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Measuring and maintaining the data for frequency of Power Grid through AC Mains.

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Abstract -The paper presents a good economical method to measure electrical frequency of the single-phase power supply. Overcoming the drawbacks of the traditional frequency measuring devices and methods, a more reliable measuring device is designed using Arduino which use Atmega328 microcontroller which would be beneficial to farmers who use non-conventional energy sources for agriculture purpose, to check the electrical frequency of their system, so as to save their IM in low frequency conditions to avoid saturation. Arduino Uno is considered as it has good resolution. This study also provides the information about the traditional and normally used methods for frequency measurement and the pros and cons associated with it. The prototype will display and record the readings taken which will be useful for future analysis of the system. Algorithm implemented in the system is made so as to provide better computation speed and the margin of error is minimum. The measuring device is protected from disturbances happening in the input side whose frequency is to be measured with the help of an optocoupler, thus providing a smooth functioning.

Key Words:Measurement of electrical frequency, economical method, Arduino uno microcontroller

1.INTRODUCTION

Alternating current (ac) frequency is the number of cycles per second in an ac sine wave. It is measured in hertz (Hz). In India 50 cycle/sec i.e., 50 Hz, grid frequency is maintained. Grid operators controls the frequency by giving necessary instructions to generating stations. It is an important parameter in power systems as it deals with the stability of the system. The equipment in our home, factory or office is designed to operate at a 50Hz within a tight tolerance of 1% (49.5Hz to 50.5Hz) therefore it's very important to keep the frequency of our power supply stable. For the synchronizing of generators with grid it is important that the frequency of the system and frequency of the grid should be equal otherwise it may lead to failure of synchronization.

While dealing with electricity and electrical devices measurement is the important factor to be considered so as to measure frequency of electricity of domestic consumers a frequency measurement device is needed. Instruments like multimeter and CRO are capable to measure frequency but they are very costly and have their own disadvantages, so to overcome those disadvantages an frequency meter using Arduino uno is introduced. As per the current scenario it is seen that the use of non-linear power system load is increased so that harmonic contamination in the power quality increases ,When the imbalance of the power supply and demand occurs between systems, it will result in system frequency variation [1], and thus the frequency is very important parameter as it deals directly with the stability of the systemto keep generators of power grid in synchronization it is important to match and balance or maintaintheir frequency equal. Mismatch of frequency of grid and alternators,equipment's result in failure of system. Here Arduino is the heart of device and it has a better resolution which is useful for accurate measurement.

Arduino Uno is selected as it has many advantages over the other microcontroller. It is cheap, easy to maintain and can be programmed easily as per the desired results of the programmer. For programming the controller Arduino IDE is used. Also, the clear and easy programing environment is not limited to only windows operating system, the board is flexible to use and can modified using any system. The handiness of the Arduino board also provides a better hand in easy maintenance of the device.

Now if the grid frequency fluctuated more than it is allowed, the power transmission system will become unstable and eventually collapsed. The drop in frequency at the grid indicates that the demand is higher than the supply, while the jump in frequency indicates otherwise. Hopefully the measurement device that is developed could assist the relevant stakeholders to monitor the quality of the grid frequency thus increase the awareness of the importance of understanding the behavior of the grid frequency [12].

2. Need to measure frequency

Most importantly frequency acts as a mediator between the device and the supply, so mismatch of the frequency will have its consequences on the device and also if the variation in frequency continues then that may cause permanent damage to

the device. It can be avoided if a proper frequency measuring technique is implemented.

Throughout times the measurement devices have always proven to act as a troubleshooting tool for engineers. The frequency also helps to understand the behavior of inductance and capacitance present in the system. Various measurement techniques and the effects of frequency are being discussed in here. Also, while measuring the grid frequency it has to be taken into consideration that the instrument used for measuring is accurate and has a good resolution as it should be able to measure the slightest change.

2.1 Effect of variation in frequency

Various effects due to variations in frequency are as follows:

A. Effect of increase/decrease of supply or demand in power system:

When the supply is decreased, or demand is increased beyond the generated power, then the speed of rotation of the generator is decreased which causes frequency to reduce, as the speed of rotation is directly proportional to the frequency. The stored Kinetic Energy of the alternator also reduces which results in affecting stability of the system.

B. Effect on transformers:

If the frequency increases then the secondary voltage increases. Increase in frequency also affects the V/F ratio of the transformer which give rise to the core losses thereby reducing the efficiency of Transformer. Under changing frequencies, the transformer may get into saturation. The skin effect on the conductor is also proportional to the change in frequency.

C. Frequency affecting reactive power:

As inductive reactance is directly proportional to the frequency and capacitive reactance is inversely proportional to frequency and as $Q=V^2/X$, where X may be inductive or capacitive reactance. Thus, change in frequency affects the reactive power of the system.

D. Effect on electrical appliances:

Appliances such as TV set if operated at lower frequencies then a slight hum is observed on the set and also the picture in the display is disturbed which may result in instability of the device.

2.2 Methods to Measure Frequency

Various frequency measurement devices and algorithms are employed by the power supplier and distribution organizations to measure frequency accurately and in real time. These methods are proven to be useful but have drawbacks like high cost and difficult to employ them in the system. While taking considerations of only devices like CRO and frequency meters which are performing well but it requires some practice so as to use them.

If we consider measuring the frequency of grid using CRO then we have to plug the CRO probes to the AC supply whose frequency is to be measured. Then by optimizing the signal and observing the AC wave on the CRO screen we are able to determine the frequency by counting no. of horizontal divisions and multiplying it by the respective scale. Then taking the reciprocal of the answer we are able to determine the AC frequency.

Now if we consider of measuring the frequency using a vibrating reed frequency meter then we have to have a close look on its working and construction. Now, as this frequency meter consists of an electromagnet comprising of a laminated armature and winding connected with a resistance. Other main thing in the construction is its reeds which are placed near the electromagnet. For measuring frequency, we have to have a close look on the reeds as they experience a force and the one with maximum vibrations is taken into consideration and then frequency is determined by taking the reading of that reed.

So, after discussing these methods it is sure that these methods have disadvantages which need to overcome. Measurement using oscilloscope requires keen observation and also it needs a good operator who will determine the results accurately and also it needs manual calculations to finally calculate the frequency also for the frequency meter discussed above has a big disadvantage that if the observation is not done properly then the results may vary from accurate results and also in normal working also the accuracy of the device is not proper. To overcome these drawbacks a device is made which measures the frequency easily and precisely. It uses the principle of zero crossing of AC wave which is mostly used in many frequency measurement algorithms. This zero crossing is detected by the Arduino uno controller as on and off pulses which determines the total time of one cycle of input wave. The algorithm so developed requires minimum time calculations which are processed fully automatically by the device and gives the real time data logging. This real time data helps to analyze the variations in frequencies. This analysis is required to have a better understanding of faults or misbalance in the grid. The measurement technique explained here is designed such that it will sense and record the data even under major fault conditions.

3. Component Details

Table -1: Components Table

Resistor	220 ohms(Ω)
Diode 1N4001	1 A, 50V
Optocoupler PC817	100mA, 400V
Arduino SD Card Module	16 GB (micro)
Arduino UNO	5V
LCD 16 *2	4.7V -5.3V
Potentiometer	10 KΩ

Resistor: The property of circuit that opposes the flow of current is called resistance. The electronic device is commonly used to reduce the power or current in an electronic device. Resistors operate on the principle that

energy can be neither created or destroyed, only changed from one state to another. A resistor is made of a material that has a specific amount of resistance to current flow. Resistors are selected for the amount of resistance they possess. This value is measured in Ohm's (Ω).

Diode: A diode is a device which allows current flow through only one direction. That is the current should always flow from the Anode to Cathode. The 1N400x series is a family of popular one ampere general purpose silicon rectifier diodes commonly used in AC adapters for common household application. For 1N4001 diode the maximum current carrying capacity is 1A it withstands peaks up to 30A.

Optocoupler: An optocoupler is basically an interface between two circuits which operate at (usually) different voltage levels. The key advantage of an optocoupler is the electrical isolation between the input and output circuits. With an optocoupler, the only contact between the input and the output is a beam of light. This is especially necessary for the coupling between high-voltage information-gathering circuits and low-voltage digital logic circuits. A current is first applied to the optocoupler which makes the infrared LED emit a light that's proportional to the current. When the light hits the photosensitive device, it switches on and starts to conduct a current as any ordinary transistor might.

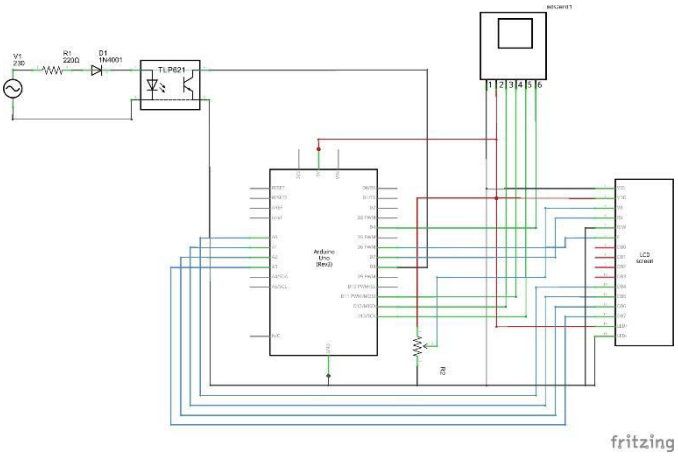
Arduino SD Card Module: The module (Micro-SD Card Adapter) is a Micro SD card reader module, and the SPI interface via the file system driver, microcontroller system to complete the Micro-SD card read and write files. Arduino users can directly use the Arduino IDE comes with an SD card to complete the library card initialization and read-write. This is the primary storage unit of our device which will store the data up to 16 gigabytes.

Arduino UNO: The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.

LCD 16*2: The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this displaying custom characters, special and even animations, etc. The 16×2 liquid crystal display contains two horizontal lines and they are used for compressing the space of 16 display characters. This module will receive direct commands from the Arduino and will display the frequency.

Potentiometer: A potentiometer is defined as three terminal variable resistors in which the resistance is manually varied to control the flow of current. The potentiometer is a simple device used to measure the electrical potentials between the end of the wire and any point along it will be a potential proportional to the length of wire to that point.

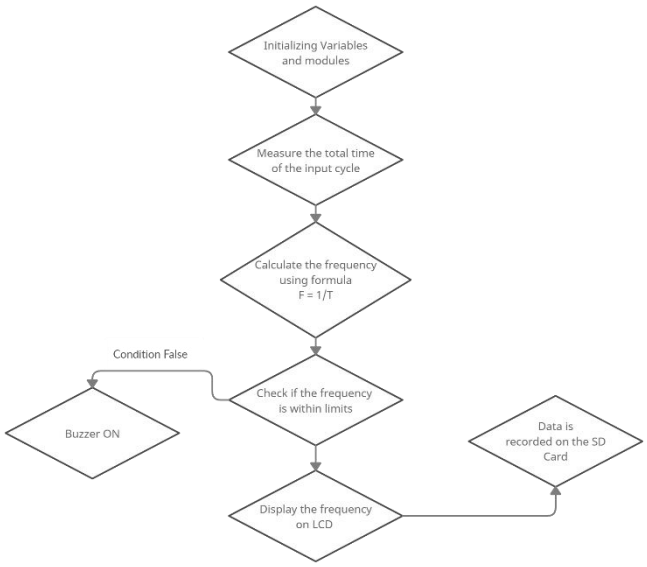
4. Circuit Diagram



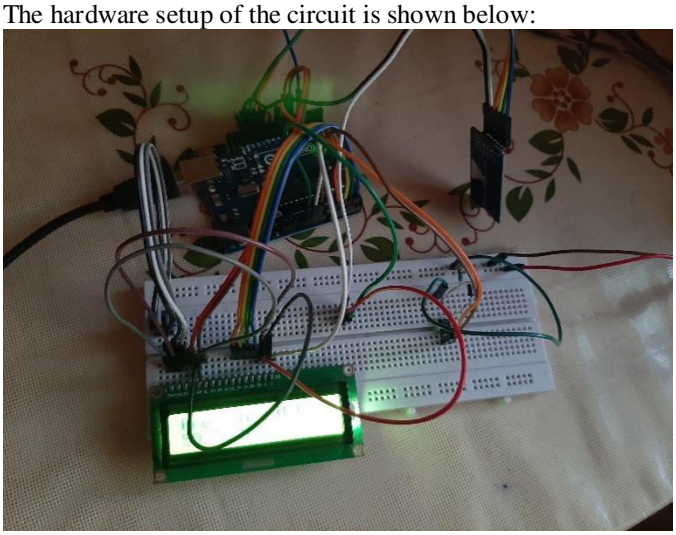
The above figure shows the actual connection and circuit of the hardware to be employed. The supply is firstly connected to the optocoupler through the half wave rectifier circuit. The half wave rectifier circuit is employed so that the AC voltage gets converted into the DC voltage and one cycle of the input is eliminated and it becomes easier for us to correctly measure the on and the off time of the supply signal which will be useful for calculating the frequency of the supply. The circuit employs an optocoupler which makes it safer to use in any case of faults in supply. With help of our algorithm and Arduino UNO board we are able to determine the frequency and the results are stored in a memory unit connected it. The data is transferred from the Arduino UNO to the memory unit through serial communication.

5. Algorithm and Working

Below shown represents the algorithm of the device



It is clear from the above flowchart that for the programming part of the device first the initialization of variables is done and all the libraries are included in the Arduino IDE after which the help of half wave rectifier ckt implemented the Arduino UNO is able to sense the ON and OFF time of the input cycle. Electrical frequency is calculated by taking the reciprocal of the time measured. This value is recorded on the SD card which is used as a memory storage element and the interaction of SD card and Arduino is made via the serial data communication and the data is printed on the LCD screen.
The hardware setup of the circuit is shown below:



APPLICATION

1. It will benefit the farmers who use solar power for agriculture purpose, to check the output frequency of the inverters so as to save their IM in low frequency conditions.
2. Hostel owners who have solar rooftops can check whether their operating frequency is within tolerance limit or not.
3. It can be used in laboratories for experiments as it directly measures frequency and no calculations are required to be done.
4. It can be used as a good alternative for the normally used devices for frequency measurement.
5. The range of the meter can be extended by adding external circuits

CONCLUSION

It is required and is essential to measure and monitor the grid frequency continuously to avoid any kind of grid failures and misfunctioning of the power system. By not maintaining the frequency as per standard rules designed by the national authority of the specific country could lead to serious problems on both consumer and the supplier side. The measurement technique should also provide a well-structured report of the on-going variations in the frequency and also the operator who is monitoring will have to cross check the data with the manual readings which he records in his register to check whether the device is properly functioning or not.

Also, as for the Arduino used for measuring purpose should not be restricted only as per the algorithm displayed there can be many modifications to the circuit for various other purposes. This Arduino helps us and ease the problems of designing the complex circuits which are present for performing this job.

As for the device explained it has given accurate results and the margin of error is also very less. It displays and also maintains the data for future use while consuming less power. The safety of the device is also excellent as the optocoupler isolates the main functioning parts from the ac mains. The device gives the data keeping all as per the standards mentioned by the governing authority. The device so designed gives no sign of damage or degradation even after long use.

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