration of AT89S52

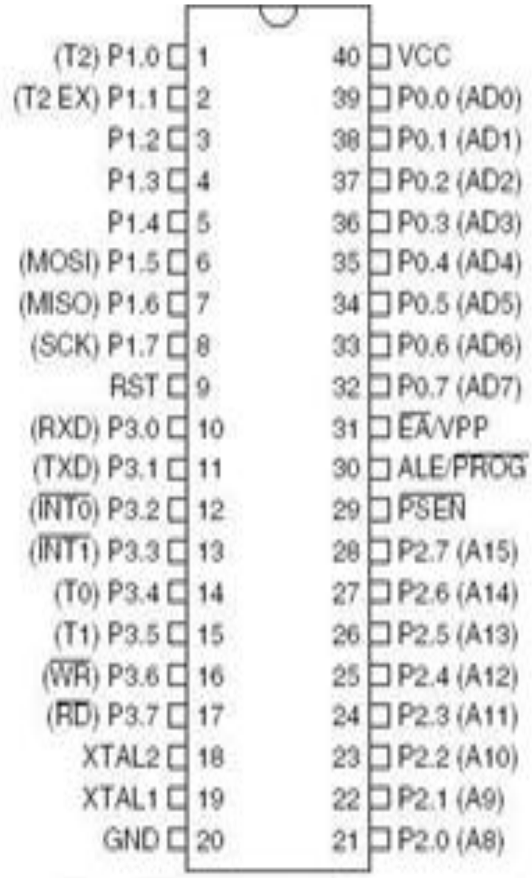

Fig.3.PIN DIAGRAM OF AT89S52Pin Description:

VCC: Supply voltage

GND: Ground

Port 0-

Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs. Port 0 can also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode, P0 has internal pull-ups. Port 0 also receives the code bytes during Flash programming and outputs the code bytes during program verification. External pull-ups are required during program verification.[1]

Port 1-

Port 1 is an 8-bit bidirectional I/O port with internal pull-ups. The port 1 output buffers can sink/source four TTL inputs. When 1s are written to port 1 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, port 1 pins that are externally being pulled low will source current (IIL) because of the internal pull-ups. In addition, P1.0 and P1.1 can be configured to be the timer/counter 2 external count input (P1.0/T2) and the timer/counter 2 trigger input (P1.1/T2EX).[1]

Port 2-

Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. The port 2 output buffers can sink/source four TTL inputs. When 1s are written to port 2 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, port 2 pins that are externally being pulled low will source current (IIL) because of the internal pull-ups. Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that uses 16-bit addresses (MOVX @ DPTR). In this application, port 2 uses strong internal pull-ups when emitting 1s. During accesses to external data memory that uses 8-bit addresses (MOVX @ RI), port 2 emits the contents of the P 2 Special Function Register.[1]

Port 3-

Port 3 is an 8-bit bidirectional I/O port with internal pull-ups. The Port 3 output buffers can sinks/source four TTL inputs. When 1s are written to port 3 pins, they are pulled high by the internal pulled-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pull-ups.[1]

SHUNT CAPACITORS

Shunt capacitor banks are used to improve the quality of the electrical supply(i.e. by improving power factor of the system) and the efficient operation of the power system. Studies show that a flat voltage profile on the system can significantly reduce line losses. Shunt capacitor banks are relatively inexpensive and can be easily installed anywhere on the network.[1]

CURRENT TRANSFORMER

The main function of the current transformer is to step down the current in a measurable value. Basically the C.T. senses the load current in the line. The part of the C.T. is its transformation ratio on which it will transform the current. These ratios are such as 100A/10A, 50A/5A, etc. then these C.T. sends the signal to the microcontroller.[5]

ZERO CROSSING DETECTORS

The zero crossing detectors are a sine-wave to square-wave converter. The reference voltage in this case is set to zero. The output voltage waveform shows when and in what direction an input signal crosses zero volts. If input voltage is a low frequency signal, then output voltage will be less quick to switch from one saturation point to another. And if there is noise in between the two input nodes, the output may fluctuate between positive and negative saturation voltage Vsat. Generally IC LM339 is used as a zero crossing detector.[5]

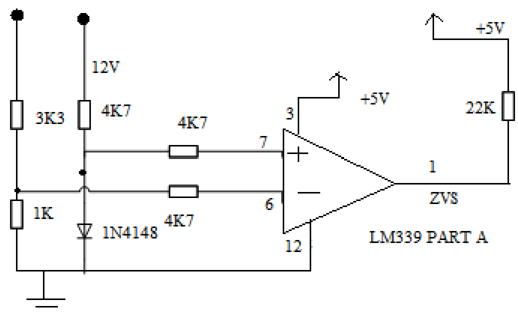

Fig.4. Voltage Sense

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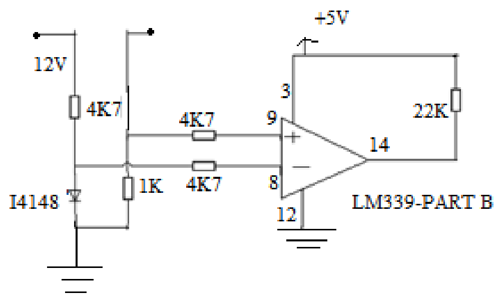

Fig.5. Current Sense

RELAY

A relay is an electrically operated switch. Relays are used to control a circuit by low-power signal or where several circuits must be controlled by one signal.[1]

RELAY DRIVER ULN2003

ULN2003 is a high voltage and current Darlington transistor array. It is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode Clamp diode for switching inductive loads. The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs may be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED gas discharge), line drivers, and logic buffers.[1]The ULN2003 has a 2.7 KW series base resistors for each Darlington pair for operation directly with TTL or 5V CMOS devices.[1]

VII. CONCLUSION

By observing all aspects of the power factor it can be concluded that power factor is the most significant part for the electricity supply company as well as for the consumers i.e. industries. Utility companies have to suffer power losses due to low power factor hence they impose penalty charges on consumers for low power factor. By installing suitably sized power capacitors into the circuit the power factor is improved and the value becomes nearer to unity. By using this APFC system the efficiency of the system is highly increased and also the consumers get rid of low power factor thus they don't have to pay penalty charges to the utility company.

The automatic power factor correction using shunt capacitor banks is very efficient as it reduces the cost by decreasing the power drawn from the supply. As it operates automatically, manpower is not required and thus this Automated Power Factor Correction using shunt capacitors can be used for the industrial purpose in the future.

Thus we have presented the possible advanced method for the correction of the power factor.

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