Indonesian Journal of Electrical Engineering and Computer Science
Vol.11, No.1, July 2018, pp. 224~232
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v11.i1.pp224-232

Smart Monitoring and Controlling of Frequency Deviation by Using MATLAB GUI and ARDUINO DAQ Card

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Article Info

Article history:

Received Jan 12, 2018
Revised Mar 17, 2018
Accepted Apr 14, 2018

Keywords:

HMI Human Machine Interface
DAQ Data Acquisition Card
Home Area Network
MATLAB

ABSTRACT

Electricity transmission and distribution in most of the countries are needed to be improved by the construction of new networks. These improvements are not that much cost effective and if cost is tried to be reduced then the quality and efficiency of the system is compromised which is not suitable at all for the current system. In addition obtaining planning permission and carrying out construction is so much difficult in busy cities. The main objective of this research is to monitor and control frequency deviation. A simple MATLAB controlling and monitoring system is being developed and the ARDUINO DAQ card is used to calculate the frequency deviation. The purpose of respective research is basically based on a dummy load which is used to show the usage of particular equipment's used in a home such as fridge, freezer, oven, lighting system, and domestic wet appliances such as washer dryer which are attached these to a DAQ and then to a controlling and monitoring GUI MATLAB based. However, this research is focused on the monitoring and controlling of the frequency deviation.

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1. INTRODUCTION

Modern era is known as the age of energy efficient building other commercial or residential sector. Advanced engineering introduced many new technologies for this purpose as smart monitoring and controlling techniques is help to control the frequency deviation. The purpose of smart monitoring and controlling system is to automate and take control the frequency deviation of electrical equipment in the most efficient way. That makes it possible for the consumer to save their appliances. In an Ac power system the balance between the generation and demand determines the response of frequency, if the demand and generation is unbalance for example due to some loss in generation, a sudden change of demand or a change of output power of renewable source , the frequency change rapidly. Large frequency damages the induction motor or transformer because of the highly magnetizing current is required to maintain the flux. These devices are mostly used in distribution network and transmission and as well as it's also use in home appliance [1] [2]. Frequency response of demand Reduction based on local frequency was discussed in 1980 by Schweppe [15]. This patented idea was for an automatic responsive switch to control e.g. a smelter for industrial load or a water heater for domestic load (17). A measurable parameter inside temperature of smelter or a heater and the system frequency is decided when to switch on or off the load. For example, if the temperature of an industrial plant was among its most and minimum limit and also the frequency was low it had been converted at a lower temperature that it most. Likewise, once the frequency was high it had been switched on at better temperature than its minimum. The result was linear variation of the works temperature point with the system frequencyA Simulation Studies that linearly varied the switching temperatures of fridges linearly with the system frequency was under taken by short. When the frequency was the higher (or lower) than the normal, fridges switch off (or on) at a higher (or lower) temperature than the switching temperature for normal operation. The results showed that, for a sharp generation loos of 1320 MW, the frequency drop will be reduced by concerning 0.4 HZ once there's management of fridges. Within the simulation, forty million fridges were transitioned to produce 1320 MW of frequency [3].

Today is the modern era and there is a vast demand of automation optimization controlling and monitoring of Electrical and equipment used in industrial plant, residential and commercial building etc. In a Ac power system the balance between the generation and the demand is very important for example due to some loss in generation, a sudden change of demand or a change of output power of sources the frequency and the voltage change rapidly. Large change in the frequency damages the induction motor because of highly magnetizing current is required to maintain the flux. Research is covering the limited modules in term of frequency to ensure that if there is a large disturbance in term of frequency. It will switch off the appliances to prevent from the large damage.

2. METHODOLOGY

The aim of this research is to develop a fast, reliable and cost efficient system. Especially considering frequency deviation factor. The main aim is to minimize the damages which were happen due to the frequency deviation. The research is oriented on a dummy load which is used to show the usage of particular equipment's used in a building such as Fridge, Oven lighting system, and multimedia equipment's which is attached to a DAQ (Data Acquisition Card) and then to a controlling and monitoring unit on a computer, on which monitoring and controlling will be done by a GUI on Matlab as illustrated in figure 1.

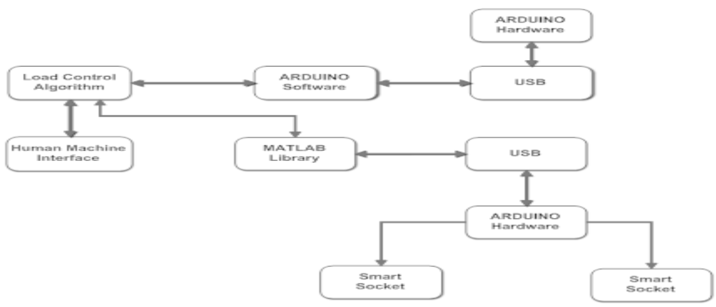

Figure 1. The State Diagram of Load Group

2.1. Prototype Hardware Design

The project moves on in developing part of the hardware model that is used to monitor and control two dummy load models. The dummy loads consist of a bulb. The hardware controller system design can be briefly simplified to manual and auto mode system. These are further discussed in the upcoming sections. Prototyping and analysis test will be carried out after that. Figure 2 show the frequency monitoring circuits for the dummy load it will also help us monitor and calculate the power usage of our system [4] [5].

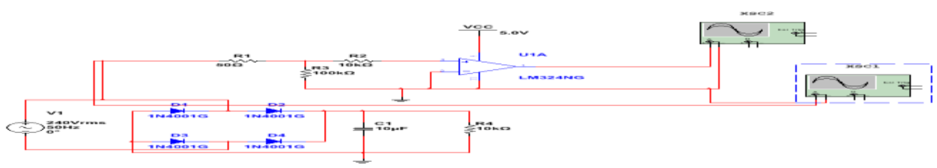

Figure 2. Frequency Detection Circuits

2.2. Block Diagram of Research Hardware

Figure 3 shows the block diagram of the Research hardware design. The system consists of software and also hardware parts. The hardware parts consist of several components like the dummy loads, switches, pulse. While the software part includes the controller and data acquisition card which will then be controlled by means of MATLAB GUI. As mentioned previously, only parts of the developed MATLAB GUI will be used in the Research project [6] [7]

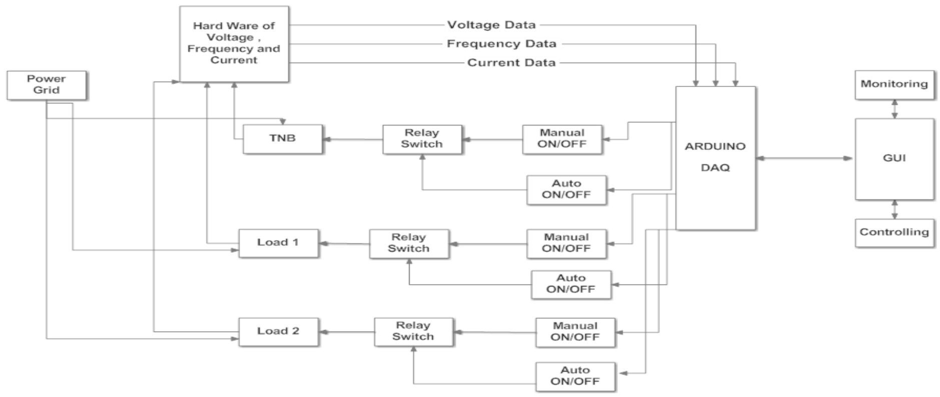

Figure 3. Block Diagram of Research Hardware

The above system can be explained in terms of monitoring system and controlling system [8] [9].

2.3. Monitoring System

In the monitoring system dummy load is used to represent the actual load of appliance such as freezer, washer, and dryer. Beside this ARDUINO R3 Mega 2560 is used as the DAQ of the Research. Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as the, frequency with a computer. Figure 4 shows the block diagram between the dummy load, DAQ device and the computer [10].

Figure 4. Block Diagram between Dummy Load, DAQ Device and Computer

Beside this MATLAB GUI is also monitoring the dummy load. MATLAB GUI refers to the Graphics User Interface it is a type of user interface that allows the user to interact with electronic devices through graphical icons and visual indicators such as secondary notation, as opposed to text-based interfaces, typed command labels or text navigation [11].

2.4. Controlling System

The controlling system consists of mainly relays. The relays are used for switching purposes, which is to turn enable turning on and off the loads. The relays obtained the incoming pulses from the MATLAB Graphic User Interface (GUI) that is programmed with the desired control [12] [13]. The control technique can be basically described in manual and auto system. The manual system depicts the usual manual system where the loads can be manually switched on or off. Meanwhile, the auto system is whereby based on MATLAB GUI whereas MATLAB get the data from ARDUINO and after getting data it pass signal to the system whether its need to be on or off . This is to say that the on off period is defined by administration according to the time and hence the loads are controlled by this timer technique [13].

Based on calculated values from an algorithm which ran in computer decided when switch on and off different load. The smart load controller send the signal through home are network to smart socket. The smart socket switch the appliance that was plug into the socket. In this experiment the sockets were represented by the lamp load [14] [15].

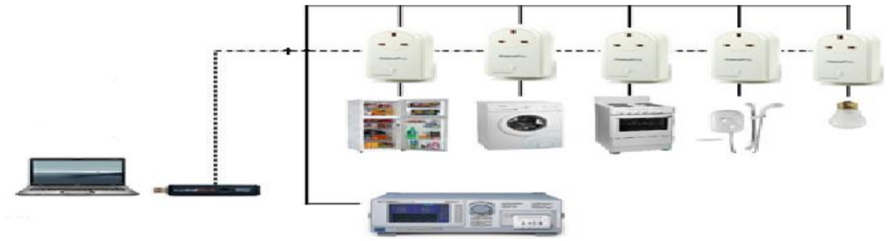

Figure 5. GUI for Controlling and Monitoring

3. RESULTS AND DISCUSSION

The Load Controller, implement into PC Consist of software modules for the load control algorithm, Human machine interface HMI and communication libraries. The controller continuously ran the software module in a loop reading the values of frequency etc., running the algorithm and updating the HMI [16]. The algorithm called a function in the communication libraries to transfer the data between the algorithm and smart socket through the port of computer use ARDUINO hardware and software for transfer the data between the Load control algorithm and smart socket. The ARDUINO communication libraries encode or decode the data sent and receive by using the communication protocol of the smart socket. The HMI display all the values and graph of algorithm [16]. In the implementation of HAN the smart socket communicate with HMI through ARDUINO. The ARDUINO DAQ card controller was connected to the computer through USB port and also ARDUINO was used to sand the control signal to the smart socket [17] [18].

3.1. Primary Frequency Response

The load algorithm was used to control the lamp load which represents the domestic appliances. As shown in table 1 Group the appliances according to their characteristics. Load 1 represent the thermostatically controlled devices such as fridges and space heater load 2 hub/oven in second case load 1 was domestic wet appliances with induction motor and heater and the load 2 were the appliances with resistive heating element and also lighting load [19]. The load types resistive and lighting are insensitive to a drop in system frequency while the induction motors and thermostatically controlled appliance show some natural reduction in a load with the drop in frequency [19]

When the system frequency fell the algorithm switch off the loads at the different frequencies then it switch on the load when predefined time had passed or the frequency recovered. A random time delay was applied to the switching on of each Load Group in a House. As the load controller in each house decided this random time independently, the reconnection times of each Load Group across the distribution system was random this avoiding the abrupt demand increase [20].

The frequency at which the load 1 and load 2 were switch off and the time they were disconnected is given in table 1 .This time were chosen by the consumer at the degree of disturbance. The maximum switch off time table 1 is determine the disturbance to the consumer. The switch off the fridges and heater (maximum off time 1 min) and hobs/oven (maximum off time is 30 sec) is unlikely to be noticed due to their thermal storage. The frequency at which the network would initiate wide-spread load shedding to avert the collapse of the power system [21]

Table 1. The frequencies and time periods of the load control scheme for case 1

Group	Appliances	^{F}OFF (Hz)	^{F}ON (Hz)	^{T}OFF (s)	T_M (s)	T_D (s)	T_R (s)	Maximum off time $T_{OFF}+T_M+T_D+T_R$
I	Electric space and water heaters, Fridges and freezers	49.7	49.8	30	10	10	10	1 min
II	Hubs/Oven	49.5	49.6	10	10	5	5	30 sec

For all Load Group $F_{NOMINAL}$ = 50 HZ

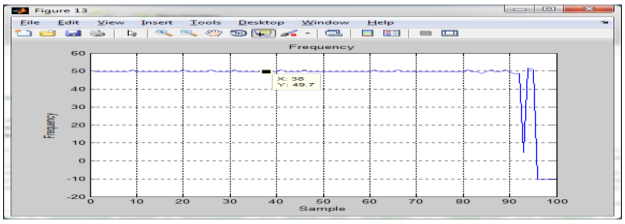

Figure 6. Switch Off Frequency of Load 1 (Fridge/Freezer)

Figure 6 show the switch off frequency of load 1. The switch off frequency of load 1 is 49.7 and the load 1 is representing the thermostatically control device such as fridge freezer. When the frequency is below then 49.8 the load 1 will be automatically switch off and it will wait until the frequency recover and the predefined time passed [22].

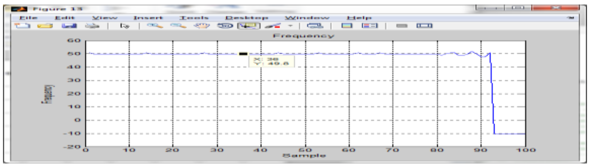

Figure 7. Switch On Frequency of Load 1 (Fridge /Freezer)

Figure 7 show the switch on frequency of load 1 the controller switch on the load when predefined time had passed or the frequency recovered. The switch on frequency of load 1 is 49.8 Hz. A random time delay was applied to the switching on of each Load Group in a House [22] [23].

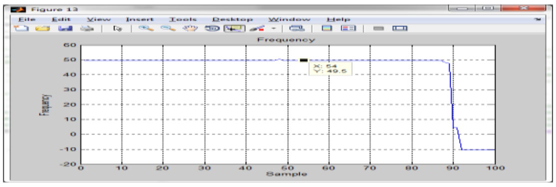

Figure 8. Switch Off frequency of load 2 (Hub/Oven)

Figure 8 show the switch off frequency of load 2. The switch off frequency of load 1 is 49.5 Hz and the load 2 is representing the hub/oven.

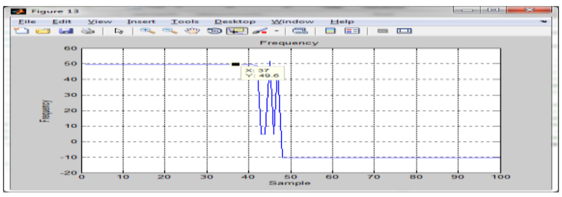

Figure 9. Switch On Frequency of Load 2 (Hub/Oven)

Figure 9 show the switch on frequency of load 2 the controller switch on the load when predefined time had passed or the frequency recovered. The switch on frequency of load 2 is 49.6 Hz. A random time delay was applied to the switching on of each Load Group in a House [24].

3.2. Load Control Algorithm for Frequency

The algorithm is explained by using the state diagram shown in figure 10. When the system frequency is normal, the load remained in state 1 continuously checking the frequency. When the frequency is dropped below the switch Off Frequency (FOFF) of a particular Load Group in Table 1, the algorithm moved to the state 2 and sent control signals to all the loads in that Load Group to switch them off. In state 2, the algorithm kept the loads switch off for Load Switch off Period (TOFF). Then all loads moved to state 3 [25] [26] [27].

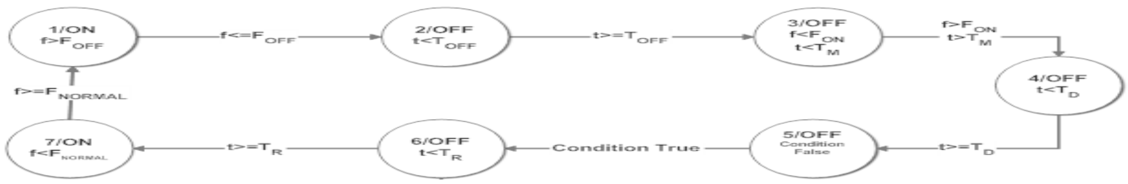

Figure 10. The State Diagram of Load Group for Frequency

In state 3, the frequency was monitored for Frequency Monitoring Period (TM) to check whether it had recovered up to Switching on Frequency (FON). If the frequency had recovered during TM, the algorithm moved to state 4 without waiting to complete TM. The algorithm waited in state 4 for; Delay Period (TD) - a period which avoided switching on loads immediately after the frequency recovery. Then it moved to state 5 [28].

In state 6, the algorithm generated a uniformly distributed random number tR (0 ≤ tR≤TR) and waited for time before moving to state 7. When moving to state 7, the algorithm sent control signals to reconnect all the loads of a Load Group. After reconnecting the loads, the algorithm waited (in state 7) until the system frequency was restored to FNORMAL. This waiting in state 7 prevented retriggering the algorithm due to the frequency fluctuations that might occur in the power system [28] [29].

3.3. Simulation of an Example Frequency Event

The HMI screen shown in figure 12 was obtained by the gradually reducing the output frequency of the converter (by using the frequency control input signal [30]. When the frequency dropped below FOFF of each Load Group (in Table 1), the algorithm started the state transitions (moving from state 1 to 2 as described in section previous section, as the frequency was increased to 50 HZ before the end of monitoring period (TM) of the all Load Groups (fridges and heaters, hobs and oven, washer and dryers and lighting load), the algorithm moved out from state 3 without waiting to complete TM. The TR time is the actual switching on instance based on the randomly generated switching on time (tR).The instantaneous, minimum average and maximum lop times taken by the software modules (the controller ran the modules in a loop) were measured by the software internally calculate by the software. (In Figure 11). The time taken to read the meter and switch off a Load Group are calculated by the software internally [31].

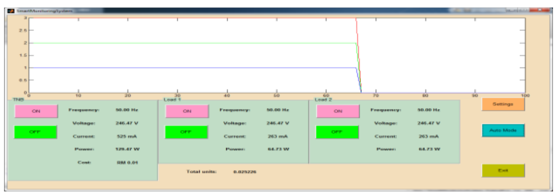

Figure 11. The HMI (Human Machine Interface)

3.4. Operating Time of Experimental Rig of Frequency

The total time of experimental rig was made up of the operating times of the frequency convertor (t1) and four different elements of the load control scheme (t2 to t5) as show in figure 12 and figure 13. The total operating time (t1+t2+t3+t4+t5) of the experiment rig was obtained by giving a step input to the frequency convertor (by changing the frequency by the help of frequency controller) [32] [33].

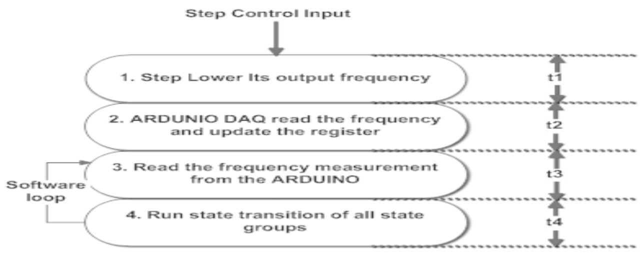

Figure 12. Operating Time of the Component of the Experimental RIG When the Frequency is ≥ Switch On Frequency

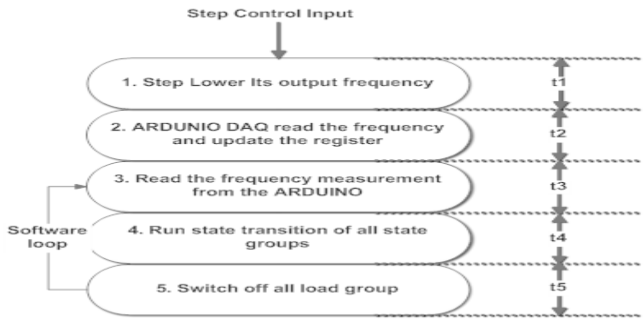

Figure 13. Operating Time of the Component of the Experimental RIG When the Frequency is < Switch On Frequency

When the load 1 is fridge and electric space heater the frequency above the 49.7 HZ , the load control software continuously loop through step 3 to step 4 figure 13 when the frequency drop the load, the load control software looped through step 5 figure 14 to switch off loads. The load control software continually measured the time to complete every software loop and calculate the average loop time and the maximum loop time because the software spent most of the time going through step 3 and step 4 without switching off loads, the average loop time was t3+t4. The maximum loop time gave t3+t4+t5 when the software went through step 5 to switch off loads9.An experimental load control scheme was develop using commercially available smart load controller and smart socket. When the power system frequency and voltage drop or become high from the respective values, the controller switch of the domestic load to provide the primary frequency and voltage response. Based on the disturbance that would be caused to the customer, different domestic load is switch off at different frequency and voltage and switch on when the predefined time has passed or the voltage and the frequency had recover and for the peak demand its help to control the peak hour. At the particular peak hours the domestic load was switch off and when the particular peak hour had finish the controller switch on the particular domestic load.

4. CONCLUSION

The main objective of this research is to minimize the power loss and to improve the frequency deviation. A simple MATLAB programing and the ARDUINO DAQ card is used to calculate the frequency deviation response.The purpose of The Proposed Research is basically oriented on a dummy load which is used to show the usage of particular equipment’s used in a home such as fridge, freezer, hub/oven, lighting system, and domestic wet appliances such as washer dryer which are attached to a DAQ and then to a controlling and monitoring unit on a computer, on which monitoring and controlling is being done with GUI on MATLAB for controlling. However, this research mostly emphasizes on the monitoring and controlling of the frequency deviation.Furthermore a controller can control appliances in a house to provide the primary response, by using the frequency measurement obtain from the ARDUINO. The switching operation of different appliances can be coordinate by the controller. A load controller that reads power system frequency from an ARDUINO and a switches off load when the system frequency drop or become high was develop during this research work. Load control scheme that switch off the domestic loads to provide primary response was investigated.

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