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Automated Power Factor Diagnose and Improver using IOT

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ABSTRACT

This paper presents the simple and low-cost design of an IOT based automatic power factor correction (APFC) system for single-phase domestic loads. The proposed design uses relays to switch the capacitor banks in order to correct the power factor of inductive loads. An Arduino board controls the switching of relays based capacitor reactor bank depending on power factor measured. The Arduino is programmed to non-stop monitor and calculate the power factor of the connecting load by sensing the signal from CT, PT and Zero Cross Detectors (ZCDs), and keep the power factor of the load above the reference value (0.95) by appropriately energizing the capacitors in parallel to the connecting load through relays switching so as to correct power factor close to unity. The value of power factor before and after improvement is displayed on LCD. The hardware prototype of the proposed APFC design is also developed to validate its operation. The satisfactory and acceptable results of the APFC system testing have confirmed that the suggested design yields a reliable output and can be further used in any single-phase practical application to ensure the power factor close to unity. Power factor can be monitored on thingspeak website transmitted via nodemcu module.

KEYWORDS: *Power Factor, Relays, IOT, Thingspeak, Capacitor banks*

1. INTRODUCTION

Most of the domestic/industrial loads in the modern electrical distribution systems are inductive in nature. This loads cause change in power factor from unity to lead or lag in turn causing power losses as well as wealth loss. So it is necessary to correct the power factor so as to recover losses. And to take pf close to unity or unity. Therefore, to avoid or to reduce this financial burden, to minimize the system losses and to increase the system efficiency and reliability the electric utilities all over the world generally install static capacitor banks on secondary distribution lines to improve/correct the poor power factor and to reduce the current carried by these domestic loads [7]. However, the exercise of using a bank of static capacitor by utility companies to correct the power factor on the secondary distribution lines is not an effectual approach in the developing countries. This is because of the untrained and non1technical staff to correctly compute and fix the capacitor banks on suitable location of the power distribution lines.

In addition, the repair and maintenance service of these installed capacitor banks is very rare, scarce and expensive. Moreover, these static capacitor banks are continuously on1line and canbe damaged to distribution system by drawing large line current at the times of low energy demands by domestic consumers. As a result, this strategy to overcome the problem of power factor in distribution system by utility companies has become inefficient, uneconomical and wasteful. Thus, there is a strong requirement for better systems and exercises to improve the power factor of power distribution systems for single-phase domestic consumers. The installation of automatic single-phase power factor correction systems by each power consumer at his own premises to improve the power factor of his loads is one of the good choices to solve the aforementioned issues as well as an excellent means to reduce the electricity bill of his energy consumption. Further, this is an easy and low-priced solution to improve the overall efficiency of distribution system. Therefore, this paper presents the design and practical implementation of an Automatic Power Factor Correction System (APFC) for single- phase domestic loads. The proposed system uses capacitor banks to compensate the lagging power factor of inductive loads. The capacitor banks are energized through IGBTs whose switching is controlled by an Arduino board. The Arduino is programmed to continuously monitor the power factor of the connecting load and initiate the operation of capacitor bank through relays if the load power factor is below the reference value (0.98). World's first microwave power Transfer experiment in the ionosphere called the MINIX Microwave Ionosphere Non-Linear Interaction Experiment rocket experiment is demonstrated by Japan in 1983. Similarly, the World's first fuel free airplane based on microwave energy transfer was flown in 1987 from Canada [6] .In 2015 a South Korean Company named Samsung Launched World's. first "Wireless Charging Mobile Phones" named Samsung Galaxy note 5 and Samsung Galaxy age+ respectively [2].

The power factor has great importance in the electrical energy sector, as it is the essence of long term, reliable, efficient and economic operation of power system as well as effective utilization of available power [9]. Therefore, its correction to improve the distribution system efficiency and reliability has been remained a hot topic in the fields of research. There are many studies found in literature on this subject Choudhury presented the design of single-phase Power Factor Improvement (PFI) device [10]. The PFI device was practical implemented using ZCD, bridge rectifier and chopper circuit to correct the power factor of small signal low power loads in the adjustable range of 8.8518.E8 by switching the capacitors. The key feature of this device was its simplicity and low cost due to the use of standard logic chips without microcontroller or ASIC. Afridi suggested the scheme of an automatic single-phase power factor improvement controller [11]. The controller in the said scheme was practically implemented using PIC microcontroller which senses the power factor by continuously monitoring the load of the system and performs the control action through a proper algorithm by switching the capacitor banks through different relays and improves the power factor of the load in case of lagging power factor. Rana at al. [5] also proposed the identical design of automatic power factor improvement by using microcontroller as in [11]. However, in their design, they used resistors instead of potential transformer and a low cost microcontroller IC (ATmega8) because of its programming simplicity that make their system for automatic power factor correction most economical than any other single phase power factor improvement controlling system. Like in [5, 11], Tiwari et al. [12] also propounded the design of single-phase power factor correction technique thru automatically switching the capacitor banks by means of microcontroller. The proposed technique based on AT89C51 microcontroller that was brain and the heart of the entire power factor controller system. The ZCD is used before the microcontroller to sense the current and voltage signals. The purpose of this auto adjustable power factor correction system was to ensure the entire power system always preserved unity power factor. In addition, this system also controlled the additive harmonics and transient phenomena of the power system. Raj et al. [4] also proposed the same approach as in [5, 11, 12] for automatic power factor correction using microcontroller. The emphasis of power factor correction in their design was on domestic loads. Their relay based switching control depended on AT8EC52 microcontroller that ensured the power factor remains above 0.9. Ishak et al.[1] also presented the analogous design as in [4, 5, 11, 12] for automatically correcting the single-phase power factor. However, the switching control circuit of their proposed system was based on Arduino UNO board that energize the capacitor in parallel to the load through relay circuit when the power factor value dropped below8.E. Islam et al. also worked on the power factor correction for single-phase loads. Their approach for the correction of power factor was active type and based on modified Vienna rectifier switching topology. However, it provides almost ripple free input current, lower input current THD about to 5.6% and improved power factor up to 0.992 but the proposed topology was so complex. Mane et al. [9]

2. SYSTEM DESIGN

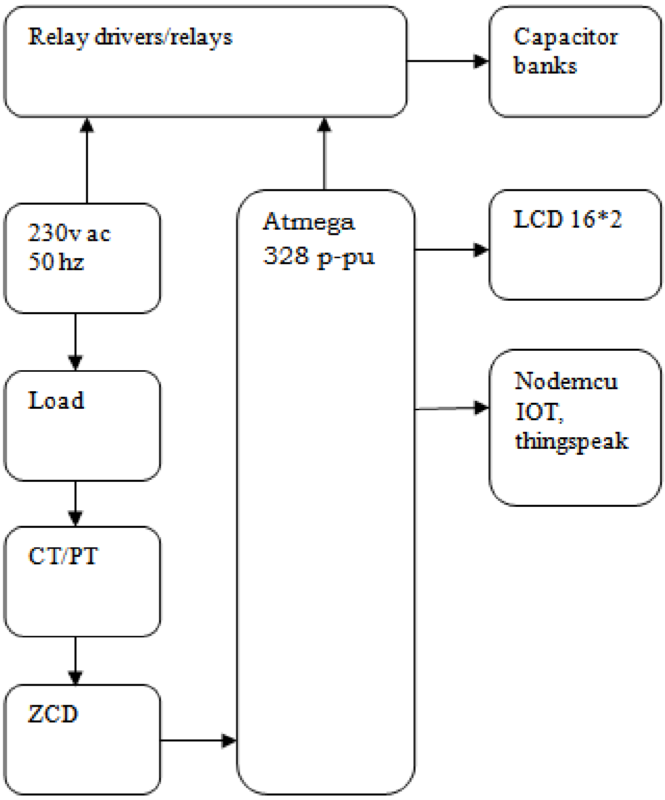

Figure1: Basic Block Diagram

The prototype hardware consist of arduino controller atmega328p-pu, which will measure current via current sensor acs712 20 ampere module, PT to measure ac voltage. Zero crossing detector to measure lead or lagging values, nodemcu to send measured power factor to thingspeak, system works on 12v/5v 1ampere power supply. The Arduino board/microcontroller is the brain of this system that is programmed to measure and correct the power factor of the connecting load. The voltage and current signals from the single-phase line are stepped down at low power level suitable for Arduino processing using Potential Transformer (PT) and Current Transformer (CT) respectively. These signals from PT and CT are fed to Arduino through sensing circuit's and Zero Cross Detectors (ZCDs) for the measuring of the current and voltage, and phase difference respectively to further calculate the power factor and the active power of the connecting load. The Arduino send the control signal to switching circuit in case of low power factor that energize the capacitor bank parallel to load through relays switching. This process is repetitive until the desired correction of the power factor which is above reference i.e. 0.95. The value of power factor after and before correction for the connecting load is displayed on LCD with some pause.

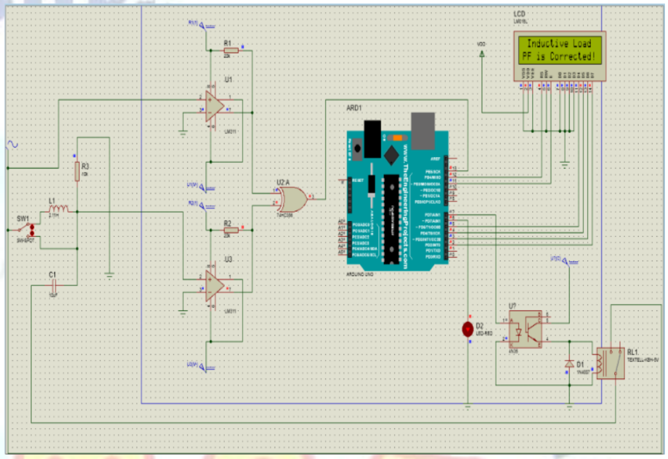

Figure2: Basic circuit diagram

The power required for the operation of Arduino board and the other peripherals of the proposed APFC system, is supplied through a 5V DC power supply. The proposed APFC system takes the voltage and current signals of the connected load through PT and CT respectively. These signals are fed to the analog pins of the Arduino board through sensing circuits and ZCDs to measure the power factor of the connected load in the following ways. For voltage measurement, the signal from a PT is fed to Arduino board via a half wave rectifier circuit. While, the current measurement is achieved by feeding the signal from a CT to Arduino board through a half wave rectifier circuit. However, the Arduino microcontroller cannot read the current directly; it can only read voltage, so a burden resistor of appropriate value is used before the rectifier to convert the current signal from CT into voltage signal for Arduino processing. The phase shift measurement between the current and the voltage signal of the connected load to find the power factor is taken through ZCDs. The two op-amps are used between the Arduino board, a PT, and a CT. These op-amps convert the sine wave signals come from PT and CT into square waves with different amplitude. The square wave signals are fed to the analog pins of the Arduino.

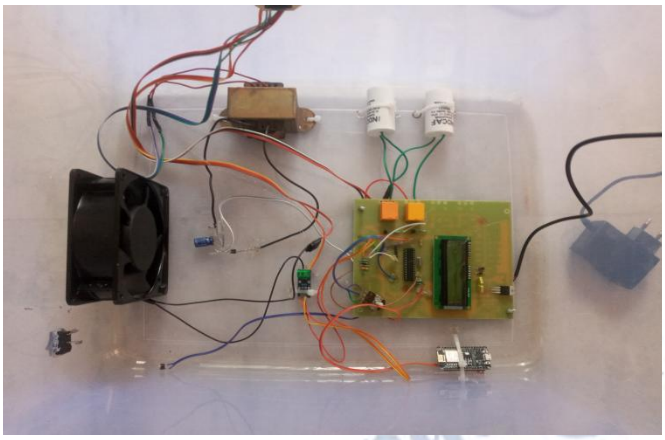

Figure3: hardware setup

The Arduino microcontroller evaluates both the square waves and measures the difference in pulse width of the both waves that corresponds to phase shift measurement that is thus further used to calculate the power factor, of the connecting load. The microcontroller of the Arduino board stores these initial values before correction into memory and alongside check, that the calculated value of power factors of the connecting load either it is below or above the reference value that is 0.95 for the proposed APFC system. In case of above 0.98 power factor, the Arduino simply displays the computed values on LCD and the results of LCD before and after correction remains the same and the operation of power factor correction is not initiated. However, upon power factor below 0.98, the Arduino microcontroller initiate the process of power factor correction as it sends the signal to turn ON the transistor that activates the opto-coupler.

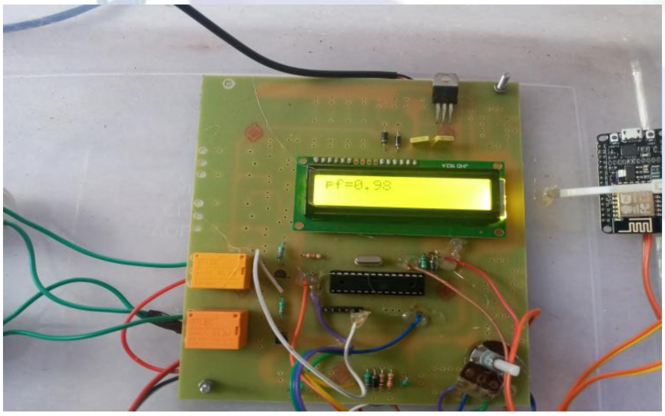

Figure4: result power factor after bank connect 0.98

The output of the opto-coupler is used to drive the relay by introducing gate current. The gate current from the output of the opto-coupler switch the relay in ON state, which in turn energize the capacitor bank parallel to load. After energizing the static capacitor parallel to load for the correction of power factor of the connecting load, the Arduino board measures the improved power factor again by sensing the signals from PT and CT through ZCDs. The Arduino microcontroller compares the improved value of power factor with the reference value and initiates the process of power factor correction again if the improved value is below the reference value. This process of power factor correction is repeated until the required correction of power. After measurement and correction of power factor the values are sent to thingspeak via arduino through nodemcu wifi esp8266 module. Which can be monitored from anywhere in the world via internet.

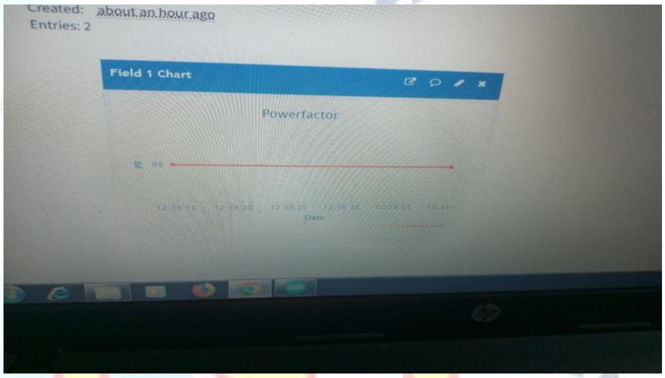

Figure5: power factor readings upload to thingspeak

3. CONCLUSION

Power factor can be measured and corrected to approximate unity so as to reduce power losses to decrease electricity bills. Through IOT power factor can be monitored from any where in the world also can be controlled by automatic/manual switching of capacitor banks via igbt which again decrease switching losses and power consumption as compared to relay based switching. Results showa that power factor is corrected from 0.92 to 0.98 and also can be monitored on website thingspeak via internet.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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