ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

AN INTELLIGENT METHOD FOR LOAD SHARING OF TRANSFORMERS WITH TEMPERATURE MONITORING ANDAUTOMATIC CORRECTION OF POWER FACTOR

Rekha. T*, Bindu Prakash Asna.S,Dinesh.S, Nandana.S.Prasad
Assistant Professor, Department of EEE, College of Engineering Perumon, Kollam,Kerala, India
Associate Professor, Department of EEE, College of Engineering Perumon, Kollam,Kerala, India
B.tech Scholars, Department of EEE, College of Engineering Perumon, Kollam,Kerala, India

ABSTRACT
Distribution transformers are an important part of power system which distributes power to the low-voltage users directly, and its operation condition is important for the entire distribution network operation.However, their life is significantly reduced if they are subjected to overloading and overtemperature resulting in unexpected failures and loss of supply to a large number of customers thus effecting system reliability.Protection against fault in power systems is very essential and vital for its reliable perfomance..Thus to protect the transformers from overloads and over temperature, the concept of load sharing has been proposed, wherein, automatic load sharing occurs whenever the rated conditions are exceeded. From engineering and economical standpoint, the most favourableconditions for a power supply is attained when the power factor is close to unity .Thus in order to attain increased voltage levels on the load and reduced electric utility bills, a temperature monitoring and power factor correction circuit is also included.

KEYWORDS: Load sharing, Power factor improvement, Temperature Monitoring

INTRODUCTION
Distribution transformers are one of the most important equipment in power system.The reliable operation of a power system depends upon the effective functioning of the distribution transformer. Therefore monitoring and controlling of key parameters like voltage, current and temperature are necessary for evaluating the performance of the distribution transformer and also helpful to avoid or reduce disruption due to sudden unexpected failure.A power system becomesfaulty due to the occurrence of undesirable conditionslike short circuits,overcurrent, overvoltage etc.

Transformers being one of the most significant equipment in the electricpower system, needs protection as a part of the general systemprotection approach. Moreover the increasing population and their unavoidable demands have lead to an increasing demand on electrical power. With this increasedneeds, the existing systems have become overloaded. The overloading at the consumer end appears at the transformer terminals which can affect its efficiency and protection systems.

One of the reported damage or tripping of the distribution transformer is due to thermal overload. To escape the damaging of transformer due to overloading from consumer end, it involves the control against overcurrent tripping of distribution transformer.

In this project we have made a simplified approach to protect the transformers from unusual conditions mentioned above. Where the technology of the day has given the opportunity to use the latesttrends, microcontrollers are one of the day requirements which can be applied in the remote protection of transformers.

For this purpose two similar types of distribution transformers are used so that, if any one transformer fails, then immediately another transformer is brought into the circuit during over loading, over temperatures, input voltage variations and provides conventional 230V supply to the consumers without burning of transformers.

Most of the loads (eg. 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 generator down to the utilization devices. So in this paper an automatic power factor correction circuit is also incorporated with the load sharing module.
Although, independent modules for load sharing and power factor improvement has been implemented earlier, a combination of both has not yet been practically implemented (fig.1). Figure below shows the basic block diagram of the proposed system.

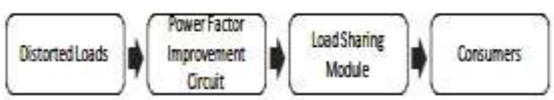


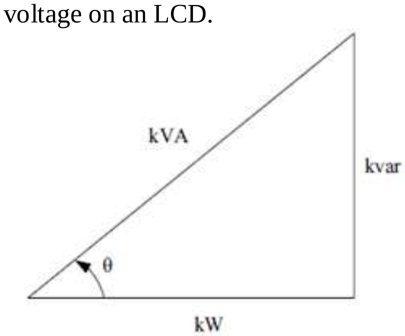
Figure: 1 ***General Block Diagram.***

Thefollowing section of the paper provides a brief overview about power factor improvement system and successive sections will describe the load sharing module, followed by temperature monitoring, so as to provide un-interrupted power supply to the energy consumers

Power Factor correction

Determination of Power Factor

Power factor is a measure of how effectively electrical power is being used by a system. To understand power factor, we first have to know that power has three components: working, reactive and apparent power (fig.2). Working power is the current and voltage actually consumed. It performs the actual work, such as creating heat, light and motion.
Working power is expressed in kilowatts (kW), which register as kilowatt-hour on electric meter. Reactive is not useful work, but it is needed to sustain the electromagnetic field associated with many commercial/ industrial loads. It is measured in kilo volt amperes- reactive, or kVAR. The total required capacity, including working and reactive power, is known as apparent power. It is expressed in kilovolt-amperes or KVA.
Most utility companies apply a surcharge when the power factor goes below 0.9 (or 90%). So an automatic power factor correction unit (fig.3) 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.
In this proposed system 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. It displays the time lag between the current and voltage on an LCD.



$$\cos\theta = \frac{kW}{kVA} = PF$$

Figure: 2 ***Power Triangle***

The program takes over to actuate appropriate number of relays from its output to bring shunt capacitors into the load circuit to get the power factor till it reaches near unity. The microcontroller used in the project belongs to 8051 family.

Power Factor Correction Module

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

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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to reduce transmission losses and improve voltage regulation at the load.

Power factor correction module (fig 3) 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.

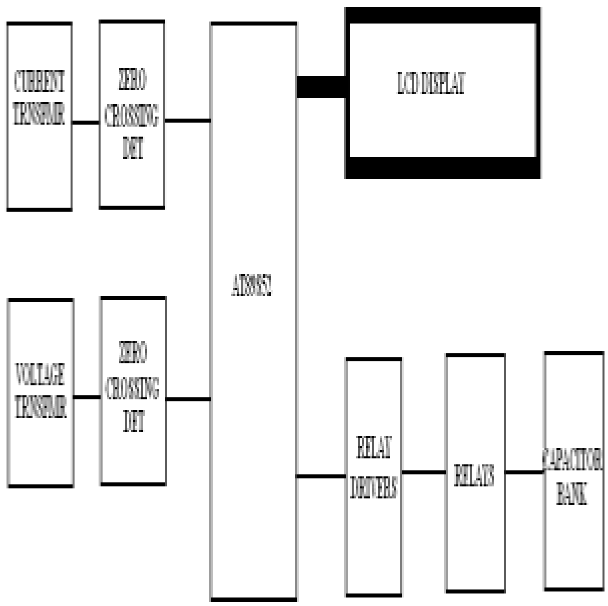

Figure:3*Power Factor Correction Unit*

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 electricital industries, 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.

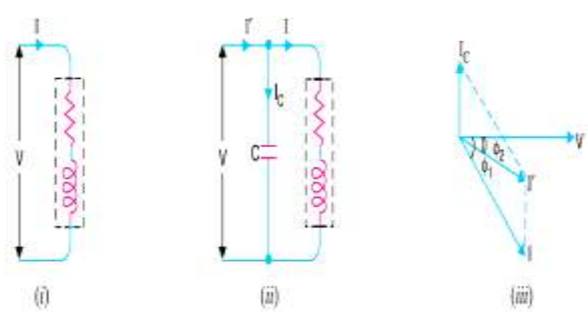

Figure: 4 *Principle of Power Factor Correction*

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 overvoltagefluctuations. As such, reactive elements cannot simply be applied at will, and power factor correction is normally subject to engineering analysis.The principle of Power factor correction is shown in fig 4.

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. The proposed system was experimentally tested and the result is obtained as shown in fig.5

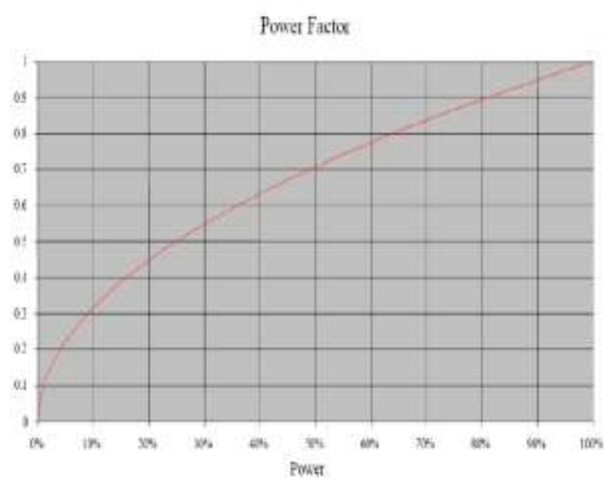

Figure: 5*Output Power Vs Power Factor*

Benefits of power factor correction

The advantages that can be achieved by applying the correct power factor correction are:

1. Environmental benefit-reduction of power consumption due to improved energy efficiency. Reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations.
2. Reduction of electricity bills.
3. Extra kVA available from the existing supply.

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4. Reduction of I2R losses in transformers and distribution equipment
5. Reduction of voltage drop in long cables
6. Extended equipment life- reduced electrical burden on cables and electrical components.

Further the project can be enhanced by using thyristor control switches instead of relay control to avoid contact pitting often encountered by switching of capacitors due to high in rush current.

LOAD SHARING MODULE

Distribution Transformer is a critical equipment in power system. The reliable operation of a power system depend up on the effective functioning of the distribution transformer. Therefore monitoring of key parameters like voltage, current and temperature are necessary for evaluating the performance of the distribution transformer and also helpful to avoid or reduce disruption due to sudden unexpected failure.

For monitoring the load current continuously, current transformer is used and the output of current transformer is fed to micro-controller through A-D converter. Similarly for monitoring transformer body temperature or oil temperature operational amplifiers are used with suitable temperature transducer. For over voltage parameter monitoring, the input voltage to the transformer primary is fed through autotransformer and the over voltage is checked. Normally the single phase transformer primary is designed to operate at 230V AC.

If the input voltage is more than 250V AC continuously, then there is a chance that the primary winding may burn due to over voltage. To protect from this, supply to the primary is provided through a relay contact, so that, relay energizes and disconnects the supply to the transformer primary. The outputs of the over load, over temperature, over voltage parameters are converted into digital pulses using A-D converters and the digital information are fed to micro controller for necessary action.

The primary of the 230:12V AC transformer is connected to a variable AC input voltage (autotransformer), and the output is connected to a load which is usually electrical appliances such as bulbs, electric heater etc. A step down transformer is used to rectify the voltage to a pure 5V DC and feed into the ADC pin of the microcontroller for monitoring the voltage of the transformer.

At the secondary side of the transformer, a current sensor is connected in series between the load and the transformer secondary terminal for sensing, the load current, output of the current sensor is then feed to the microcontroller ADC pin for monitoring. A LCD is used to display the transformer voltage, current and temperature.

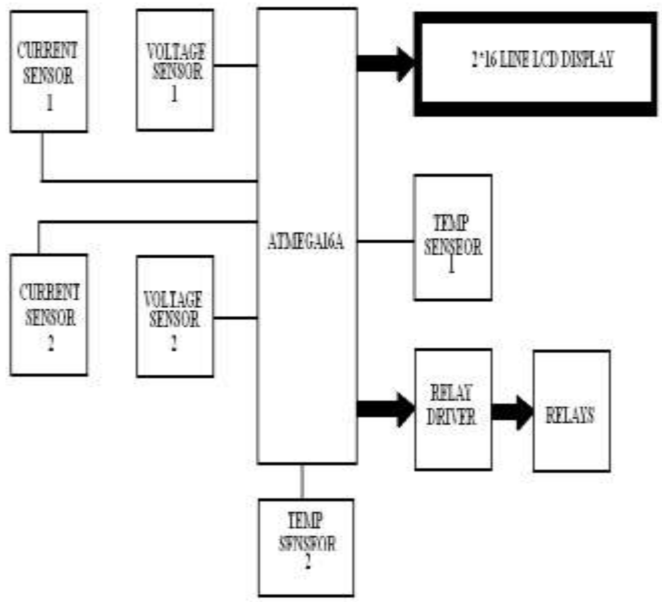

Figure: 6 ***Block diagramof Load Sharing***

While monitoring the transformer parameters, whenever the load current exceeds the transformer rated current, the microcontroller detects an overcurrent faults and it sends a trip signal to the overcurrent relay, thereby protecting the transformer from blowing off.

TEMPERATURE MONITORING

The project also consists of a temperature monitoring circuit implemented by means of a temperature sensor namely LM35.The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly pro-proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 sensor monitors the temperature of the transformer continuously. These values are send to the ADC of the microcontroller. Whenever the temperature of transformer exceeds a specific value (which will be set in the microcontroller) then the main transformer will be turned off automatically and the load will be transferred to the standby transformer. This will give ample time for the main transformer to cool and thus prevents the reduction in efficiency. If temperature increases beyond a critical value then the efficiency of the transformer decreases(60%). This can be prevented using the temperature monitoring circuitry.

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RESULTS AND DISCUSSION

In order to verify the performance of the proposed microcontroller based transformer protection system, a hardware prototype was implemented with an AVR microcontroller ATMEGE16 with a 16MHz crystal oscillator.Voltage and current sensing circuits were designed for sensing the transformer voltageand current.Whenever the current of one transformer exceeds 700mA the microcontroller sends signal to the relay and the auxiliary transformer will be turned on automatically.

The power factor correction circuit was also implemented successfully with 8051 microcontroller. The power factor was automatically corrected to unity when a lagging load was connected.

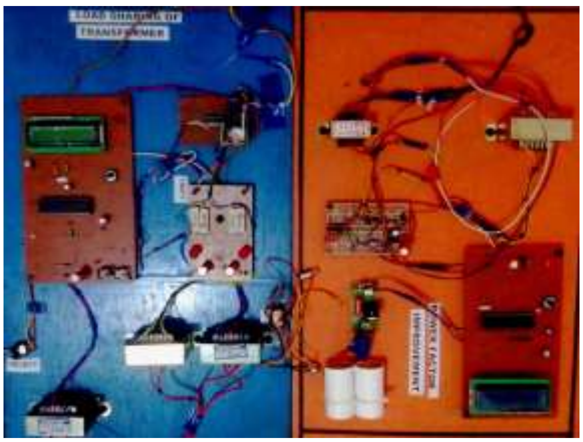

Figure:7 ***Hardware implementation***

CONCLUSION

Implementation of a very simple and low cost load sharing module along with power factor improvement system is illustrated in this paper. A demo unit is fabricated to monitor and control three important parameters, high input voltage , load current and temperature for distribution transformers protection and to provide un-interrupted power supply to consumers. Apart from these three parameters, power factor of load has also been improved nearly to unity.

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