Development of embedded systems based automated load shedding and electricity monitoring scheme

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Abstract : Industrial revolution in India since 19th century has resulted into a sudden shift of residential population from rural to large towns. Thus urbanization and industrialization have resulted in an unpredictable increase in electricity demand. A direct impact of this increased demand has resulted into an intense pressure that is build up on national electricity grid due to excessive load. This effect is more observed especially during peak demand periods. It becomes mandatory to reduce this pressure on grid in order to have reliable and continuous supply. One solution to this problem would be the construction of additional power generating facilities, but this solution is not economic as the installation is very costly as well as more power generating facilities will be a threat to the environment. This solution thus has to be eliminated. A more feasible solution to this problem would be an instrument like maximum demand controller which can monitor the heavy load demand during peak hours.

In this paper, an automated load shedding module is developed for study and research. The module uses an ARM processor combined with a switching circuit to implement a load shedding plan. The developed module is also useful as a research topic for illustrating power system automation among students and researchers.

Index Terms - Maximum demand controller, Automated load shedding, ARM processor.

I. Introduction

Today the world in which we live is the world of digitalization. The technological evolution has taken us to stage where we can do nothing without the help of sophisticated instruments like computers, mobiles, wireless instruments etc. India is a developing country with the vigorous development of the economy. India has experienced the continuous increase of load density over the whole power distribution system. The electricity distribution may became overloaded due to load growth and substation planning and it complicates the distribution system operation in areas with high load density. There is an acute power shortage every corner of India. It is becoming unavoidable, to cut down the load from one section & supply to other section, which can be done locally or through PC remotely. This project is a very good example of embedded system as all its operations are controlled by an intelligent software and a program inside the processor. The theme of this project is to control the power distribution for the purpose of load shedding. In this project, we are using ARM processor, since this processor has two ports which are more than enough for the project. Technology used as an embedded system is the core of today's digital circuit design in industry. This system uses it for the centralized operation and control. The technology used here is embedded technology which is the future of today's modern electronics. For developing automated load shedding technique we have used different equipments such as ARM processor, power supply (12 Volts), relay, transistor, voltage regulator, current transformer, LED, lamp load, switch etc. Finally we have developed an ARM based control system and a technique of load control for fixed load. Also, technique for load shedding time balancing system is shown here in this entire project.

II. Existing Load Shedding Scheme

The electrical power system is a real time energy delivering system. Real time means that the power is generated, transmitted and distributed to the consumers. The function of an electrical power system is to connect the power plant to the loads with the help of interconnected system of transmission & distribution networks. Electricity is generated at power plants and moves through a complex system, substations, transformers, and transmission and distribution lines that connect electricity producers and consumers. A major part of an electrical power system is that it transmits most of the generated electricity in the entire network which is usually found in the distribution system. Distribution system or commonly referred as distribution line which is the part after electricity transmission at the distribution substation. Distribution line's main purpose is to transmit the generated electrical power through conductors to different parts of consumer service area. These lines typically use voltage for power circulation needed by the consumers. Distribution lines are said to be the final stage before satisfying the consumers demands or end users demands before power is delivered to them.

Therefore, The currently used electrical power system consists of three principal components:

1) Power Plant
2) Transmission Lines and

3) Distribution Line

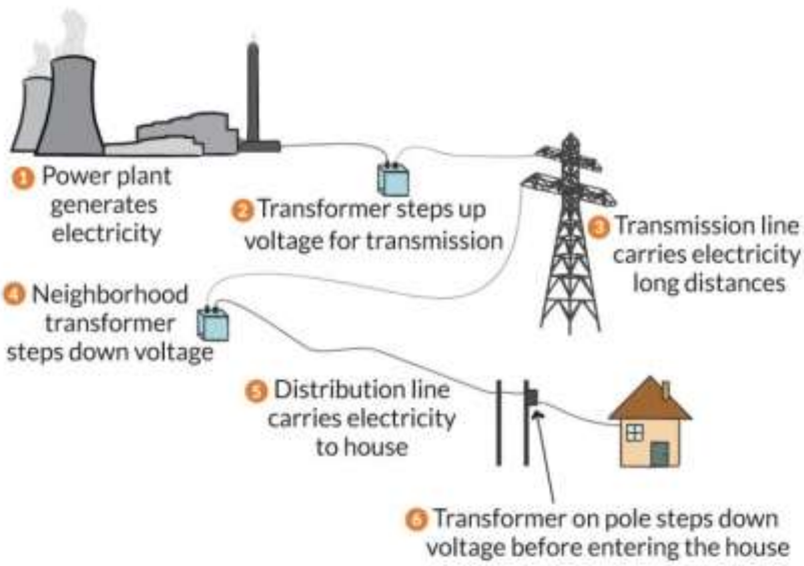

Figure 1: Power System Network

The transmission lines are the connecting links between the power plant & distribution line systems. A distribution system connects all the individual loads in a given locality to the transmission lines. In the shedding process, under a main power plant there are several sub-stations who perform power-cut for a certain period of time to control the shortage of electrical energy used by the people of the locality. Workers form the electrical authority are engaged in the substations who attend the calls and directions from the main power plants & as per the upper levels direction, power system of some area are cut down by the workers for a particular period of time. And then after the completion of load shedding for those areas, electricity for some other areas are cut-off. In this way the load shedding of electrical energy is covered up by the electrical authority.

III. System Model

The work shown in this project is related to load shedding of electrical loads using ARM processor. Design of the control system and management of load shedding of various loads are the main concern of this work. The load shedding time is controlled through computer. When the load shedding scheme is started, the ARM processor gives command to the relay to shed the particular load from the system and finally the entire operation is observed on computer display which has GUI (Graphical User Interface).The block diagram of entire system is as follows:

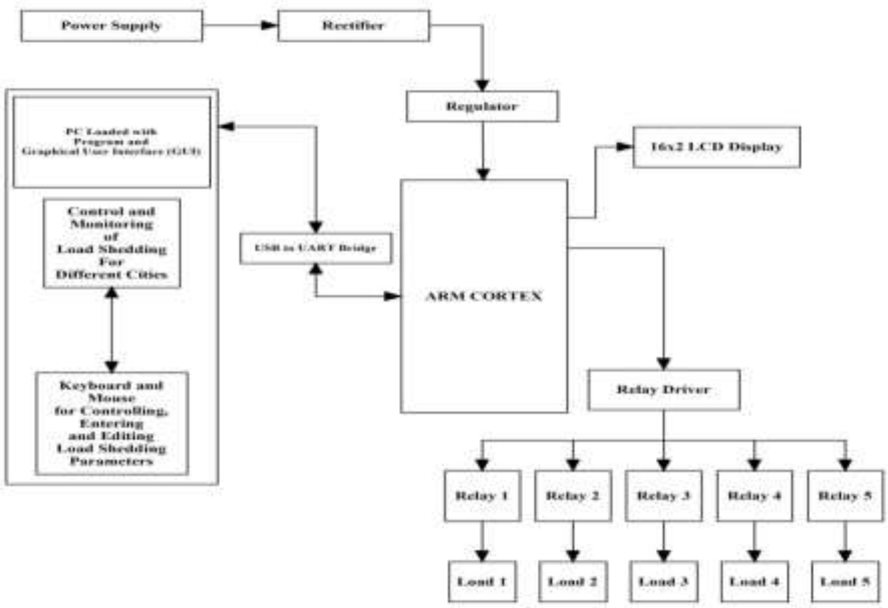

Figure 2 : Block Diagram of the system

IV. Hardware Components

1) Arduino Due ARM CORTEX M3 processor

The Arduino Due is a microprocessor board based on the Atmel ARM Cortex-M3 CPU. It is the first board based on a 32-bit ARM core microprocessor. Unlike most boards, the ARM Due board runs at 3.3V. The maximum voltage that the I/O pins can tolerate is 3.3V. Either of the USB ports can be used for programming the board, though it is recommended to use the Programming port due to the way the erasing of the chip is handled. The Native USB port can also act as a USB host for connected peripherals such as mice, keyboards, and smartphones.

2) Relay Driver

A relay driver circuit is a circuit which can drive, or operate, a relay so that it can function appropriately in a circuit. An electronic circuit will normally need a relay driver using a transistor circuit stage in order to converter it's low power DC switching output into a high power mains AC switching output. The driven relay can then operate as a switch in the circuit which can open or close, according to the needs of the circuit and its operation. PNP, NPN, or MOS transistors are used to make a relay driver circuit.

3) Single Pole Double Throw SPDT Relay

These are high quality Single Pole - Double Throw (SPDT) sealed relays. They are used to switch high voltage, and/or high current devices. This relay's coil is rated up to 12Volts, with a minimum switching voltage of 5Volts. The contacts are rated up to 5A (At 250Volts AC, 30Volts DC).

4) LCD

A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical, easily programmable, have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

5) Single Chip USB-To-UART Bridge

The CP2102 simplifies the upgrade from RS232 to USB by providing a complete solution with royalty-free drivers that eliminate the need for additional software. The highly-integrated USB to UART bridge reduces board space, simplifies design and reduces development time. The CP2102 includes a USB 2.0 full-speed function controller, USB transceiver, oscillator, EEPROM, and asynchronous serial data bus (UART) with full modem control signals in a compact 5 x 5 mm MLP-28 package. No other external USB components are required.

V. Simulation Environment

1) Arduino IDE

The Arduino IDE is a programming environment for most Arduino-based projects. The open-source Arduino software is easy to write the code and upload it on the board. The environment is written in Java. It can also available for use with any other Arduino boards.

2) Visual basic 6.0

Visual Basic is a third-generation event-driven programming language first released by Microsoft in 1991. It evolved from the earlier DOS version called BASIC. BASIC means Beginners Allpurpose Symbolic Instruction Code.Visual Basic is engineered for building safe and object-oriented applications. Visual Basic enables developers to target Windows, Web, and mobile devices. As with all languages targeting the Microsoft .NET Framework, programs written in Visual Basic benefit from security and language interoperability.

VI. Implementation of System

1) The proposed system consists of Arduino Due ARM Cortex M3 processor, is the main part of the project which controls and drives all peripherals. The timings to the individual areas can be set by user using RTC (Real-time clock) on GUI (Graphical-User Interface) on PC. Once the time is set the ARM processor will start sending the data on to the UART of the ARM processor through PC USB port. The data from the GUI contains current local time, customer bill amount, total electricity units consumed and information on whether to turn ON/OFF the supply to each individual areas.

2) The processor receives this data and uses this to control each SPDT Relays, to display the current local time and Status of the System on the GUI (Graphical User Interface), and to send the notification about the load shedding.

3) In the proposed system generation of electricity usage bill is made automated by reading the Watt Hour pulses using Photodiode and ARM Processor. The Photodiode Senses the pulse count, when each time the LED on AC energy meter

flashes. the overall count is then sent to the GUI. When the pulses are counted, the graphical representation is displayed on GUI. It also calculates the total bill amount for used electricity units by the user.

4) After the defined time interval, the ARM processor cut-off the power by triggering a relay which acts as a switch between power supply from the energy meter power input. Thereby it removes the manual work to cut off the power supply and to provide power supply back to turn on another relay.

VII. Experimental Results

1) This project is implemented to make the load shedding system to be automated by using ARM processor based embedded system. When an automated load shedding mode is working, the power is supplied to one particular area and cut down to another area.

2) This projects can also works as city load shedding management system. The energy meter is connected to the system reads the electrical energy consumed by the load which may be considered as individual cities and sends that entire data to the central location or control center which will control the load shedding schemes for more than one cities.

3) The program was written using the Arduino Sketch language in Arduino IDE to implement the load shedding schedule. The program was uploaded to the Arduino Due processor installed in the laboratory scale module from the PC using a USB to UART bridge connection. Even after the PC is disconnected, the Arduino Due continues to perform switching operations in the different time intervals with the load shedding plans as described in the next points.

1) In this project, the full programming simulation is done using the hardware and software specifications required for automated load shedding scheme. Below are some of the snapshots are given for hardware circuitry and software simulation. The project GUI on computer which controls the load shedding scheme also acts as a simulator:

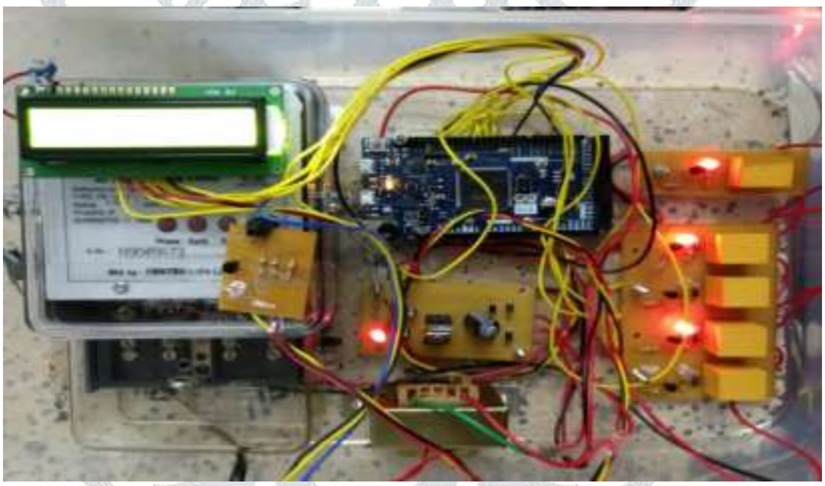

Figure 3 : Implementation of hardware circuitry

Figure 4 : GUI at initial stage (Before load shedding)

Figure 5 : GUI after 23 hours (after load shedding)

2) LED's are used to represent electric loads. As shown in the hardware circuitry in Figure 3, consisting Arduino Due processor and the switching relay circuit. The Arduino Due is connected to relay through a resistor-transistor pair. The transistors are used to switch the LED's on or off depending on signal received from the output pins of Arduino Due. The program is implemented such that LED's will turn on or off for showing load shedding scheme of a particular area.

3) After the load shedding scheme is applied to the given set of loads, the following readings are obtained for given arrangement:

Table 1 : Power consumption in a 24-hour period

Sr.no	Time (in hours)	Total Units (in Megawatts)	Units per hour (in Megawatts)	Total bill (in Indian Rupees)
1	0	0	0	0
2	2	6	3	36
3	4	13	0	78
4	6	22	2	132
5	8	27	1	162
6	10	30	1	180
7	12	35	2	210
8	14	42	2	252
9	16	52	1	312
10	18	60	1	360
11	20	68	0	408
12	22	74	3	474
13	24	87	2	522

4) A connection of power distribution network for 4 areas is considered depending on the load. This 4 areas include residential, industrial, commercial and hospital and healthcare. These all 4 areas where the load shedding scheme is to be applied are connected to one central location from where the controlling and managing the load shedding is done. The entire operation is controlled on PC via GUI. The GUI also includes a feature which is total bill generation depending on time interval and total units consumed in each hour of operation. The same system setup can also used to manage the load shedding amongst more than one cities.

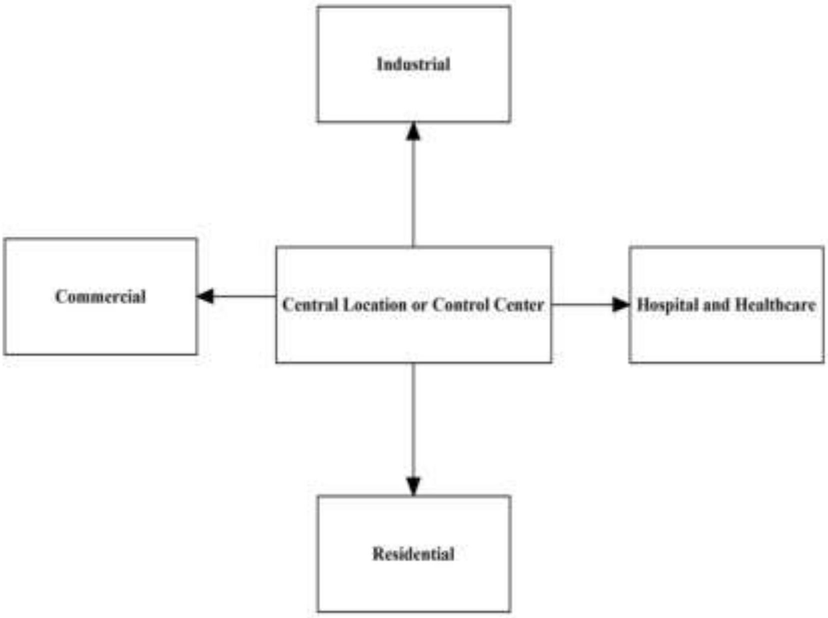

Figure 6 : Power distribution network for 4 areas under load shedding consideration

5) For the same setup, it can also be concluded that this scheme was made to run for 24 hours representing and covering the eight time zones. The table is drawn on the approximate analysis of load shedding in 4 areas where the scheme can be applied. Table 1 describes the power consumption for 24-hour period for a given set of loads. Figure 6 shows that the four areas considered were residential, industrial, commercial and hospital and healthcare.

Table 2 : Power distribution chart for different Time zones

Time zones	Residential	Industrial	Commercial	Hospital and Healthcare
12.00am - 3.00am	1	1	0	1
3.00am - 6.00am	1	0	0	1
6.00am - 9.00am	1	0	0	1
9.00am - 12.00pm	1	1	1	1
12.00pm - 3.00pm	1	1	1	1
3.00pm - 6.00pm	1	1	1	1
6.00am - 9.00am	1	1	1	1
9.00am - 12.00am	1	1	0	1

Note: 1 = Load is ON, 0 = Load is OFF

6) From the power distribution chart, it is clearly seen that the residential and hospital and healthcare areas require 24 hours of uninterrupted power supply while the industrial and commercial areas requires power supply during their operational hours.

7) The table 1 is describing an approximate analysis of power consumed for different time zones. The table 2 describes the power distribution chart for different time zones for 4 different areas where the load shedding schemes can be applied. For a 24 hour period, the time zones are divided into a 3 hour periods. The approximate power consumed by all these areas in the defined time periods is a tentative analysis made for applying an automated load shedding scheme in that particular time zone.

8) From the above tables, it is concluded that in the 24 hours period, the residential and the hospital and healthcare areas are consuming more power than industrial and commercial areas, whereas the industrial and commercial areas are consuming power than residential and hospital and healthcare areas during their operational hours only. For the given experimental setup, the approximate total units consumed are also given. The maximum consumption of power is noted for 24 hours period is from 9.00am to 9.00pm for all the areas. So depending on the results made in the above analysis, an automated load shedding scheme can be applied in the particular time zone.

VIII. Conclusion and Future scope

In this paper, an automated load shedding module was developed and used to study the use of embedded technology in the field of power system automation. This is for the purpose of awareness creation and development of using low cost and locally available materials. A programmed processor was used to automatically perform switching operations in various stages of the lab-scale model of the given arrangement and to optimize the available power, in line with the load shedding plan. This was done without human intervention as against the practice in many parts of India. Since the scheme was automated, human error was completely eliminated. Future work would include the incorporation of remote and real-time power monitoring and control capabilities. This would make it suitable for teaching and research of modern power concepts such as the micro grid, and the smart grid.

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